Background Information and Methods Testing for the Development of a Plant Community Monitoring Protocol for Six Prairie Parks

Agate Fossil Bed National Monument
Effigy Mounds National Monument
Homestead National Monument of America
Pipestone National Monument
Scotts Bluff National Monument
Wilson's Creek National Battlefield

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1.0 INTRODUCTION

The prairies of North America developed through the interaction of climatic variation, grazing by ungulates, and fire started by lightning or native people. Within the past 200 years, European settlement has led to the conversion of most of the tallgrass prairie and a significant portion of mixed-grass prairie to intensive agriculture (Howe 1994). Two controlling factors of prairie diversity, fire and large-ungulate grazing, were eliminated or placed under human control. Furthermore, fragmentation of prairies into smaller, more isolated plant and animal populations has resulted in increased risk of species loss through local extinction, decreased likelihood of recolonization from outside the local remnant, and the possibility of reduced fitness resulting from inbreeding and genetic drift (Risser 1996).

The parks in the Prairie Cluster Long-Term Ecological Monitoring Program, hereafter referred to as the Prairie Cluster Program, are small, historic, or cultural sites. However, these parks contain prairie remnants, and recent and historic prairie restorations and are islands of plant diversity in otherwise species-poor landscapes (Bennett 1996). In the absence of presettlement disturbance regimes of fire and grazing, prairie remnants must be managed to be preserved (Howe 1994). Resource managers of the Prairie Cluster parks use prescribed fire to simulate presettlement environments, promote native C_4 grasses, and control invasive exotic and native woody species. They also use herbicide and biological control of exotic species, mowing, woody removal, and reintroduction of native species in their efforts to preserve and restore prairie communities. Other parks within the prairie region employ grazing as a management tool. Managers of the Prairie Cluster parks need to know if their management strategies are effective in maintaining or restoring prairie plant community composition and diversity.

This report and the accompanying protocol provide the information necessary to: 1) establish plant community baselines in selected areas of each park, 2) develop a suite of summary variables to comprehensively describe prairie communities, 3) make a preliminary assessment of whether the sampling design and sampling intensity are sufficient to detect changes over time, 4) develop analytical methods to detect temporal change, (5) develop conceptual models to integrate plant community monitoring with related monitoring components, and (6) document the sampling design, analytical techniques, and baseline data in a descriptive monitoring protocol.

2.0 PRAIRIE CLUSTER PROGRAM PARKS

Because no single park encompasses the variability inherent in the Great Plains, the Prairie Cluster Program is based on a cluster of six geographically distinct parks: Agate Fossil Beds (AGFO) in

Nebraska, Effigy Mounds National Monument (EFMO) in Iowa, Homestead National Monument of America (HOME) in Nebraska, Pipestone National Monument (PIPE) in Minnesota, Scotts Bluff National Monument (SCBL) in Nebraska, and Wilson's Creek National Battlefield (WICR) in Missouri. Located along an east-west precipitation gradient and a north-south temperature gradient, these parks capture much of the climatic and biotic variability of all parks in the Great Plains. These parks contain a mix of mixed-grass prairie (AGFO and SCBL), tallgrass prairie (HOME and PIPE), and savanna/woodland/glade sites (EFMO and WICR) with both high-quality and degraded examples of most communities (Willson and Stubbendieck 1987). The Prairie Cluster parks also encompass a range of prairie restoration histories from historic (HOME) to recent (EFMO, HOME, PIPE, and WICR). All of these parks are small in size (mean 466 ha, range 79 to 831 ha), near the average of all parks in the Great Plains. Many vegetation management issues critical to these parks are common to other small, natural areas in the region.

3.0 OBJECTIVES

The purpose of plant community monitoring in the Prairie Cluster Prairie Cluster Program parks is to detect and describe long-term changes in grassland plant communities. Monitoring also will provide park managers with annual summaries of the current status and year-to-year changes in these plant communities. We have identified four specific plant community monitoring objectives for the Cluster Prairie Cluster Program parks: 1) characterize species composition, structure, and diversity of remnant, disturbed, and restored prairies and oak savanna/woodlands; 2) determine whether the structure, composition, and diversity of remnant, disturbed, and restored prairies change over time; 3) identify changes in community structure, composition, and diversity as directional, cyclical, or random; and 4) investigate whether temporal changes are correlated with specific management practices. We anticipate our monitoring strategy can be applied to answer the following questions:

1) What are the species composition, structure, and diversity of remnant and restored prairies?
2) Are the structure, composition, and diversity of remnant and restored prairies changing? If so, is this change directional, cyclical, or random?
3) Are trends in species composition, structure, and diversity correlated with climatic variables or management activities such as prescribed fire?
4) Are restored communities approaching a reference condition of community composition, structure, and diversity?

5) Are the distribution and abundance of widespread exotic species changing over time? If so, is this change correlated with management efforts?
6) Are communities that contain rare species changing? Are the changes correlated with the demographics of rare species monitored under separate protocols?

4.0 BASELINE ESTABLISHMENT

4.1 Management units

Each park differs in the plant community types present and the condition of the management units. Within management units, resource managers are currently implementing various management strategies, including prescribed fire, herbicide and biological control of exotics species, mowing, woody species removal, and reintroduction of native species (Boyle et al. 1990). At each Prairie Cluster Program park, we selected for monitoring management units that represent a range of community types (prairie, savanna, woodland, and glade), conditions (high-quality remnants, restored areas), and management strategies. We also selected a few communities that have a high diversity of rare species (e.g. Sioux quartzite prairie at PIPE) (Table 1).

4.2 Sampling design

Numerous sampling methods have been used to estimate frequency and abundance of prairie plant species and to describe prairie community dynamics (Weaver 1954, Kucera and Koelling 1964, Becker and Crockett 1973, Owensby et al. 1973, Glenn and Collins 1990). We used the Konza Prairie Long-Term Ecological Research (LTER) Program sampling design as our prototype because of similarities in plant communities and in the scale and scope of the research and monitoring questions. The Konza LTER sampling design consists of permanent 50 m transects randomly located within each management unit with five square 10 m^2 plots systematically spaced along each transect. The plot is the unit of sampling and analysis (Gibson 1988, Collins and Glenn 1991, Glenn and Collins 1992, Collins 1992).

We modified the Konza LTER design to include permanent 50-m paired transects randomly located within each plant community/management unit with five circular 10 m^2 plots systematically spaced along each transect. Transects increase the efficiency of finding permanent plots and provide a framework for quickly sampling large numbers of plots (Thompson 1992). This sampling strategy is appropriate for long-term studies at both the community and landscape levels of analysis (Peet et al. 1998). It is also appropriate for various vegetation types because it can accommodate remnant plant communities by adjusting plot arrangement and number. Furthermore, the design is easy to learn and to implement.

4.2.1 Sampling unit

We have identified the plot as the analysis unit for investigating changes within the plant community. Because of the dramatic effect of disturbance on large-scale patterns, changes in grassland structure are obvious at an intermediate, or community, level scale of analysis (Collins and Glenn 1990). Collins and Glenn (1990) found that regardless of scale of analysis, prairies are dominated by a few matrix-forming grass species that effectively control community structure. A large number of less abundant species, referred to as satellite species, occupy the remaining space (Collins 1987, Collins and Glenn 1990). Collins and Glenn (1988) found that community-level patch structure was defined mainly by satellite species. Patch structure was defined by the satellite species because the dominant grasses occurred in all patch types. Satellite species defined patches that vary spatially within and between growing seasons at a spatial scale of 10 m^2.

The above-referenced works and others (Gibson 1988, Collins and Glenn 1991, Glenn and Collins 1992, Collins 1992) demonstrate that 10 m^2 plots are the most effective for investigating community-level change in prairie communities. Because small-scale variation in prairies likely occurs at scales smaller than the distance (3.7 m) between plots along the transects (S. Collins, personal communication, Collins and Glenn 1990), the plots are distanced enough not to fall into the same microsite or patch and can be considered independent samples (Lesica and Steele 1996; Elzinga et al. 1998; Knapp, personal communication). We have included a detailed discussion on associated sampling design issues in Appendix A.

4.2.2 Plant community variables

Monitoring for plant community change requires estimation or measurement of a suite of parameters because no single metric or statistic is adequate to detect significant vegetation change over time (Bowles et al. 1996). We chose diversity and richness indices and a ratio of exotic:native species richness to provide information on compositional change. We chose frequency (relative and absolute) and abundance (foliar cover) of species guilds to investigate structural and compositional change in prairie and wooded communities. Along with these variables, we also estimated woody stem density and basal area to provide information on structural changes in the forests, woodlands, and savannas. We also estimated characteristics such as percent cover of grass litter, bare soil, woody debris, and vegetative cover for each vegetation stratum (total herbaceous, shrub, and tree canopy) to provide additional structural information on each plant community.

4.3 Sampling methods

4.3.1 Transect pair and plot establishment

In some parks, a management unit delineated a plant community while in other parks, multiple plant communities were found within a management unit. In management units with varied topography and/or heterogeneous vegetation, we identified plant communities using vegetation maps, soil maps, slope position, and aspect. Identification of plant communities in larger management units prior to sampling ensured accurate description of community composition and variability.

We identified sampling localities within a designated plant community using a random numbers table. If the random number placed the paired transects on a vegetation boundary (e.g. a transition zone between a disturbed prairie remnant and a high-quality prairie remnant), we moved the paired transects into the habitat type to be sampled. Within each plant community identified for sampling, we randomly located two or more 50-m paired transects. The paired transects are 20 m apart and run parallel to each other and to the elevation contours. Along each transect we established five 10 m^2 circular plots at 10-m intervals (Figure 1). Within each 10 m^2 circular plot, we nested a 0.1 m^2 circular plot and a 1.0 m^2 circular plot. In the small communities where the sample site encompasses a large proportion of the total area (e.g., goat prairie at EFMO, Sioux quartzite prairie at PIPE, and bluff top communities at AGFO), we placed a single transect pair.

We marked each transect at both ends with rebar. Using a global positioning system (GPS) unit, we recorded the coordinates for the end points of each transect. During sampling, we took photos of each transect from the permanent transect endpoints to have visual documentation of vegetation change. Appendix B includes transect locations and documentation data.

4.3.2 Plant community sampling

Herbaceous plants. We recorded species presence in the nested 0.1 m^2 and 1.0 m^2 plots within the 10 m^2 plots. In each 10 m^2 circular plot we recorded species presence and estimated foliar cover of all herbaceous and shrub species using a cover class index modified from Daubenmire (1959) (Table 2). Only species rooted in the plot were recorded or included in estimates of foliar cover. Multiple-stemmed woody shrub species were included in the herbaceous sample. The 10 m^2 plot was divided into quarters by bars, which facilitated an accurate estimate of foliar cover for each species.

Woody plants. In each 10 m^2 plot, we counted the number of small seedlings (stems > 0.5 m tall), large seedlings (stems > 0.5 m tall but < 2.5 cm diameter at breast height (dbh)), and saplings (stems > 2.5 cm dbh but < 5.0 cm dbh) of each woody species. Where there were overstory trees (e.g., Bloody Hill glade at WICR), we sampled the rectangular 0.1 ha area between the paired transects as an overstory plot (Figure 1). In each overstory plot, we identified and recorded all trees > 5.0 cm dbh. All trees were given a condition code (D = Dead, C = Coppice sprout) to be used in understanding structural changes over time.

We used the U.S. Department of Agriculture Natural Resources Conservation Service's Plant List of Accepted Nomenclature, Taxonomy, and Symbols (PLANTS) database (USDA 1995) to standardize plant taxonomy among parks. We housed voucher specimens in the herbarium at Wilson's Creek National Battlefield.

Timing of sampling. We visited each park twice during each year, once in spring or early summer and again in late summer or fall. We tried to sample each park during the seasonal flowering peaks. The priority was to sample once when the cool-season grasses and forbs were in full bloom and again when the warm-season grasses were either in flower or seed. We sampled parks during each period in generally the same order to minimize within-season differences that could potentially confound year-to-year comparisons within a park. Although some pre-vernal species may have senesced before the first sampling, we felt that most species were likely detected in these two periods. We sampled woody species during the second sampling period.

In 1996, we conducted field trials of the sampling methods at SCBL and PIPE. Subsequently, we conducted baseline studies of the plant communities in all six parks. We sampled EFMO, PIPE, SCBL, and WICR during 1997 and 1998 and HOME and AGFO during 1998. In 1999, all parks were sampled. The number of transect pairs established in a given park differed by extent of each plant community type and the time and personnel constraints associated with sampling.

4.3.3 Environmental sampling

We sampled structural and environmental variables in every 10 m^2 plot. We estimated the cover of bare soil, bare rock, grass litter, leaf litter, and woody debris using the modified-Daubenmire cover values listed in Table 2. We used a compass azimuth and clinometer to measure slope aspect and slope angle, respectively, for each 10 m^2 plot. Aspect, a circular variable, was transformed to a linear scale by treating all azimuths as deviations from 205°, approximately the most xeric aspect in terms of solar radiation and moisture demand (Parker 1982). For each transect pair, we determined the soil series and type from soil series maps. We also recorded any evidence of disturbance such as old roadbeds, fences, and animal burrows.

