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Interim Report:
Development of the Vegetation Component of the National Park Service's Northern Great Plains Inventory and Monitoring Network's "Vital Signs" Monitoring Plan

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Introduction

This interim report is a compilation of the information gathered and processed to date for incorporation into planning documents for the National Park Service's Northern Great Plains Inventory and Monitoring Network (“Network”). The ultimate goal of this project is to develop the vegetation monitoring component of the Network’s “Vital Signs” monitoring plan by March 30, 2006. To complete this goal, the following objectives must be met:

1. Provide a review, synthesis, and assessment of park vegetation, park goals and objectives in regards to those resources, and authorities and policies affecting those resources and park management thereof.
2. Provide a review, synthesis, and assessment of vegetation monitoring efforts being conducted by NPS and non-NPS entities in and around Network parks.
3. Provide a detailed review, synthesis, and assessment of past, present, and potential future stressors affecting park vegetation.
4. Solicit input from park staff, other interested agencies and organizations, subject-matter experts, and experts knowledgeable in the theories, principles, and methods of monitoring vegetation resources.
5. Conduct a decision-making process that ranks potential floral indicators and identifies those specific indicators that should be monitored.
6. Develop monitoring protocols for selected floral indicators that is scientifically defensible and can be implemented within the logistical, fiscal, and administrative constraints of the I&M Program and Network parks.
7. Identify normal limits of variation of selected indicators and thresholds which trigger management actions.
8. Identify potential management actions in response to indicators reaching trigger points.
9. Work closely with the Network Data Manager to develop GIS databases, tabular databases, statistical analyses, and infrastructure needed to implement a monitoring program.
10. Present all of this information in a coherent and complete document that can readily be integrated into a comprehensive monitoring plan following recommended NPS guidelines.

These objectives fall into two broad phases or tasks of the project:

<u>Task 1</u>: Collect, review, and assess literature, data, and other information related to park vegetation resources. Review and summarize programs and methods for vegetation monitoring being used in the Northern Great Plains, including programs within NPS (e.g., Fire Effects monitoring, Long-term Ecological Monitoring program, Exotic Plant Management Team), and outside of NPS (e.g., Forest Service monitoring programs). As part of the data mining process the PI should have a meeting at each park with park management and natural resource specialists. The PI should work closely with park staff to identify stressors to park vegetation, park management objectives, and the role of park vegetation in overall park health. Non-NPS plant ecologists shall be consulted as needed.

Task 2: Using the information collected in Task 1, develop a complete list of potential indicators of vegetation health and condition. Clearly describe and justify the potential indicators on the list, and describe some potential approaches to monitoring such indicators, and the potential implications to park management. From the complete list of potential indicators work with park staff, the Network Coordinator, and other subject-matter experts to identify and select a final list of indicators to be monitored at the individual parks. Such a list will need to reconcile park-specific needs and issues against the efficiency of a uniform Network approach. For the selected indicators design monitoring protocols. Such protocols shall include study design and data collection methods, statistical analyses, personnel needed, and project costs. For the selected indicators develop thresholds or exceedence levels that trigger management actions, and identify potential management actions. Present the information in a final report.

This report concentrates on those objectives related to Task 1, but provides some preliminary suggestions for objectives related to Task 2. The report is organized by Objectives. In general, the earlier sections of the report are more complete than the later sections. (For example, I feel that Objective 1, Part A, and Objective 2 are complete except for a few loose ends regarding monitoring by other agencies in the vicinity of Network parks.) This is primarily due to the status of the Network at this time: only preliminary scoping meetings with individual parks have been held; an ecological model for the Network parks has not been constructed; and potential indicators have not been thoroughly worked out. For all these reasons, I took the liberty of adapting models and indicators described by the Heartland I&M Network to address Objectives 3-6. Although this may be a bit premature, I believe my doing so has provided a framework for use by the Network in future meetings, as well as for the "straw dog" of a monitoring protocol I was asked to produce. At this stage, it is impossible to address Objectives 7-10.

I look forward to continued participation in this project.

Objective 1. Provide a review, synthesis, and assessment of park vegetation, park goals and objectives in regards to those resources, and authorities and policies affecting those resources and park management thereof.

Part A: Review, synthesis, and assessment of park vegetation.

The information for this section was compiled from four primary resources: the USGS-NPS Vegetation Mapping Program; two documents compiled by The Nature Conservancy for the Black Hills, *Black Hills Community Inventory* (Marriott *et al.*, 2002) and *Ecoregional Conservation in the Black Hills* (Hall *et al.*, 2002); state lists of rare plant species or species of concern; and NatureServe Explorer, the web-based data clearinghouse of NatureServe, a non-profit biodiversity information organization that works in partnership with state Natural Heritage programs.