5.0 SUMMARY VARIABLES

The plant community variables and indices selected for data summary purposes are complete, descriptive and easily interpretable. We use diversity and other community indices, as well as structural and compositional summaries, to describe the current status and monitor plant community change through time in the Prairie Cluster Program parks and to provide resource managers with easily interpretable and timely feedback to assist in assessing management practices (Pickett et al. 1992). We include a description of the community variables and indices selected for yearly summaries in Table 3.

5.1 Diversity, richness, and evenness indices

5.1.1 Species diversity

Measures of diversity are frequently used as indicators of the well-being of ecological systems (Magurran 1988). *Species diversity* is a measure of equitability of species across samples. A large number of diversity measures have been proposed, and many are in use (Pielou 1974). The Shannon diversity index (H') (Shannon 1948) is appropriate when a random sample of species abundances have been obtained from an entire community.

For each community type, we calculated Shannon diversity index as:

$$H' = - \sum p_i \ln p_i;$$

where p_i is the abundance of species *i* expressed as a proportion of the total cover. We calculated Shannon diversity twice, once using all species and a second time using only native species.

5.1.2. Species richness

Species richness is simply a count of the number of species in a defined area at a given time, which in this case refers to the number of unique species recorded for all sample units within each community type. Species richness of a sampled area is an estimate of the total number of species present in a specific community type. Actual species richness of a community type is not usually known; the estimate of richness (S) always underestimates true richness.

A change in total species richness may reflect an increase or decrease in either exotic or native species. Total species richness, along with exotic species richness and native species diversity, provides a more complete picture of the presence and equitability of both native and exotic species in the community.

5.1.3. Species evenness

Evenness measures the disparity among species abundances. Maximum evenness occurs when all species abundances are equal; greater differences among species abundance result in lower evenness values (Pielou 1977). Using the estimate of richness (S), maximum species diversity (H_{max}) is calculated as the log of S (lnS). The ratio of observed diversity (H') to H_{max} is a measure of evenness (E) (Magurran 1988). We calculated evenness twice, once using all species and a second time using only native species as:

$$E = H'/H_{max} = H'/\ln S$$

We found that determining evenness was more useful in forests than in prairie communities. Prairie communities are characterized by a few dominant species, resulting in low evenness. Degraded prairies dominated by exotic grasses cannot be discerned from communities dominated by native grasses; the evenness index does not distinguish between high-quality and degraded communities as both have similar distribution patterns of dominant species.

5.2 Community composition

5.2.1 Overstory and understory plants

In woodland communities (i.e. SCBL, EFMO, and WICR), we report the *tree overstory* (stems ≥ 5.0 cm dbh) in total basal area and density and mean dbh (0.1 ha plot extrapolated up to a hectare). We report mean density for five size classes (cm dbh): 1) 5 to 14.9, 2) 15 to 24.9, 3) 25 to 34.9, 4) 35 to 44.9, and 5) 45 to 54.9.

Trees ≤ 25 cm dbh can be further divided into five diameter classes (Table 4). Abrams (1988) and Tester (1989) have shown that prescribed fire treatments tend to affect trees with diameters less than 25 cm; this relationship can be investigated by examining changes in the two smallest size classes. The tree data can be used to understand the effects of management, specifically prescribed burning and mechanical thinning, on overstory density, structure, and regeneration.

We report mean density for the *tree understory* (stems < 5.0 cm dbh) from the 10 m^2 plots (extrapolated up to a hectare). We used three size classes (cm dbh) in reporting mean density: 1) small seedlings (stems < 0.5 m in height), 2) large seedlings (stems ≥ 0.5 m in height but < 2.5 cm dbh), and 3) saplings (stems ≥ 2.5 cm dbh but < 5.0 cm dbh).

5.2.2. Shrubs and herbaceous plants

For shrubs and herbaceous plants, we used the 10 m^2 plot data from all sample units within a community to generate information on frequency and cover. Cover is useful in the description of the dominant species but is less useful in the description of less-common species or species of low cover. Frequency data is used to assess changes in the abundance of the less-common species. We calculated frequency and cover for individual species and species guilds.

Frequency is defined as the number of times a species is present in a given number of plots of a particular size (Raunkiaer 1934). We report species frequency as the proportion (or percentage) of plots in the community type in which the species occurs.

$$\text{Frequency of species } i = \frac{\text{Number of occurrences of species } i}{\text{Total number of plots}}$$

Cover is defined as the ground occupied by perpendicular projection of the aerial parts of individuals of the species under consideration to the ground (Greig-Smith 1983). We used the median values of each cover class interval to estimate percent cover for each herbaceous and shrub species. Cover was expressed for each species and species guild as the mean cover per community type using the 10 m^2 plots within the community types as the sample unit.

Ecological guilds were first defined by Root (1967) as those species that have significant overlap in niche requirements. Kindscher (1994) similarly defines an ecological guild as being composed of species that occupy similar positions along a resource gradient in a community. Kindscher (1991) used multivariate analysis of ecological and morphological traits to verify eight guilds of prairie species. With the exception of adding one guild found in savanna and glade communities (ferns and fern allies), we have adopted Kindscher's guild classification. For each park, we assigned herbaceous and shrub species to one of the following nine guilds: warm-season (C_4) graminoids, cool-season (C_3) graminoids, annuals and biennials, ephemeral spring forbs, spring forbs, summer/fall forbs, legumes, ferns, and woody shrubs (Kindscher 1991).

We calculated relative frequency and relative cover for each guild from 10 m^2 plots for each community type as:

$$\text{Relative \% cover of guild } i = \frac{\Sigma \text{ \% cover guild } i}{\Sigma \text{ \% cover of all species}}$$

$$\text{Relative \% frequency of guild } i = \frac{\Sigma \text{ occurrences of species in guild } i}{\Sigma \text{ occurrences all species}}$$

We also calculated importance values (relative % cover + relative % frequency/2) for herbaceous and shrub species using the 10 m^2 plot data from each management unit/plant community. The importance value gives an overall estimate of the influence or importance of a plant species in the community. Summary information by guilds is useful for interpreting the type and quality of prairie as well as detecting compositional shifts among guilds that might result from management.

5.2.3. Exotic species

Exotic species are those species that humans intentionally or unintentionally introduced into an area outside of its natural range. Exotic species can influence ecological processes including trophic level relationships; interspecific competition; primary and secondary succession; nutrient cycling; and ecosystem productivity, diversity, and stability (Bratton 1982). Manual removal (cutting and mowing), burning, and biological control of exotics are being used in some of the management units at most of the parks. We used exotic:native ratio, relative cover, relative frequency, and mean cover of exotics to assess the status of exotic species distribution and investigate effects of management on exotic species distributions over time.

Exotic:native ratio. For each community type, we calculated the *ratio (R)* of exotic plant species to total number of native plant species as:

$$R = EX{:}S$$

where EX is the number of unique exotic plant species and S is the total number of unique native species tallied across all plots within a community type.

Relative cover and *relative frequency.* Relative cover and relative frequency of exotics provide comparative information on the distribution of exotics across community types within a prairie park and on the extent of exotic invasion within a specific vegetation type over time.

We calculated the relative cover and relative frequency of exotic species for each community type as:

$$\text{Relative \% cover of exotics} = \frac{\Sigma \text{ \% cover exotics}}{\Sigma \text{ \% cover all species}}$$

$$\text{Relative \% frequency of exotics} = \frac{\Sigma \text{ occurrences species exotics}}{\Sigma \text{ occurrences all species}}$$

5.3 Community structure

Community structure consists of three components: 1) vertical arrangement, 2) horizontal arrangement, and 3) abundance of constituent plant species within the community (Kershaw and Looney

1985). Community structure dictates the appearance of a community as a whole and is closely related to growth form (Greig-Smith 1983). We used physiognomic characteristics to obtain a coarse depiction of the structure of the plant community, and reported mean percent tree canopy cover and mean percent herbaceous and shrub cover. We calculated the mean and variance using the 10 m^2 plot data.

We measured aspects of the physiognomy of communities to explore physical changes resulting from management activities. We estimated the cover of bare soil, bare rock, tree leaf litter, grass litter, and woody debris at ground level for each 10 m^2 plot (Table 5). We will be able to test for correlations between changes in the physical environment with changes in species composition or in the dominance of certain guilds of species, for example, following a fire. Fire events destroy living and standing dead biomass and alter the availability of critical resources such as nitrogen, light, and soil moisture (Hurlbert 1988). Changes in litter cover, bare ground, and woody debris are directly affected by fire spread and intensity (Knapp and Seastedt 1986). These changes have been correlated with changes in species composition, or the dominance of certain guilds of species following a fire (Collins et al. 1998). Appendix C provides details on integrating changes in fuel monitoring with the plant community monitoring efforts.

6.0 SAMPLING DESIGN ASSESSMENT

6.1 Stratification verification

Large management units (South Unit at SCBL and Manley Woods at WICR) were first stratified by soil type, slope position, and slope aspect prior to sampling in order to segregate plant compositional differences associated with these environmental factors. We used the data from 1998 for South Unit at SCBL and the data from 1997 for Manley Woods at WICR to ordinate plot data by Detrended Correspondence Analysis (DCA).

The results from South Unit at SCBL support our designations of native prairie and brome-dominated prairie (Figure 2). We analyzed both the entire data set and a reduced data set with species in less than 5% of all plots removed from analysis. Axis eigenvalues and lengths and the positioning of plots in the ordination were similar for both. The ordination displays the gradient in plant community composition from a brome-dominated degraded community to a native prairie to a ponderosa pine woodland in a positive direction along axis 1. The overlap in a number of plots from native prairie and brome-dominated prairie reflects the similarity in composition in the two community types. The plots in brome-dominated prairie positioned in the ordination with plots in native prairie were plots along transect pairs 1 and 2. Although located in a degraded prairie dominated by brome, the plots were characterized by patches of brome and native prairie.

The DCA ordination from Manley Woods at WICR shows inconclusive evidence that slope position and aspect should be used in stratification (Figure 3). The results suggest that the sample units are placed in similar community types and that Manley Woods can be treated as one community type.

6.2 Intensity assessment

The numbers of transect pairs designated for each study unit was a decision strongly affected by personnel and time constraints. As a basic rule, we established at least 20 plots (two transect pairs) within each plant community. To assess the adequacy of our sampling intensity in detecting long-term change, we ran power analysis on a subset of plant communities (5 of 19) using two years of baseline data. We selected plant communities for analysis where there were 1) two years of consecutive sampling, 2) relatively stable climatic conditions for both years, and 3) no management efforts within the last five years. Specifically, we were interested in identifying community variables in which we could detect at least a 20% change over time with a high (90%) level of confidence. Using power analysis, we tested which variables could be used given our current sampling design and the variable's inherent year to year variability. Further, we identified how many more plots would be necessary to detect at least a 20% change if our sample size was not adequate.

Power analysis identified a number of variables that will be consistently useful in long-term or trend analysis. These include species richness and exotic species richness, and total forb cover. In four of the five communities used in analysis, we currently had adequate samples to detect changes in relative frequency and importance value of the C_3 grasses and C_4 grasses guilds. Woody species stem density, although not analyzed using power analysis, likely can also be used in long-term analysis. For some communities, we found that a lower α level is required to detect a 20% change. For example, to detect a 20% change in percent mean cover in the herb guild in the Calamovilfa unit at AGFO, must be set at 0.20. While this may seem low for statistical significance, in monitoring, high power (low β) lessens the chance that a change detrimental to the resource goes undetected. We have included the results of the power analysis in Appendix D.

6.3 Frequency assessment

Sampling frequency refers to the frequency of sampling within a year and over years. We sampled twice annually, once in the spring, and once in the late summer/early fall. The spring sampling allows for identification and cover estimates of cool-season grasses and spring forbs while the late summer/early fall sampling allows for accurate estimation of warm-season grasses and mid- to late-flowering forbs.

While it would be ideal to sample each year, sampling effort is a compromise between budgetary constraints and sampling needs. Sampling a number of years consecutively and averaging across the years can provide an accurate estimate of the variable sampled (Lesica and Steele 1996). Initially, it is best to sample annually for a number of years and, from this baseline information, select a sampling time period that helps minimize variability associated with short-term changes in compositional dynamics (D. Hartnett, personal communication). We suggest a sampling regime of 2 to 3 years of consecutive sampling followed by 3 years without sampling as a minimum sampling effort.

Once baseline data via annual monitoring is collected and analyzed, it may be necessary to alter the sampling frequency by community type, management regime, and/or weather patterns. While yearly monitoring may be necessary for some community types, less frequent monitoring efforts may be adequate for others. Communities demonstrating high structural and compositional variability or communities harboring rare species should be monitored more intensely than more stable or less unique communities. Restoration sites should be monitored annually after initial and during subsequent restoration efforts to effectively estimate community change. Prolonged extreme weather conditions, such as drought, will create a need for annual monitoring of all plant communities.

7.0 TEMPORAL CHANGE DETECTION

7.1 Short-term analytical methods

7.1.1 Statistical analysis

Community indices and summary variables can be compared through time to provide information on short-term changes in a community (Table 5). For example, pre-burn data can be compared to post-burn data to test for significant differences in pre-burn and post-burn plant community structure and composition. Rather than performing year to year comparisons, we suggest using the mean generated across a number of years in analysis. By investigating change between time periods, the probability decreases that any differences found could be attributable to a single year of extremely favorable or unfavorable environmental conditions.

To assess changes in community structure, we suggest using mean percent cover of each plant stratum and, where applicable, density of seedlings and saplings and basal area of trees. To assess changes in species composition, we suggest using species richness, exotic species richness, mean percent cover of exotics, and mean percent cover and importance value of the species guilds of interest. However, which variables are used will depend on the specific question of interest.

By using statistical analysis, the difference between the two time periods compared can be reported with a stated level of confidence that a real difference has/has not been detected. We suggest using the paired *t*-test to test for significant differences in nonproportional variables between time periods (Table 5) and the nonparametric test, McNemar's test, to test for significant differences in proportional variables between two time periods. The paired *t*-test is appropriate for repeatedly sampled permanent plots because it ignores the between-plot variability and specifically looks at the differences for each plot between time periods. Proportional data such as percent frequency and the exotic:native ratio cannot be analyzed with parametric statistics because of violations of normality.

When testing nonproportional data for change between three or more time-periods, a Bonferroni adjustment reflecting the number of comparisons being made needs to be applied to the threshold *P* value (Elzinga et al. 1998). This is called the Bonferroni paired *t*-test. Proportional data cannot be tested for change between three or more years.

While there are contradicting views on the use of nonparametric tests for nonproportional data (Seaman and Jaeger 1990, Smith 1995, Elzinga et al. 1998), there are a number of options available. An appropriate nonparametric test for nonproportional variables when testing between two time periods is the Wilcoxin's signed rank test (Elzinga et al. 1998). Appropriate nonparametric tests for nonproportional data when testing for change between three or more time periods are the Friedman's test and the Wilcoxin's signed rank test with Bonferroni correction (Elzinga et al. 1998).

7.1.2 Parameter estimation and confidence intervals

Parameter estimation and associated standard errors are an alternative strategy to statistical hypothesis tests (Johnson 1999). Using parameter estimation over the years can guide the process of achieving long-term objectives (Mulder et al. 1999). When used over a number of years, parameter estimation and confidence intervals recorded at interval time periods can determine if a community variable, (e.g. total species richness, exotic species richness, and exotic:native ratio) is constant, increasing, or decreasing over time. Further, periodic estimates of the direction and magnitude of change occurring provide an ongoing evaluation of management efforts.

Parameter estimation involves estimating a parameter (mean, total, or proportion) and constructing a confidence interval around the estimate (Elzinga et al. 1998). The associated confidence intervals provide a measure of the uncertainty in the estimation. A narrow 95% confidence interval provides the assurance that the parameter is well estimated. Species richness, exotic species richness, mean percent cover of exotics, mean percent cover and importance value of species guilds, and the mean percent cover of selected individual species can all be used in parameter estimation.

7.2 Long-term analytical methods

7.2.1 Community trend analysis

In trend analysis, the objective is to ascertain whether there has been a change in the annual means for the variable over time. Our study design lends itself nicely to repeated measures analysis, which allows for the significance of trends generated by the sequential sampling of plots to be tested. The trend analysis that we suggest is described in detail in Lesica and Steele (1996). Lesica and Steele (1996) use a repeated measures design with a multivariate general linear model. A multivariate general linear model is used because the observations are not independent but possess a correlation structure due to the repeated sampling of plots (Lesica and Steele 1996). The repeated measures model compares whether the average annual mean across all years within a time period is different between time periods. Error is estimated by using between-plot, within-year variation, and statistical inference is restricted to the management unit (plant community) and the sampled years.

We also feel this is an appropriate analysis model because of the sampling frequency regime that will be implemented (e.g. sampling for a number of consecutive years over x number of years). Using a mean value across time periods reduces the effect of short-term variation. The sample mean of multiple years is more precise than that from a single year (Elzinga et al. 1998, Lesica and Steele 1996). Because we are dealing with primarily perennial plant species, variability in cover estimates is highly variable from year to year. The above model accommodates for the effects of high frequency variation to allow for an assessment of the significance of long-term trends (Lesica and Steele 1996).

We performed power analysis to assess the adequacy of our current sampling intensity and the usefulness of the community variables and metrics in measuring community change over time. We provide the results and a discussion of power analysis in Appendix D. We feel there are a number of variables that will be useful in assessing community-level change through time. Table 6 provides a summary of the community variables and metrics that we feel can be used in long-term analysis and the appropriate statistical methods for analysis.

Alternative statistical methods are available for use in specific circumstances. The repeated measures design can be analyzed by the univariate mixed-model analysis of variance (Sokal and Rohlf

1981) when there is one site and one attribute of interest (Lesica and Steele 1996, 1997). Time series analysis (Brillinger 1994) can be used when the number of years is substantial (e.g. at least 50 years). The paired *t*-test can test for differences in mean values for nonproportional data between two time periods; McNemar's test can test for differences in mean values for proportional data between two time periods. The Bonferroni *t*-test, Tukey test, and Student-Neuman-Keuls test can be used in comparisons of nonproportional data between multiple time periods. The Tukey test and the Student-Neuman-Keuls test are most suitable for multiple comparison tests on more than 8 to 10 years of data (Glantz 1992).

When sufficient years of data are available, multiple regression analysis and correlation analysis can be used to investigate correlative relationships in plant community metrics, environmental conditions, and management strategies (e.g. species richness, species guild importance value, exotic species richness, exotic species percent cover, years since burn, soil type) (Gibson 1988, Smith and Knapp 1999).

7.2.2. Landscape-level analysis

Long-term monitoring efforts can benefit from the investigation of similarities and differences between community types. Summary tables and the multivariate analyses Detrended Correspondence Analysis (DCA), Cluster Analysis, and Two-Way Indicator Species Analysis (TWINSPAN) are useful exploratory tools for detecting large-scale compositional differences. DCA can also be used to detect large-scale compositional shifts within a plant community by ordinating data from sequentially sampled years (Bowles et al. 1996). Several statistical procedures can test for significant differences in species composition between plant communities. Richness, exotic species richness, diversity, and the exotic:native ratio can be compared using the *t*-test or the Mann-Whitney U test. Differences in species composition can be compared using a similarity index, specifically Sorensen's Coefficient of Similarity, or a multivariate analysis, Multi-Response Permutation Procedure (MRPP). MRPP is a nonparametric analogue of linear discriminant analysis similar to the *t*-test and the one-way analysis of variance F test (Zimmerman et al. 1985). Such comparative information can be used to set long-term management objectives for degraded plant communities, or used to compare a restoration site to a high-quality prairie to evaluate progress.

8.0 MONITORING COMPONENT INTEGRATION

Efforts should be made to integrate vegetation community monitoring efforts with related monitoring components as data are collected. Constructing a comprehensive framework for analyzing correlated factors is beyond the timeframe of this report. We present a conceptual model outlining how the vegetation community data can be integrated with rare plant, exotic species, adjacent land-use, butterfly, and local climate monitoring efforts in Figure 4.

There are a number of reasons to integrate monitoring components. There are a number of community types where vegetation data will be useful in interpreting distribution patterns and abundance of other taxa (Table 6). For example, on Bloody Hill Glade, *Lesquerella* population status and vegetation community data can be analyzed for declining or increasing populations and changes in vegetation community composition and structure. Plant composition data can provide information on butterfly habitat and foraging preferences. On the other hand, monitoring components also will be helpful in the long-term analysis of plant community data (Table 7). Fluctuations in local climate can provide explanations for variability in percent foliar cover, species richness, and flowering and fruiting cycles. Adjacent land-use and exotic species data can identify communities highly vulnerable to exotic species invasion.

Plant community data also can be integrated with prescribed fire fuel monitoring. We have provided a method for collecting fire fuel information that is modified from the NPS Western Region Fire Monitoring Handbook (Appendix C). By collecting data on fire fuels in the communities where vegetation monitoring is performed rather than elsewhere, we can investigate prescribed fire intensity and fire behavior as well as the effects on the vegetation community.

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Table 1. Plant communities and management units sampled at the Prairie Cluster Program Parks.

	Park/acreage	Plant community (total acres within the park)	Management unit (size in acres)	Number of Transect pairs
Tallgrass prairie	HOME (160)	Tallgrass prairie restoration (100)	Upland prairie (55)	2
			Lowland prairie (43)	3
	PIPE (282)	Tallgrass prairie restoration (80)	Unit 4 (40)	3
		Tallgrass prairie (112)	Unit 2 (61)	4
		Sioux quartzite prairie (5)	Sioux quartzite prairie (5)	2
Prairie-glade/savanna	EFMO (1476)	Tallgrass prairie restoration (100)	North restoration unit (50)	2
			South restoration unit (25)	1
		Goat prairie (5)	5 of 16 goat prairies sampled	5**
	WICR (1751)	Limestone glade (40)	Bloody Hill glade (12.5)	3
		Upland woodlands (145)	Manley woodland (70)	4
		Tallgrass prairie restoration (425)	Units 1N/1O (50)	2
Mixed-grass prairie	SCBL (3003)	*Stipa - Carex filifolia* prairie*	South bluff (500)	3
		Degraded *Stipa - Carex filifolia* prairie*	South bluff (500)	4
		Pinus pondersoa - Juniperus scopulorum woodland *	South bluff (500)	2
		Mixed-grass prairie restoration (42)	1998 golf course restoration (42)	2
		Mixed-grass prairie *	Adjacent to 1998 golf course	2
	AGFO (3055)	*Calamovilfa longifolia - Andropogon hallii* prairie	University/Carnegie Hill (850)	4
		Schizachyrium scoparium - Bouteluoa-Carex filifolia prairie	University/Carnegie Hill (850)	2
		Stipa comata - Carex filifolia prairie	University/Carnegie Hill (850)	1
		Pascopyrum smithii prairie	University/Carnegie Hill (850)	1
		Degraded *Calamovilfa longifolia -Andropogon hallii* prairie	University/Carnegie Hill (850)	2

*Acreage unknown.
** 3 of the 5 transect pairs were modified to accommodate habitat size limitations.

Table 2. Modified Daubenmire cover value scale used to determine herbaceous/shrub species cover for the Prairie Cluster Program Parks

Cover class codes	Range of cover (%)	Class midpoints (%)
7	95-100	97.5
6	75-94	85.0
5	50-74	62.5
4	25-49	37.5
3	5-24	15.0
2	1-4	2.5
1	0-0.99	0.5

Table 3. Data summary and routine reporting of community composition.

	Variable	Calculation
Community composition	Diversity	$H' = -\sum p_i \ln p_i$;
	Richness	S = Total number of species
	Evenness	$E = H'/H_{max} = H'/\ln S$
	Overstory	Total BA and density Mean dbh Mean density by size class
	Understory	Mean density of: 1) Small seedlings < 0.5 m in height 2) Large seedlings ≥ 0.5 m in height, < 2.5 cm dbh 3) Saplings ≥ 2.5 cm dbh, < 5.0 cm dbh
	Ground flora Individual species	Frequency sp_i = number of occurrences/total number of plots Mean % cover $sp_i = \Sigma$ % cover/total number of plots
	Ground flora Ecological guilds	Relative % cover of guild i = $\frac{\Sigma \text{ \% cover guild}_i}{\Sigma \text{ \% cover of all species}}$ Relative % frequency of guild i = $\frac{\Sigma \text{ occurrences species guild}_i}{\Sigma \text{ occurrences all species}}$ Importance value of guild i = $\frac{\text{Rel. \% cover + Rel. \% frequency}}{2}$
Exotic species distribution	Exotic:native ratio	R=EX:S (EX = number of exotic sp., S= number of native sp)
	Distribution	Relative % cover (see species guild calculations above) Relative % frequency (see species guild calculations above) Importance value (see species guild calculations above) Mean % cover of exotics = $\Sigma \frac{\text{\% cover exotic species}}{\text{total number plots}}$
Community structure	Vegetation	Mean % tree canopy cover Mean % herbaceous and shrub cover
	Environment	Mean % grass litter Mean % tree leaf litter Mean % bare rock Mean % bare soil Mean % woody debris Mean % unvegetated surface

Table 4. Diameter distributions within a diameter class.

Diameter class	Diameter range	
	Centimeters	Inches
1	4.5 - 9.4	1.8 - 3.7
2	9.5 - 14.4	3.8 - 5.6
3	14.5 - 19.4	5.7 - 7.6
4	19.5 - 24.4	7.7 - 9.6
5	≥ 25.5	≥ 9.7

Table 5. Community variables and metrics and statistical analyses used in making comparisons between time periods to test for change. Suggested statistical analyses that can be used with each variable and metric are also listed.

Comparisons	Type of variable	Variables/metrics	Significance test
Two time periods	Nonproportional	Species richness Exotic species richness Woody stem density Mean % cover – exotic species Mean % cover - species guilds Importance value – species guilds	• Paired *t*-test • Wilcoxin's signed rank test (nonparametric alternative) • Friedman's test (nonparametric alternative)
	Proportional	Frequency Exotic:native ratio	• McNemar's test
Three or more time periods	Nonproportional	Species richness Exotic species richness Woody stem density Mean % cover – exotic species Mean % cover - species guilds Importance value – species guilds	• Bonferroni paired *t*-test • Tukey test (nonparametric alternative) • Student-Neuman-Keuls test (nonparametric alternative)

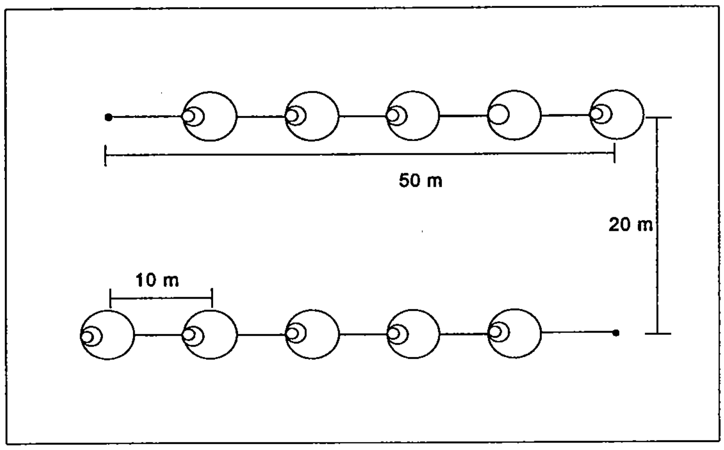
Table 6. Community variables and metrics useful in long-term analysis given our current sampling design. The management questions reflect the concerns that can be addressed given the variables listed; we provide statistical analysis techniques that are applicable to the question and variables.

Community metrics and variables applicable for long-term analysis	Management question	Statistical analysis technique
Community metrics Exotic species richness Species richness Community variables Mean percent cover - dominant species guild Mean percent cover – forb species guild Relative Frequency – species guilds * Importance Value – species guilds *	Has there been a change in a plant community metric or variable over the past 10 years?	Repeated measures design - multivariate general linear model
Community metrics Exotic species richness Species richness Community variables Mean percent cover – exotic species Importance Value – species guilds * Environmental and management-related variables Climate variables Soil variables Fire frequency Mowing intervals Herbicide treatment intervals	Is the detected change associated with an environmental condition or a specific management strategy?	Correlation analysis Regression analysis
Community variables Multivariate community data Presence/Absence Percent cover by species/guild	Are there compositional differences in this restoration site and the adjacent remnant native community?	Exploratory analysis Detrended correspondence analysis (DCA) Cluster analysis Two-way indicator species analysis (TWINSPAN) Statistical analysis MRPP Sorenson's index of similarity

*See Appendix D for discussion of species guilds

Table 7. Integration of Prairie Cluster monitoring components

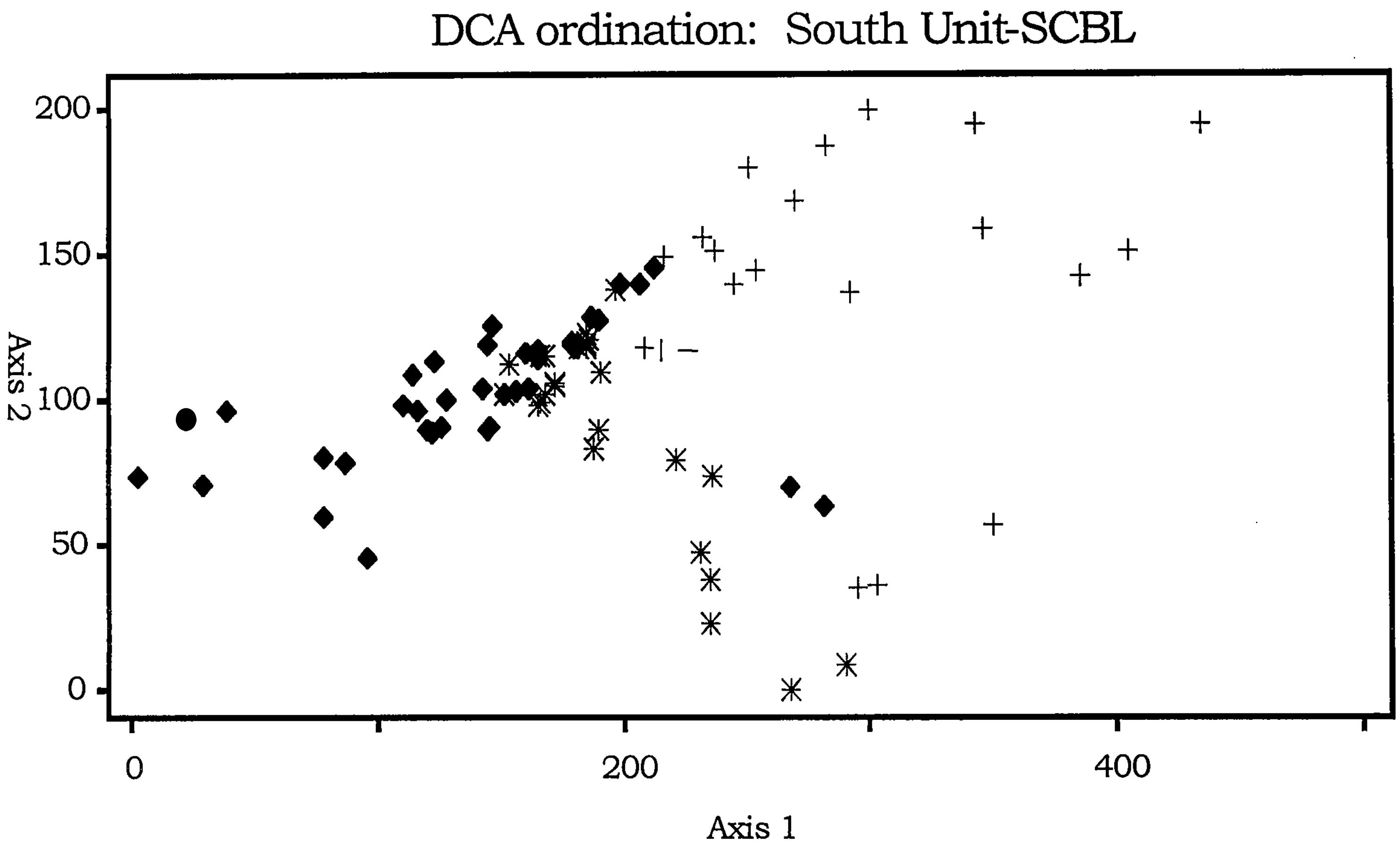
Management question	Vegetation monitoring metrics/tools		Related monitoring tools
Integrating vegetation monitoring with studies of other taxa			
Do prairie remnants support diverse bird and butterfly assemblages?	Diversity, structure and composition of prairie plant community	→	Abundance and diversity of prairie birds and butterflies
Is current management of vegetation communities improving threatened and endangered species habitat?	Prescribed fire regime/other management strategy Structure and composition of prairie plant community	→	Population size of rare species
Are exotic control efforts effective?	Frequency and abundance of invasive exotics	→	Control measures
Using other monitoring components to better our understanding of vegetation monitoring data			
Are changes in land-use impacting prairie plant communities?	Native richness and diversity Exotic/native ratio Guild structure	→	Spatial pattern of land-use change Community invasibility potential
Are changes in land-use affecting exotic species?	Distribution and abundance of invasive exotics	→	Spatial pattern of land-use change Status of the community's susceptibility to invasive species
How is prescribed fire impacting prairie communities?	Species diversity and richness; Exotic:native ratio Guild structure	→	Frequency, seasonality, severity of prescribed fires
Are restoration methods working?	Species diversity and richness Exotic:native ratio Guild structure	→	Guild structure of potential native plant community



Plot sizes	Vegetation component sampled
$0.1\ m^2$	Herbaceous and shrub species presence recorded
$1\ m^2$	Herbaceous and shrub species presence recorded
$10\ m^2$	1. Foliar cover of all herbaceous and shrub species estimated using cover class values; 2. Stems of woody seedlings (< 0.5 m tall), large seedlings (> 0.5 m tall and < 2.5 cm dbh), and saplings (> 2.5 cm DBH and < 5.0 cm dbh) counted.
0.1 ha	Within the 0.1 ha between the paired transects, species and DBH of all trees > 5.0 cm DBH recorded.

Figure 1. The sampling unit used in plant community monitoring

Figure 2. DCA ordination results for the south unit of Scotts Bluff National Monument.



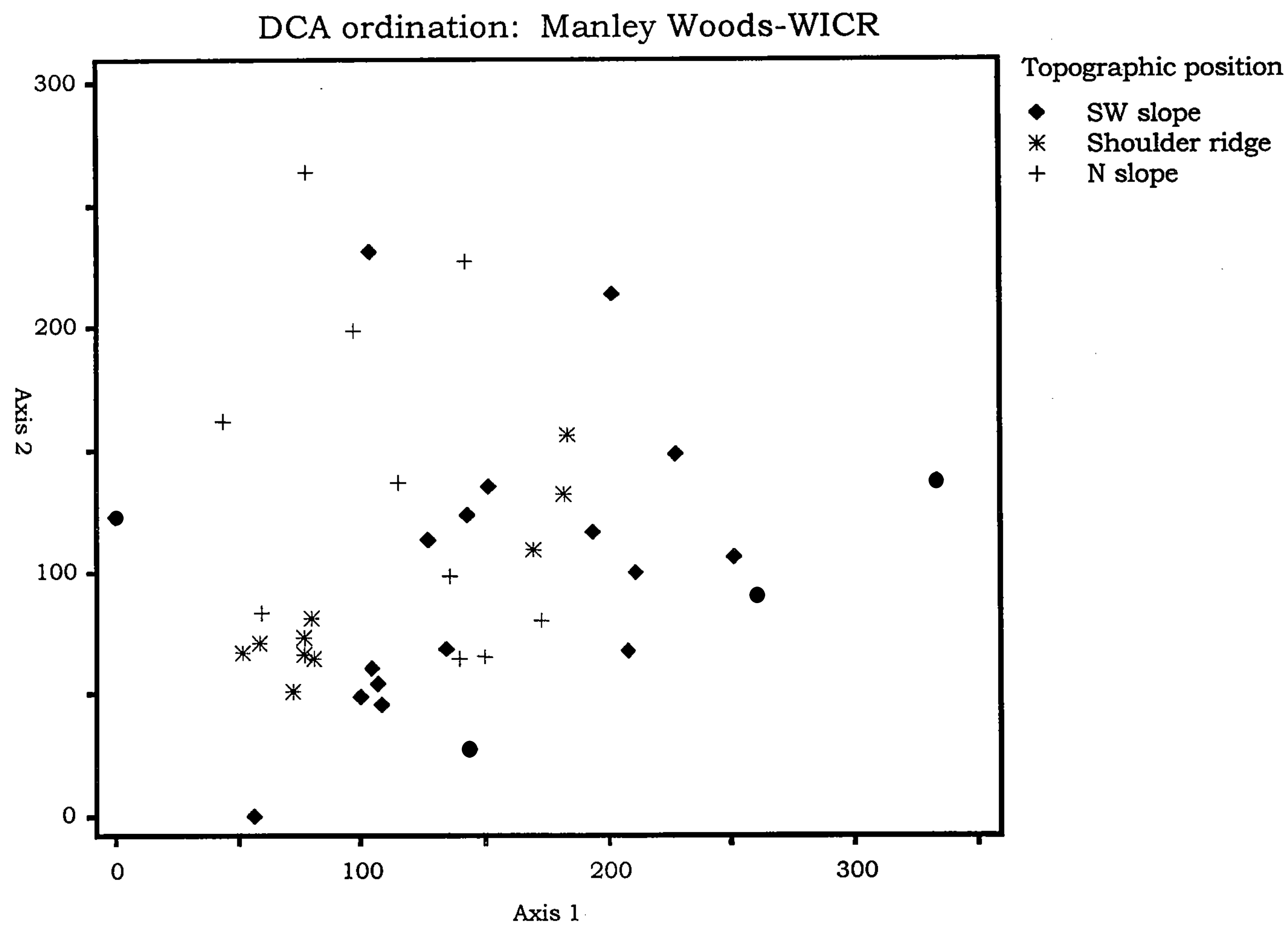
Plant Community

♦ Brome-dominated prairie

+ Native prairie

* Ponderosa pine woodland

Figure 3. DCA ordination results for Manley Woods at Wilson's Creek National Battlefield.



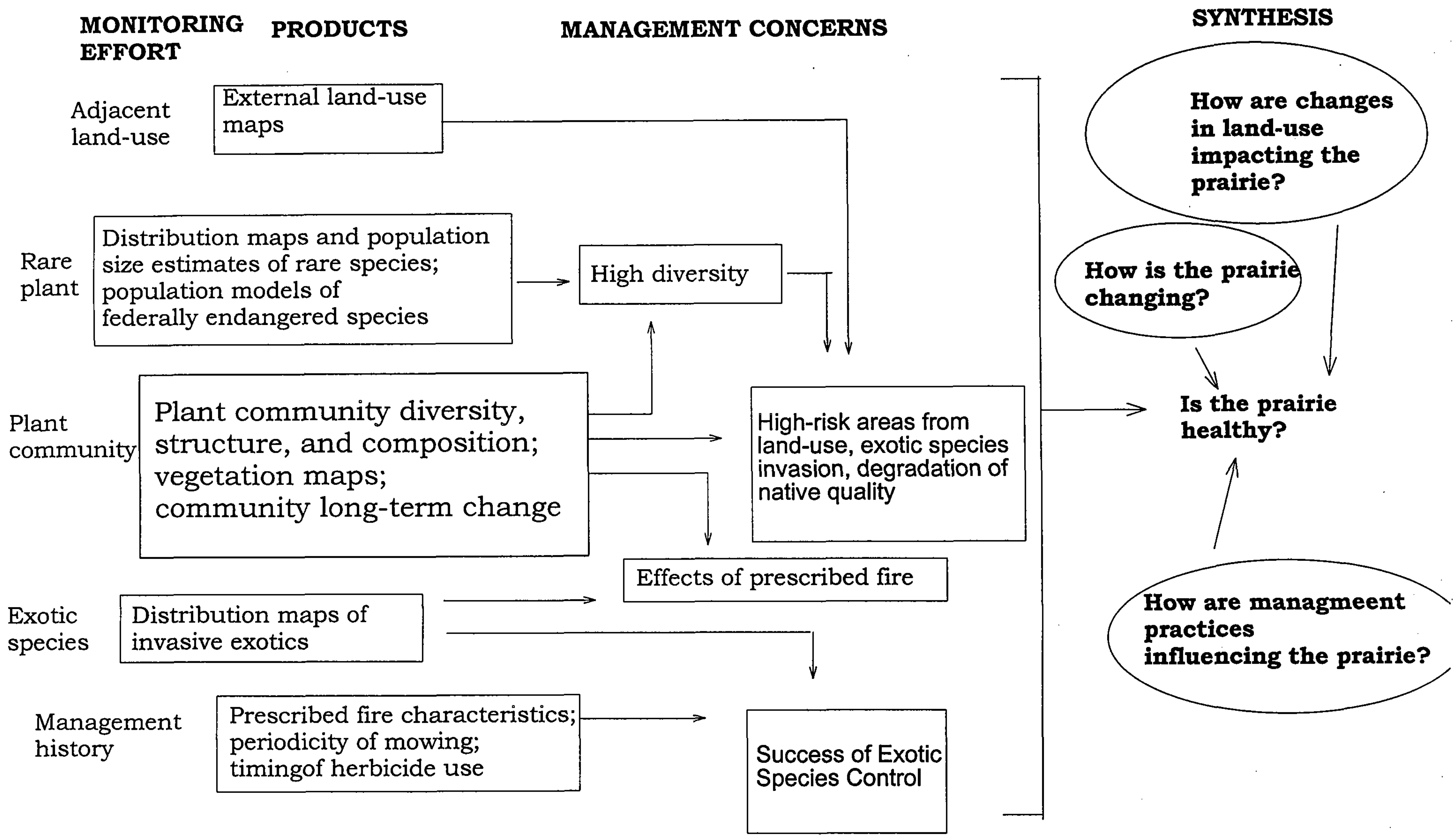


Figure 4. Conceptual Model of Integrated Monitoring Components

1.0 A DEFINITION OF PSEUDOREPLICATION

Hurlbert (1984) defines pseudoreplication as the use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (samples may be) or replicates are not statistically independent. Pseudoreplication refers not to a problem in sampling design per se but rather to a particular combination of experimental design and statistical analysis inappropriate for testing the hypothesis of interest. The sampling design we have chosen for long-term plant community monitoring could be seen as pseudoreplication because plots are placed systematically along transects. We argue that the scope of the plant community monitoring program limits the applicability of this concern because the monitoring project is designed for information to be extrapolated specifically from the plot level to the community/study unit level.

2.0 PLANT COMMUNITY MONITORING: A PERMANENT SAMPLING DESIGN

The plant community monitoring in the Prairie Cluster parks is what Hurlbert (1984) defines as a mensurative experiment, an experiment where measurements are made at one or more points in space or time. Space or time is the only "experimental variable" or "treatment." The plant community monitoring looks primarily at change within communities over time. The objectives deal primarily with characterizing remnant, disturbed, and restored prairies and oak savanna/woodlands and determining whether the structure, composition, and diversity of the remnant, disturbed, and restored prairie parcels being monitored are changing over time. The monitoring project is designed to investigate site- and management-specific questions and not to extrapolate to the larger (i.e., greater than community) prairie landscape.

Because we are interested in the effect of *time* as a "treatment," we are dealing with a permanent sampling design. Temporal pseudoreplication refers to situations where an experimental unit is sampled repeatedly through time and the samples are treated as if they represent independent experimental units. Permanent plots design are in violation of temporal pseudoreplication; the design generates dependent, not independent observations. The observations from a single plot are correlated because they are more alike than those from different plots. An appropriate statistical analysis for permanent plots designs is one that recognizes plot as a factor in the analysis (Lesica and Steele 1997). The plot factor is treated as a random effect; the effect of the plot factor differs among plots but is the same for a given plot in all years. Conversely, the year factor is treated as a fixed effect because the sample is restricted to the years of interest. The problem of detecting change in plant communities amounts to determining if the year effects are different (Lesica and Steele 1997). The analysis we have chosen, a repeated measures design with a multivariate general linear model, is appropriate for a permanent plot design.

3.0 UNIT OF ANALYSIS

We have two options in analysis: 1) the plot can function as the analysis unit, or 2) the plots can be pooled to the transect pair level, and the transect pair then functions as the analysis unit. Which option is used depends on whether the plots along transects are independent. If the plots along transects are not independent, the transect pairs are the analysis unit.

Space in prairie communities is dominated by a few species of perennial grasses. The remaining space is occupied by a number of species that occur frequently but at lower levels of abundance (Gotelli and Simberloff 1987). Distribution patterns in prairies are considered bimodal; the prairie community is comprised of a small number of species that are abundant and a larger group of species that are sparsely distributed. This pattern in community structure has been observed at regional, community, and local scales (Collins and Glenn 1990, 1991).

Hanski (1982) introduced the core-satellite hypothesis concerning regional patterns in species distribution. The hypothesis states that within a region, a large number of sparse, or "satellite," species occur at only a few sites, and a distinct mode of dominant, or "core," species occurs throughout the region. Gotelli and Simberloff (1987) found that within-community level distribution patterns supported the core-satellite hypothesis, and Collins and Glenn (1990, 1991) found the core-satellite hypothesis applicable not only at the regional scale (km^2) but at the community level and the local scale (m^2). Collins and Glenn (1990) stated that patterns in community structure are fractal (Palmer 1988), with the larger unit composed of smaller units similar in structure to the larger unit. These patterns of self-similarity imply that the same factors affecting species distribution and patterns of community structure on a large spatial scale may be the same as, or constrained by, those factors operating on smaller scales (Collins and Glenn 1990). Thus, regardless of the scale of analysis, prairies are dominated by a few matrix-forming grass species that effectively control community structure with a large number of less abundant species, referred to as satellite species, occupying the remaining space (Collins 1987, Collins and Glenn 1990). Because of the repeatability of community pattern at local and regional scales, Collins and Glenn (1990) found 10 m^2 plots to be adequate for community-level sampling in prairie communities.

Within a community, patches are delineated as distinct assemblages of species, potentially repeatable over space (Forman and Godron 1986). Collins and Glenn (1988) found that community-level patch structure in tallgrass prairies is defined mainly by satellite species. Patch structure was defined by the satellite species because the dominant grasses occurred in all patch types. Satellite species defined patches that varied spatially within and between growing seasons, fluctuating year to year in abundance and distribution (Collins and Glenn 1988; Collins and Glenn 1991). Bartha et al. (1995), in looking at fine-scale spatial patterns in tallgrass prairie in upland, slope, and lowland positions, found that characteristic scales of association between individual species were between 1.2 m and 3 m, regardless of topographic position.

We are using the 10 m^2 plots to investigate change in the plant community. The above-referenced works and others (Gibson 1988, Glenn and Collins 1992, Collins 1992) support that 10 m^2 plots are effective in investigating community-level change in prairie communities. Further, because small-scale variation in prairies likely occurs at scales smaller than the distance (3.7 m) between plots along transects (Bartha et al. 1995; S. Collins, personal communication), the plots are distanced enough not to fall into the same microsite or patch and can be considered independent samples (Lesica and Steele 1996; Elzinga et al. 1998; Knapp, personal communication).

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Appendix B. Sample unit location information.

Agate Fossil Beds National Monument

	EASTING	NORTHING	COMMENT	System	Zone	Datum
1	604840.965	4696461.852	4bs	UTM	13T	NAD 1983 (Conus)
2	604879.068	4696428.812	4bf	UTM	13T	NAD 1983 (Conus)
3	604865.986	4696414.138	4af	UTM	13T	NAD 1983 (Conus)
4	604828.218	4696446.571	4as	UTM	13T	NAD 1983 (Conus)
5	604863.738	4696359.372	5bs	UTM	13T	NAD 1983 (Conus)
6	604905.154	4696332.049	5bf	UTM	13T	NAD 1983 (Conus)
7	604910.280	4696339.514	5af	UTM	13T	NAD 1983 (Conus)
8	604868.979	4696367.285	5as	UTM	13T	NAD 1983 (Conus)
9	602981.041	4696649.445	1as	UTM	13T	NAD 1983 (Conus)
10	602961.155	4696649.105	1bs	UTM	13T	NAD 1983 (Conus)
11	602961.127	4696598.783	1bf	UTM	13T	NAD 1983 (Conus)
12	602981.089	4696598.942	1af	UTM	13T	NAD 1983 (Conus)
13	603477.589	4696571.181	11as	UTM	13T	NAD 1983 (Conus)
14	603444.893	4696533.174	11af	UTM	13T	NAD 1983 (Conus)
15	603429.952	4696545.615	11bf	UTM	13T	NAD 1983 (Conus)
16	603461.923	4696584.297	11bs	UTM	13T	NAD 1983 (Conus)
17	604111.104	4696263.418	6af	UTM	13T	NAD 1983 (Conus)
18	604064.063	4696245.664	6as	UTM	13T	NAD 1983 (Conus)
19	604056.994	4696263.748	6bs	UTM	13T	NAD 1983 (Conus)
20	604103.369	4696282.186	6bf	UTM	13T	NAD 1983 (Conus)
21	602911.277	4697420.539	9bf	UTM	13T	NAD 1983 (Conus)
22	602895.428	4697408.338	9af	UTM	13T	NAD 1983 (Conus)
23	602927.008	4697368.510	9as	UTM	13T	NAD 1983 (Conus)
24	602942.756	4697380.936	9bs	UTM	13T	NAD 1983 (Conus)
25	601137.026	4697261.276	10 as	UTM	13T	NAD 1983 (Conus)
26	601088.831	4697248.268	10 af	UTM	13T	NAD 1983 (Conus)
27	601083.407	4697267.467	10 bf	UTM	13T	NAD 1983 (Conus)
28	601131.431	4697280.329	10 bs	UTM	13T	NAD 1983 (Conus)
29	604798.493	4697226.648	2bs	UTM	13T	NAD 1983 (Conus)
30	604807.765	4697177.516	2bf	UTM	13T	NAD 1983 (Conus)
31	604827.207	4697180.923	2af	UTM	13T	NAD 1983 (Conus)
32	604818.007	4697230.233	2as	UTM	13T	NAD 1983 (Conus)
33	604436.041	4697472.231	8af	UTM	13T	NAD 1983 (Conus)
34	604417.785	4697480.352	8bf	UTM	13T	NAD 1983 (Conus)
35	604434.124	4697527.396	8bs	UTM	13T	NAD 1983 (Conus)
36	604452.383	4697519.443	8as	UTM	13T	NAD 1983 (Conus)
1	604936.255	4697056.820	7as	UTM	13T	NAD 1983 (Conus)
2	604949.954	4697009.110	7af	UTM	13T	NAD 1983 (Conus)
3	604930.913	4697003.529	7bf	UTM	13T	NAD 1983 (Conus)
4	604917.236	4697051.138	7bs	UTM	13T	NAD 1983 (Conus)
5	604855.823	4696987.333	3bs	UTM	13T	NAD 1983 (Conus)
6	604877.306	4696942.341	3bf	UTM	13T	NAD 1983 (Conus)
7	604859.319	4696934.169	3af	UTM	13T	NAD 1983 (Conus)
8	604837.811	4696978.487	3as	UTM	13T	NAD 1983 (Conus)

Effigy Mounds National Monument

Management Unit	Trnst No.	Corner	WP Number		Coord Type	Zone	Easting	Northing	Datum	Error
South Unit - Goat Prairie	6	SE 6AS	WP146	MARK146	UTM/UPS	15T	648039	4771470	NAS-C	5
South Unit - Goat Prairie	6	SW 6AF	WP147	MARK147	UTM/UPS	15T	647997	4771451	NAS-C	5
South Unit - Goat Prairie	6	NW 6BF	WP148	MARK148	UTM/UPS	15T	647991	4771480	NAS-C	5
South Unit - Goat Prairie	6	NE 6BS	WP149	MARK149	UTM/UPS	15T	648027	4771484	NAS-C	5
South Unit - Goat Prairie	6	MIDPLOT	WP150	MARK150	UTM/UPS	15T	648014	4771468	NAS-C	
South Unit - Goat Prairie	1	NW 1AS	WP151	MARK151	UTM/UPS	15T	648105	4769639	NAS-C	5
South Unit - Goat Prairie	1	SW 1A2S	WP152	MARK152	UTM/UPS	15T	648078	4769626	NAS-C	5
South Unit - Goat Prairie	1	SE 1A2F	WP153	MARK153	UTM/UPS	15T	648101	4769589	NAS-C	5
South Unit - Goat Prairie	1	NE 1AF	WP154	MARK154	UTM/UPS	15T	648121	4769592	NAS-C	5
South Unit - Goat Prairie	1	MIDPLOT	WP155	MARK155	UTM/UPS	15T	648107	4769610	NAS-C	5
South Unit - Goat Prairie	1	N 1BS	WP156	MARK156	UTM/UPS	15T	648124	4769582	NAS-C	6
South Unit - Goat Prairie	1	MIDPLOT	WP157	MARK157	UTM/UPS	15T	648132	4769561	NAS-C	6
South Unit - Goat Prairie	1	S 1BF	WP158	MARK158	UTM/UPS	15T	648141	4769544	NAS-C	6
South Unit - Goat Prairie	14	NW 14AS	WP159	MARK159	UTM/UPS	15T	647452	4770565	NAS-C	8
South Unit - Goat Prairie	14	NE 14AF	WP160	MARK160	UTM/UPS	15T	647414	4770603	NAS-C	8
South Unit - Goat Prairie	14	SE 14BF	WP161	MARK161	UTM/UPS	15T	647393	4770586	NAS-C	7
South Unit - Goat Prairie	14	SW 14BS	WP162	MARK162	UTM/UPS	15T	647438	4770554	NAS-C	7
South Unit - Goat Prairie	14	MIDPLOT	WP163	MARK163	UTM/UPS	15T	647424	4770579	NAS-C	7
North Unit - Goat Prairie	16	SW 16AS	WP164	MARK164	UTM/UPS	15T	647233	4772087	NAS-C	8
North Unit - Goat Prairie	16	NW 16AF	WP165	MARK165	UTM/UPS	15T	647213	4772132	NAS-C	8
North Unit - Goat Prairie	16	NE 16BF	WP166	MARK166	UTM/UPS	15T	647232	4772122	NAS-C	8
North Unit - Goat Prairie	16	SE 16BS	WP167	MARK167	UTM/UPS	15T	647255	4772071	NAS-C	8
North Unit - Goat Prairie	16	MIDPLOT	WP168	MARK168	UTM/UPS	15T	647228	4772109	NAS-C	8
North Unit - Prairie Restoration	7	NE 7AS	WP169	MARK169	UTM/UPS	15T	647893	4773019	NAS-C	4
North Unit - Prairie Restoration	7	SE 7AF	WP170	MARK170	UTM/UPS	15T	647909	4772972	NAS-C	4
North Unit - Prairie Restoration	7	SW 7BF	WP171	MARK171	UTM/UPS	15T	647891	4772966	NAS-C	4
North Unit - Prairie Restoration	7	NW 7BS	WP172	MARK172	UTM/UPS	15T	647875	4773012	NAS-C	5
North Unit - Prairie Restoration	7	MIDPLOT	WP173	MARK173	UTM/UPS	15T	647888	4772992	NAS-C	4
North Unit - Prairie Restoration	8	NW 8AS	WP174	MARK174	UTM/UPS	15T	647713	4773387	NAS-C	5
North Unit - Prairie Restoration	8	NE 8AF	WP175	MARK175	UTM/UPS	15T	647757	4773364	NAS-C	5
North Unit - Prairie Restoration	8	SE 8BF	WP176	MARK176	UTM/UPS	15T	647748	4773347	NAS-C	6
North Unit - Prairie Restoration	8	SW 8BS	WP177	MARK177	UTM/UPS	15T	647704	4773369	NAS-C	5
North Unit - Prairie Restoration	8	MIDPLOT	WP178	MARK178	UTM/UPS	15T	647729	4773357	NAS-C	7

Effigy Mounds (cont.)

Management Unit	Trnst No.	Corner	WP Number		Coord Type	Zone	Easting	Northing	Datum	Error
North Unit - Goat Prairie	13	NW 13AF	WP180	MARK180	UTM/UPS	15T	648096	4774069	NAS-C	5
North Unit - Goat Prairie	13	NE 13BF	WP181	MARK181	UTM/UPS	15T	648120	4774075	NAS-C	6
North Unit - Goat Prairie	13	SE 13BS	WP182	MARK182	UTM/UPS	15T	648132	4774053	NAS-C	6
North Unit - Goat Prairie	13	MIDPLOT	WP183	MARK183	UTM/UPS	15T	648115	4774062	NAS-C	6
South Unit - Prairie Restoration	9	SW 9AS	WP184	MARK184	UTM/UPS	15T	647696	4770462	NAS-C	5
South Unit - Prairie Restoration	9	NW 9AF	WP185	MARK185	UTM/UPS	15T	647705	4770511	NAS-C	5
South Unit - Prairie Restoration	9	NE 9BF	WP186	MARK186	UTM/UPS	15T	647724	4770507	NAS-C	5
South Unit - Prairie Restoration	9	SE 9BS	WP187	MARK187	UTM/UPS	15T	647717	4770459	NAS-C	5
South Unit - Prairie Restoration	9	MIDPLOT	WP188	MARK188	UTM/UPS	15T	647715	4770484	NAS-C	7

Homestead National Monument of America

ID	Easting	Northing	Comment	System	Zone	Datum
1	684187.124	4461909.951	5bf	UTM	14T	NAD 1983 (Conus)
2	684221.560	4461946.030	5bs	UTM	14T	NAD 1983 (Conus)
3	684236.531	4461932.076	5as	UTM	14T	NAD 1983 (Conus)
4	684201.618	4461896.045	5af	UTM	14T	NAD 1983 (Conus)
5	684335.230	4461816.582	4bf	UTM	14T	NAD 1983 (Conus)
6	684375.440	4461846.586	4bs	UTM	14T	NAD 1983 (Conus)
7	684387.203	4461830.448	4as	UTM	14T	NAD 1983 (Conus)
8	684347.046	4461801.044	4af	UTM	14T	NAD 1983 (Conus)
9	684405.262	4461763.451	3bf	UTM	14T	NAD 1983 (Conus)
10	684419.040	4461748.941	3af	UTM	14T	NAD 1983 (Conus)
11	684439.367	4461799.799	3bs	UTM	14T	NAD 1983 (Conus)
12	684453.534	4461785.691	3as	UTM	14T	NAD 1983 (Conus)
13	684557.309	4461697.988	1bs	UTM	14T	NAD 1983 (Conus)
14	684568.868	4461681.735	1as	UTM	14T	NAD 1983 (Conus)
15	684528.731	4461652.154	1af	UTM	14T	NAD 1983 (Conus)
16	684517.053	4461668.076	1bf	UTM	14T	NAD 1983 (Conus)
17	684237.016	4461667.601	2bf	UTM	14T	NAD 1983 (Conus)
18	684237.102	4461647.778	2af	UTM	14T	NAD 1983 (Conus)
19	684286.502	4461648.476	2as	UTM	14T	NAD 1983 (Conus)
20	684286.926	4461668.525	2bs	UTM	14T	NAD 1983 (Conus)

Pipestone National Monument

ID	Easting	Northing	Comment	System	Zone	Datum
1	714365.1183391	4876688.4319143	14bf	UTM	15T	NAD 1983 (Conus)
2	714413.8898107	4876698.9781942	14bs	UTM	15T	NAD 1983 (Conus)
3	714410.1309314	4876718.3363204	14as	UTM	15T	NAD 1983 (Conus)
4	714361.2878674	4876708.6408637	14af	UTM	15T	NAD 1983 (Conus)
5	714649.4764045	4876695.2493327	12af	UTM	15T	NAD 1983 (Conus)
6	714666.6756521	4876703.8297934	12bf	UTM	15T	NAD 1983 (Conus)
7	714689.3597274	4876659.2985164	12bs	UTM	15T	NAD 1983 (Conus)
8	714671.9893136	4876650.1349723	12as	UTM	15T	NAD 1983 (Conus)
9	714670.1882234	4876564.1849651	13as	UTM	15T	NAD 1983 (Conus)
10	714690.4638110	4876563.5535829	13bs	UTM	15T	NAD 1983 (Conus)
11	714693.7303375	4876613.4198662	13bf	UTM	15T	NAD 1983 (Conus)
12	714674.0611287	4876614.5360122	13af	UTM	15T	NAD 1983 (Conus)
13	714368.4761217	4876607.0509930	11as	UTM	15T	NAD 1983 (Conus)
14	714349.0677631	4876606.3819779	11bs	UTM	15T	NAD 1983 (Conus)
15	714352.4665505	4876556.8826937	11bf	UTM	15T	NAD 1983 (Conus)
16	714373.0838975	4876557.6976547	11af	UTM	15T	NAD 1983 (Conus)
17	714541.6850523	4876643.0291060	6bs	UTM	15T	NAD 1983 (Conus)
18	714538.4885606	4876602.7003500	6bf	UTM	15T	NAD 1983 (Conus)
19	714746.0261956	4876959.0873236	5bs	UTM	15T	NAD 1983 (Conus)
20	714739.9658797	4876920.2137034	5bf	UTM	15T	NAD 1983 (Conus)
21	713950.9060135	4877015.2888023	7bs	UTM	15T	NAD 1983 (Conus)
22	713969.1172487	4877022.1762070	7as	UTM	15T	NAD 1983 (Conus)
23	713984.7089731	4876975.3868595	7af	UTM	15T	NAD 1983 (Conus)
24	713966.1286390	4876969.4237985	7bf	UTM	15T	NAD 1983 (Conus)
25	714100.7931722	4877187.2038072	9bs	UTM	15T	NAD 1983 (Conus)
26	714120.7084356	4877191.5044009	9as	UTM	15T	NAD 1983 (Conus)
27	714130.2191982	4877142.5805413	9af	UTM	15T	NAD 1983 (Conus)
28	714111.0656621	4877138.7566320	9bf	UTM	15T	NAD 1983 (Conus)
29	714829.9185677	4876625.2683404	10as	UTM	15T	NAD 1983 (Conus)
30	714849.5302079	4876629.0621918	10bs	UTM	15T	NAD 1983 (Conus)
31	714842.3523858	4876678.7950731	10bf	UTM	15T	NAD 1983 (Conus)
32	714822.7063815	4876674.8480915	10af	UTM	15T	NAD 1983 (Conus)
33	713995.6931057	4877200.1533506	8as	UTM	15T	NAD 1983 (Conus)
34	713978.0528523	4877148.6205077	8bf	UTM	15T	NAD 1983 (Conus)
35	713997.8824094	4877149.9603793	8af	UTM	15T	NAD 1983 (Conus)
36	713975.8121178	4877198.6053707	8bs	UTM	15T	NAD 1983 (Conus)

Scott's Bluff National Monument

ID	Easting	Northing	Comment	System	Zone	Datum
1	606431.217	4631805.674	1bs	UTM	13T	NAD 1983 (Conus)
2	606447.352	4631798.340	1as	UTM	13T	
3	606423.416	4631753.199	1af	UTM	13T	
4	606407.761	4631761.849	1bf	UTM	13T	
6	606375.571	4631808.093	2af	UTM	13T	
7	606357.180	4631816.284	2bf	UTM	13T	
8	606381.609	4631859.362	2bs	UTM	13T	
9	606398.294	4631851.774	2as	UTM	13T	
10	606536.271	4631567.490	5as	UTM	13T	
11	606489.131	4631557.859	5af	UTM	13T	
12	606490.514	4631540.312	5bf	UTM	13T	
13	606540.477	4631547.294	5bs	UTM	13T	
14	606474.750	4631166.468	3bs	UTM	13T	
15	606520.373	4631184.738	3bf	UTM	13T	
16	606527.380	4631168.350	3af	UTM	13T	
17	606481.607	4631149.522	3as	UTM	13T	
18	606399.407	4631335.785	4as	UTM	13T	
19	606443.981	4631356.146	4af	UTM	13T	
20	606436.195	4631373.714	4bf	UTM	13T	
21	606391.072	4631353.569	4bs	UTM	13T	
22	605931.932	4631375.754	6bs	UTM	13T	
23	605914.367	4631363.872	6as	UTM	13T	
24	605901.186	4631415.845	6bf	UTM	13T	
25	605884.064	4631403.376	6af	UTM	13T	
26	605844.581	4631381.575	7af	UTM	13T	
27	605829.259	4631369.259	7bf	UTM	13T	
28	605859.043	4631329.635	7bs	UTM	13T	
29	605874.462	4631341.091	7as	UTM	13T	
30	608487.669	4632847.023	13as	UTM	13T	
31	608474.817	4632831.327	13bs	UTM	13T	
32	608513.789	4632799.330	13bf	UTM	13T	
33	608526.899	4632815.211	13af	UTM	13T	
34	608427.300	4632931.823	14as	UTM	13T	
35	608414.506	4632916.287	14bs	UTM	13T	
36	608466.310	4632899.983	14af	UTM	13T	
37	608453.252	4632884.142	14bf	UTM	13T	
38	608321.583	4632887.752	11as	UTM	13T	
39	608281.812	4632918.470	11af	UTM	13T	
40	608293.200	4632934.182	11bf	UTM	13T	
41	608333.224	4632904.432	11bs	UTM	13T	
42	608686.570	4633236.917	12as	UTM	13T	
43	608685.019	4633287.035	12af	UTM	13T	
44	608705.032	4633287.646	12bf	UTM	13T	
45	608706.292	4633237.851	12bs	UTM	13T	

Wilson's Creek National Battlefield

ID	Easting	Northing	Comment	System	Zone	Datum
1	463444.283	4106553.686	1bf	UTM	15T	NAD 1983 (Conus)
2	463275.906	4106877.264	9as	UTM	15T	NAD 1983 (Conus)
3	463283.710	4106895.078	9bs	UTM	15T	NAD 1983 (Conus)
4	463229.736	4106895.869	9af	UTM	15T	NAD 1983 (Conus)
5	463237.585	4106913.155	9bf	UTM	15T	NAD 1983 (Conus)
6	463089.174	4107039.461	8bs	UTM	15T	NAD 1983 (Conus)
7	463066.320	4107083.417	8bf	UTM	15T	NAD 1983 (Conus)
8	463047.294	4107077.908	8af	UTM	15T	NAD 1983 (Conus)
9	463070.254	4107033.955	8as	UTM	15T	NAD 1983 (Conus)
1	463460.577	4106627.688	2bs	UTM	15T	NAD 1983 (Conus)
2	463439.656	4106626.347	2as	UTM	15T	NAD 1983 (Conus)
3	463432.451	4106676.317	2af	UTM	15T	NAD 1983 (Conus)
4	463453.424	4106679.068	2bf	UTM	15T	NAD 1983 (Conus)
5	463467.439	4106554.321	3af	UTM	15T	NAD 1983 (Conus)
6	463485.610	4106556.548	3bf	UTM	15T	NAD 1983 (Conus)
7	463492.193	4106507.522	3bs	UTM	15T	NAD 1983 (Conus)
8	463472.568	4106503.134	3as	UTM	15T	NAD 1983 (Conus)
9	463429.841	4106500.580	1as	UTM	15T	NAD 1983 (Conus)
10	463450.356	4106503.208	1bs	UTM	15T	NAD 1983 (Conus)
11	463423.219	4106551.429	1af	UTM	15T	NAD 1983 (Conus)
12	463443.796	4106554.464	1bf	UTM	15T	NAD 1983 (Conus)
1	464206.089	4105469.236	5bs	UTM	15T	NAD 1983 (Conus)
2	464225.560	4105471.690	5as	UTM	15T	NAD 1983 (Conus)
3	464225.795	4105520.601	5af	UTM	15T	NAD 1983 (Conus)
4	464208.023	4105520.922	5bf	UTM	15T	NAD 1983 (Conus)
5	464304.057	4105339.272	4bf	UTM	15T	NAD 1983 (Conus)
6	464288.373	4105323.564	4af	UTM	15T	NAD 1983 (Conus)
7	464320.850	4105286.367	4as	UTM	15T	NAD 1983 (Conus)
8	464335.910	4105299.960	4bs	UTM	15T	NAD 1983 (Conus)
9	464342.160	4105091.320	6bs	UTM	15T	NAD 1983 (Conus)
10	464327.100	4105080.495	6as	UTM	15T	NAD 1983 (Conus)
11	464301.644	4105124.203	6af	UTM	15T	NAD 1983 (Conus)
12	464318.640	4105134.717	6bf	UTM	15T	NAD 1983 (Conus)
13	464298.799	4105018.836	7bf	UTM	15T	NAD 1983 (Conus)
14	464300.387	4105000.891	7af	UTM	15T	NAD 1983 (Conus)
15	464350.442	4105005.788	7as	UTM	15T	NAD 1983 (Conus)
16	464349.188	4105026.001	7bs	UTM	15T	NAD 1983 (Conus)

Appendix C. Integrating fuel monitoring and plant community monitoring.

1.0 INTRODUCTION

The methods for fuel monitoring described in the National Park Service (NPS) Western Region Fire Monitoring Handbook (USDI National Park Service 1992) can be modified slightly for use with our plot design. These methods provide estimates of fuel loadings for down dead wood, forest litter, herbaceous vegetation, standing grass, grass litter and estimates of fuel depth in both prairies and woodlands. The methods can be modified to monitor other aspects of fuel consumption and biomass production.

In the NPS Western Region Fire Monitoring Handbook (USDI National Park Service 1992), fuel data is collected in English units. Calculations to convert down dead wood (DDW) data to fuel loads require data to be collected in English units. Fuel load information can be converted from English (tons/acre) to metric (kg/ha) units once the calculations are complete.

2.0 FORESTS AND WOODLANDS

The forests and woodlands category applies to plots that contain trees larger than 5 cm diameter at breast height (dbh). Fuel data collected in forested plots consists of down dead wood weights, duff and litter depth, and litter and herbaceous fuel weights. Each type of fuel is sampled using different techniques. The techniques for calculating down dead wood weights, and duff and litter depths are taken from USDI National Park Service (1992). Litter and herbaceous fuel weights are modified from Abrams et al. (1986), Briggs and Knapp (1991), and Foster (1999).

Down dead wood: Down dead woody (DDW) fuels are defined as: all dead woody material not attached to standing shrubs, brush, or trees that is less than 6 ft above the ground. DDW fuels do not include cones, nuts, bark, needles, and leaves (USDI National Park Service 1992). DDW is inventoried with a transect intercept method using two 50-ft long DDW transects (Brown 1974, Brown et al. 1982, USDI NPS 1992).

The two 50-ft long DDW transects are randomly located along each 50-m vegetation monitoring transect, resulting in four DDW transects per sampling unit. Size classes of DDW are surveyed for different total distances along the 50-ft DDW transect: 1) along the first 6 ft of the transect, all DDW size classes are sampled; 2) from 0 to 12 ft only DDW size classes 3 and 4 are sampled; and 3) from 0 to 50 ft only DDW class 4 is sampled.

DDW size classes represent fuel timelag classes, a classification of how quickly different-sized fuel gain or lose moisture (Table C-1).

Table C-1. DDW size classes used for fuel inventory, the corresponding fuel timelag class, and length of DDW transect sampled for each size class.

DDW size classes diameter (in.)	Timelag class	Length (in ft.) sampled on DDW transect
1) 0-.25	1 hour	0-6
2) 0.25-1	10 hour	0-6
3) 1-3	100 hour	0-12
4) >3	1000 hour	0-50

The DDW transect is considered a plane 50-ft long and 6-ft high and only fuel intersecting the plane is counted. Fuel is measured exactly where it intersects the plane, or the DDW transect, to determine its size class. Fuels wider than 3 inches in diameter are measured and classified as sound or rotten, based upon the condition of the fuel. Rotten wood is DDW that is obviously deteriorating or punky (USDI National Park Service 1992).

Equations to estimate DDW fuel weight are reported in tons/acre (Brown 1974, Brown et al. 1982) and are found in Table C-2. The results can be converted to metric units after all of the calculations are completed.

Litter and duff depth. Litter depth represents the average depth (English units) of leaf or grass litter at each sampling location (Burgan and Rothermel 1984). Litter and duff depths are collected at 10 locations along the DDW transects, specifically the 1-, 5-, 10-, 15-, 20-, 25-, 30-, 35-, 40-, 45-ft. marks.

Herbaceous and litter fuels. Herbaceous and litter fuel weights are estimated from six randomly located 0.1 m^2 circular clip plots (Abrams et al. 1986, Briggs and Knapp 1991, Foster 1999). Clip plots are located near the 5-m, 25-m, and 45-m marks of each transect within a zone that extended 2 m in either direction along the transect and extended 5 m in either direction perpendicular to the transect. For example, if the values 4 and 5 were selected and we were standing at the 5 m transect mark, the clip plot was placed parallel with the 4-m mark at a distance of 5-m from the transect (direction decided with a coin toss). When necessary, the width of the sampling zone can be adjusted to assure the clip plots remained in the appropriate community type. Previously clipped plots are not resampled.

At each clip plot, all above ground biomass is clipped. Plant material contained within a bounded volume above the sample frame is included as part of the sample. Plant material rooted within the plot but extending beyond the plot perimeter is excluded, and material rooted outside the plot but extending into the plot's bounded volume is included. In the field, biomass is separated according to the following hierarchy: 1) previous year's biomass, or litter, 2) current year's dead, 3) dominant species, 4) exotics, 5) C_3 grasses, 6) C_4 grasses, 7) forbs, and 8) woody vegetation. The different groups we placed into labeled paper bags (i.e. dominant species, forb, etc.). Samples are immediately air-dried and later oven-dried at 60 degrees C for 48 hours.

3.0 GRASSLANDS

The grassland category applies to all plots without trees larger than 5 cm DBH. In grassland plots, we estimated standing grass and grass litter fuel loads. The techniques described for sampling grass litter depths and grass fuels are measured in metric units from 0.1 m^2 plots. The standing grass and grass litter fuel weights are modified from Abrams et al. (1986), Briggs and Knapp (1991), and Foster (1999). Methods for the establishment and sampling of the six 0.1 m^2 clip plots are described above.

4.0 MODIFYING METHODS FOR NEW QUESTIONS

The forest plot fuel characterization methods can be modified to monitor fuel consumption by prescribed fires (Kauffman and Martin 1989, Brown et al. 1991, National Park Service 1992), duff consumption by prescribed fires (Brown et al. 1991), and monitor and predict prescribed fire behavior (Hough and Albini 1978, Burgan and Rothermel 1984, Kauffman and Martin 1989, Brown 1982). The grassland fuel characterization methods can be modified to monitor fuel and duff consumption and to monitor grassland productivity (Zimmerman and Kucera 1977, Karl et al. 1999).

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Table C-2: Equations needed to estimate fuel weights

Total and size class DDW fuel load estimates are calculated using the following:

$$\text{Fuel size classes} < 3 \text{ in DBH: } \frac{11.64 \times n \times d^2 \times s \times a \times c}{Nl} = \text{tons/acre}$$

$$\text{Fuel size classes} > 3 \text{ in DBH: } \frac{11.64 \times n \times \Sigma d^2 \times s \times a \times c}{Nl} = \text{tons/acre}$$

Where:
n = Number of intersections
d^2 = Diameter squared
Σd^2 = Sum of squared diameters
s = Specific gravity of wood (from the Wood Handbook-Forest Products Laboratory 1987)
a = Angle factor
c = Slope correction factor
Nl = Length of sampling plane

Values for d^2, a, and Nl are listed below:

Size class	d^2 Diameter squared	a Angle factor	Nl Plane length
0-0.25 in	0.0151	1.13	6
0.25-1 in	0.289	1.13	6
1-3 in	2.76	1.13	12
>3 in sound	Calculate	1.0	50
> 3 in rotten	Calculate	1.0	50

Slope correction factors:

% slope	*C*	% slope	*c*	% slope	*c*	% slope	*c*
0	1.00	30	1.04	60	1.17	90	1.35
10	1.00	40	1.08	70	1.22	100	1.41
20	1.02	50	1.12	80	1.28	110	1.49

To convert from tons/ac to kg/ha, the following equation is used:

tons/ac x 2.47 ac/ha x 2000 lbs/ton x kg/2.205 lb = 2240.36 kg/ha.

Appendix D. Sampling frequency: an assessment of the adequacy of the sampling design in detecting change over time.

1.0 ANALYSIS TECHNIQUE USED TO ASSESS SAMPLING ADEQUACY

We used power analysis to investigate the statistical power of our monitoring program. Power analysis is a statistical technique that measures the usefulness of a sampling design to detect a specified change within the context of a specific research question. Specifically, we were interested in assessing the usefulness of the community indices and metrics in long-term or trend analysis.

Power analysis is most commonly used to investigate the statistical probability of performing a Type II, or a missed change, error. Power is the complement of the Type II error; high power corresponds to a low risk of a Type II error. For example, 90% power means that there is a 10% probability of a change going undetected.

Power analysis is also used to 1) evaluate sample size requirements given the data's variability, the selected α, and the level of change desired; and 2) evaluate the abilities of different statistical tests to detect the desirable effects given the data's variability, the selected α, and sampling intensity (Elzinga et al. 1998). In order to use power analysis effectively, management and sampling objectives and specific hypothesis-driven questions that will be addressed by the data being collected are necessary (Table D-1).

2.0 SAMPLING DESIGN ADEQUACY

Power analysis was performed on a subset of plant communities using two years of baseline data in the analysis. We selected for analysis a subset of community types (5 of 19) where there were 1) two years of consecutive sampling, 2) relatively stable climatic conditions for both years, and 3) no management efforts within the past five years. Further, the five community types selected provide an adequate picture of the range of variability typical of the community variables sampled. Two plant communities were selected from Wilson's Creek National Battlefield (WICR), and one plant community each was selected from Agate Fossil Beds National Monument (AGFO), Effigy Mounds National Monument (EFMO), and Pipestone National Monument (PIPE).

We performed power analysis on all community metrics and indices except diversity and woody stem density. We specifically wanted to address if we had adequate samples to look at changes in community composition and structure over time (given the variables and indices selected for monitoring). We ran power analysis with the plot functioning as the analysis unit. Depending on the community type, *n* ranged from 20 to 40 plots. We used different combinations of alpha, beta, and acceptable change in the analysis.

The results of power analysis for the plant communities selected are found in Tables D2-6. We found that with plot as the analysis unit, we have adequate samples for investigating long-term change in a number of variables with a high level of confidence. These variables include species richness; exotic species richness; relative frequency of exotics; and percent mean cover and importance value of the species guilds, C_3 grasses, C_4 grasses, and forbs. For some communities, a lower level of alpha is necessary to detect a 20% change. For example, in order to detect a 20% change in percent mean cover in forbs at the *Calamovilfa* prairie management unit at AGFO, alpha is set at 0.20. While this may seem low for statistical significance, in monitoring, high power (low beta) lessens the chance that a change detrimental to the resource goes undetected.

Because of the concern over pseudoreplication when using the plot as the analysis unit, we also ran power analysis with the transect pair functioning as the analysis unit. In this case, *n* ranged from 2 to 4, depending on the community type. Two questions were addressed for each variable in each community: 1) what effect size can we detect given the sampling design, and 2) what sample size is needed to detect a 20% change in a variable with 90% confidence. With the transect pair functioning as the analysis unit, we do not have adequate samples to investigate community change in any variable other than species richness (data not shown). For most other variables, a substantially greater number of transect pairs would need to be established for long-term analysis to be initiated. This is not surprising, given the low sample size of 2 to 4 samples per community type.

3.0 REFERENCES

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Table D-1. The links between management objectives, sampling objectives, and specific and hypothesis-geared analysis.

	Objective	Statement
Change/Trend Objective	Management objective	We want to see a 20% increase in the percent cover of species X in this management unit between years 1999 and 2005.
	Sampling objective	We want to be 90% sure (**power**) of detecting a 20% change (**MDC**) in percent cover. We are willing to accept a 10% chance (α) that we will make a false-change error.
	Hypothesis	There is no difference between the percent cover of species X in the management unit between the years 1999 and 2005. ($\alpha = 0.10$; $\beta = 0.10$)
	Management response	If percent cover fails to increase, additional research of other management options will be initiated; alternate management implemented by 2005.

*adapted from Appendix 3 of Elzinga et al. (1998)

Table D-2. Power analysis results for the *Calamovilfa* prairie unit at AGFO using 1997 to 1998 data. Twenty plots were used in the analysis. The *mean* is obtained by calculating the average value for the variable of interest for year 1 and year 2. The higher of the two values is used in analysis. S*t dev diff yr 1-2* is obtained by calculating the standard deviation of the differences in plot values between year 1 and year 2. The resultant value is used to describe the across-year variability inherent in the data set.

			$\alpha = 0.10$; $\beta = 0.10$		$\alpha = 0.10$; $\beta = 0.20$		$\alpha = 0.20$; $\beta = 0.10$	
One-sample paired t-test	Mean	Stan. Dev. diff yr 1-2	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change
Species richness	19.3	2.67	9%	6	8%	5	8%	5
Exotic species richness	2.2	0.88	27%	37	23%	27	24%	28
Relative frequency of exotics	0.11	0.07	43%	82	35%	60	35%	63
Total forb cover	0.990	0.300	21%	22	18%	16	18%	17
Woody cover	0.110	0.009	86%	133	87%	97	87%	102
C_3 cover	0.378	0.039	7%	5	5%	4	5%	4
C_3 relative frequency	0.112	0.040	18%	29	18%	21	18%	22
C_3 importance value	0.165	0.078	24%	50	24%	37	24%	38
C_4 cover	0.516	0.229	31%	44	25%	32	25%	34
C_4 relative frequency	0.140	0.031	14%	12	7%	9	7%	9
C_4 importance value	0.161	0.052	18%	24	12%	18	12%	19
Calamovilfa longifolia	0.347	0.114	23%	25	20%	19	20%	19
Conyza canadensis	0.055	0.058	73%	239	54%	174	54%	184
Stipa comata	0.330	0.001	1%	2	1%	2	1%	2

Table D-3. Power analysis results for the Bloody Hill Glade unit at WICR using 1997 to 1998 data. Thirty plots were used in the analysis. The *mean* is obtained by calculating the average value for the variable of interest for year 1 and year 2. The higher of the two values is used in analysis. S*t dev diff yr 1-2* is obtained by calculating the standard deviation of the differences in plot values between year 1 and year 2. The resultant value is used to describe the across-year variability inherent in the data set.

			$\alpha = 0.10; \beta = 0.10$		$\alpha = 0.10; \beta = 0.20$		$\alpha = 0.20; \beta = 0.10$	
One-sample paired t-test	Mean	Stan. Dev. diff yr 1-2	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change
Species richness	32	4.06	7%	6	6%	5	6%	4
Exotic species richness	6.567	2.05	17%	23	14%	17	15%	17
Relative frequency of exotics	0.203	0.054	15%	17	15%	13	15%	13
Total forb cover	0.520	0.139	15%	17	11%	13	13%	13
Annual forbs relative frequency	0.342	0.074	12%	12	9%	9	12%	9
Annual forbs importance value	0.282	0.085	18%	20	14%	16	14%	16
Ephemeral spring forbs relative frequency	0.069	0.035	30%	58	30%	42	30%	44
Ephemeral spring forbs importance value	0.052	0.029	38%	67	19%	49	19%	51
Fall forbs relative frequency	0.122	0.041	16%	26	16%	19	16%	20
Fall forbs importance value	0.103	0.066	39%	92	30%	67	30%	70
Spring forbs relative frequency	0.117	0.048	26%	38	17%	28	17%	29
Spring forbs importance value	0.082	0.051	37%	85	24%	62	24%	65
Total woody cover	0.260	0.167	34%	90	30%	66	30%	69
Woody relative frequency	0.247	0.051	12%	11	8%	9	8%	8
Woody importance value	0.326	0.075	12%	13	9%	10	12%	10
C_3 cover	0.051	0.056	59%	269	59%	196	59%	207
C_3 relative frequency	0.066	0.037	30%	70	30%	51	30%	54
C_3 importance value	0.072	0.050	42%	107	28%	78	28%	82

Table D-3 continued

			$\alpha = 0.10; \beta = 0.10$		$\alpha = 0.10; \beta = 0.20$		$\alpha = 0.20; \beta = 0.10$	
One-sample paired t-test	Mean	Stan. Dev. diff yr 1-2	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change
C_4 cover	0.132	0.106	45%	144	38%	105	38%	110
C_4 relative frequency	0.073	0.039	27%	63	27%	46	27%	48
C_4 importance value	0.137	0.048	22%	28	15%	21	15%	22
Bromus spp.	0.100	0.075	40%	122	30%	88	40%	93
Bouteloua curtipendula	0.457	0.040	4%	4	4%	4	4%	3
Sorghastrum nutans	0.041	0.053	72%	377	48%	272	72%	289

For Bloody Hill Glade in WICR, species have been separated into "true" species guilds based on physiognomy and flowering period. The species guilds used in analysis for Bloody Hill Glade were annual forbs, ephemeral spring forbs, spring forbs, summer-fall forbs, legumes, woody species, C3 grasses, and C4 grasses. We separated herbaceous forbs into species guilds based on flowering periods to provide information on the temporal structure of the plant community. Yet, from the power analysis results for Bloody Hill Glade, our current sampling design is not adequate to detect change in the cover, relative frequency, or importance value for the majority of the species guilds defined. However, when forbs were lumped into a larger physiognomic group, our ability to detect a 20% change increased. We suspect the variability in cover of herbaceous forbs in glade communities and the patchiness of the environment limits the use of species guilds in long-term analysis.

Table D-4. Power analysis results for the North Restoration Unit at EFMO using 1997 to 1998 data. Twenty plots were used in the analysis. The *mean* is obtained by calculating the average value for the variable of interest for year 1 and year 2. The higher of the two values is used in analysis. S*t dev diff yr 1-2* is obtained by calculating the standard deviation of the differences in plot values between year 1 and year 2. The resultant value is used to describe the across-year variability inherent in the data set.

			$\alpha = 0.10; \beta = 0.10$		$\alpha = 0.10; \beta = 0.20$		$\alpha = 0.20; \beta = 0.10$	
One-sample paired t-test	Mean	Stan. Dev. diff yr 1-2	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change
Species richness	23.75	3.51	10%	7	8%	6	9%	5
Exotic species richness	3.5	0.687	13%	10	11%	8	11%	8
Relative frequency of exotics	0.179	0.037	16%	11	17%	9	17%	9
Forb cover	1.273	0.162	11%	9	10%	7	10%	6
Woody cover	0.122	0.044	73%	244	65%	178	65%	188
C_3 cover	0.205	0.135	44%	85	34%	62	39%	65
C_3 relative frequency	0.108	0.028	18%	17	18%	13	18%	13
C_3 importance value	0.129	0.044	23%	26	23%	20	23%	20
C_4 cover	0.687	0.221	17%	16	14%	12	14%	12
C_4 relative frequency	0.157	0.048	19%	22	19%	16	19%	17
C_4 importance value	0.245	0.063	16%	16	16%	12	16%	12
Andropogon gerardii	0.627	0.131	17%	16	14%	12	14%	12
Asclepias verticillata	0.034	0.128	87%	359	88%	259	88%	276
Bromus inermus	0.165	0.175	54%	146	49%	106	49%	112

Table D-5. Power analysis results for the Manley Woods unit at *WICR* using 1998-1999 data. 40 plots were used in the analysis. The *mean* is obtained by calculating the average value for the variable of interest for year 1 and year 2. The higher of the two values is used in analysis. *St dev diff yr 1-2* is obtained by calculating the standard deviation of the differences in plot values between year 1 and 2. The resultant value is used to describe the across-year variability inherent in the data set.

			$\alpha = 0.10; \beta = 0.10$		$\alpha = 0.10; \beta = 0.20$		$\alpha = 0.20; \beta = 0.10$	
One-sample paired t-test power analysis	Mean	Stan. Dev. diff yr 1-2	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change
Species richness	24.25	4.032	7%	8	7%	6	6%	6
Exotic species richness	0.4	0.979	59%	342	52%	263	50%	247
Relative frequency of exotics	0.014	0.345	69%	304	35%	233	35%	219
Forb cover	0.417	0.189	21%	47	19%	36	19%	34
Woody cover	0.203	0.097	24%	50	20%	38	20%	36
C_3 cover	0.089	0.087	45%	202	45%	155	33%	146
C_3 relative frequency	0.091	0.022	11%	15	11%	11	11%	14
C_3 importance value	0.064	0.023	16%	30	16%	23	16%	23
Amphiocarpa bracteata	0.092	0.081	43%	168	32%	129	32%	122
Carex spp.	0.073	0.073	41%	218	41%	168	41%	159
Symphoricarpos orbiculatus	0.056	0.040	36%	111	36%	85	36%	81

Table D-6. Power analysis results for the tallgrass prairie unit at PIPE using 1998 to 1999 data. Forty plots were used in the analysis. The *mean* is obtained by calculating the average value for the variable of interest for year 1 and year 2. The higher of the two values is used in analysis. S*t dev diff yr 1-2* is obtained by calculating the standard deviation of the differences in plot values between year 1 and year 2. The resultant value is used to describe the across-year variability inherent in the data set.

			$\alpha = 0.10; \beta = 0.10$		$\alpha = 0.10; \beta = 0.20$		$\alpha = 0.20; \beta = 0.10$	
One-sample paired t-test Power Analysis	Mean	Stan. Dev. diff yr 1-2	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change	Effect size	Number of samples needed for 20% change
Species richness	27.62	2.95	5%	5	4%	4	4%	4
Exotic species richness	2.57	1.05	19%	38	16%	28	17%	29
Relative frequency of exotics	0.097	0.038	20%	35	20%	26	20%	27
Forb cover	1.610	0.339	10%	11	9%	9	9%	9
Woody cover	0.304	0.160	52%	61	19%	45	23%	47
C_3 cover	0.607	0.199	15%	25	13%	19	13%	19
C_3 relative frequency	0.152	0.020	6%	6	6%	5	6%	5
C_3 importance value	0.175	0.036	11%	11	6%	9	6%	9
C_4 cover	0.318	0.187	28%	76	22%	55	25%	58
C_4 relative frequency	0.140	0.032	7%	13	7%	10	7%	10
C_4 importance value	0.128	0.033	16%	16	8%	12	8%	12
Andropogon gerardii	0.102	0.105	49%	227	37%	165	39%	175
Bromus inermis	0.186	0.118	32%	88	27%	64	27%	67
Ratibida pinnata	0.022	0.038	92%	663	92%	478	92%	508