The USGS-NPS Vegetation Mapping Program is part of the national NPS I&M program, and its goal is to produce a vegetation map for each NPS unit. The mapping follows protocols outlined in *Field Methods for Vegetation Mapping* (The Nature Conservancy, 1994). The protocol uses a combination of aerial photograph interpretation and field work to classify vegetation of each park according to the National Vegetation Classification System (NVCS). A collaborative effort of government, scientific, and private organizations, the NVCS is a standardized, peer-reviewed system for describing vegetation types according to their structure and composition. The Northern Great Plains Network is fortunate in that most of its parks have completed vegetation maps and reports from this program. However, because the parks in this Network were one of the first to be mapped according to the NVCS, some of the names and conservation status rankings of vegetation types have changed since the reports were published. Thus, all vegetation types described in parks' vegetation mapping reports were updated according to the current NVCS database on NatureServe Explorer (see below). The vegetation types identified for mapped parks are listed in Appendix A

For the four parks in the Network that lie in the Black Hills (DETO, JECA, MORU, and WICA), planning documents compiled by The Nature Conservancy provided information on the condition of the vegetation and presence of conservation target species. These documents used results from the USGS-NPS Vegetation Mapping Program, and therefore followed the NVCS when referring to vegetation types. Marriott et al. (1999) evaluated the quality of each of the community occurrences using the EORANK (element occurrence rank) system of The Nature Conservancy and the Natural Heritage Program network. The overall rank of an occurrence is based on the condition of the vegetation, stand size, and landscape context. Overall rank varies from "A" (best) to "D" (worst). In general, large stands with appropriate species composition and lack of unnatural disturbance are ranked higher.

None of the four states in which the Network parks exist have state endangered species legislation that covers plants. However, the states do maintain lists of either "rare" plants (North Dakota and South Dakota) or "plant species of concern" (Nebraska and Wyoming), usually in conjunction with the state Natural Heritage program. These lists were obtained either from online sources (Nebraska Natural Heritage, http://www.natureserve.org/nhp/us/ne/plants.html; South Dakota Natural Heritage, http://www.state.sd.us/gfp/DivisionWildlife/Diversity/rareplant2002.htm;Wyoming Natural Diversity Database, http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm) or, when not available online, directly from the state Natural Heritage program (North Dakota). Current lists of documented species at a park were then compared to the appropriate state list to determine which, if any, rare/concern species occurred at the park. It should be noted, however, that these current lists have not been certified as accurate by the I&M certification process. When possible, information was supplemented by reports from surveys specifically designed to document rare plants at a park. These results were also compared to current rare/concern lists, as these lists are not static. Nationally listed threatened/endangered plant species were also considered, though there are very few of these in the northern Great Plains.

The conservation status of individual species and communities (vegetation types) was obtained from NatureServe Explorer (http://www.natureserve.org/explorer/). Natural Heritage programs follow a standardized procedure to determine the global (G) and state (S) status of an element (species or community). Elements are ranked from 1 (critically imperiled) to 5 (secure). When there is uncertainty about an element's status, a range of ranks (e.g., G2G3), a "U" (e.g., SU) or a question mark is used (e.g., G3?). Communities in the Network are generally in the G4 (globally apparently secure) to G2 (globally imperiled) range. A detailed explanation of the Natural Heritage ranks is given in Appendix B.

In addition to these primary sources, information on the vegetation of individual parks came from park staff, personal observation, and park-specific documents.

Agate Fossil Beds National Monument

Agate Fossil Beds National Monument (AGFO) is located on the banks of the Niobrara River in northwestern Nebraska, where mixed-grass prairie is the dominant vegetation. It was established in 1965 for paleontological and cultural resources, but its sweeping views of rolling prairie offer an unusual glimpse of what the landscape across much of the Great Plains may have looked like before European settlement.

AGFO was a prototype in the NPS/USGS vegetation mapping program (Aerial Information Systems, 1998a). Field work was completed in 1996-97. AGFO's 3,055 acres include 13 vegetation types (Appendix A), the most common of which is Sand Bluestem[1] - Prairie Sandreed Prairie. The only vegetation type considered globally vulnerable or worse is the Baltic Rush Wet Meadow (G2Q), which the authors of the report note contains some "unusual, disjunct" species. The Cottonwood - Peachleaf Willow Floodplain Woodland along the Niobrara River (G3G4) may also be globally vulnerable. However, the authors of the vegetation map report note that there is no regeneration of the trees that characterize this vegetation type within the park, and that the trees that exist now may have been escapes from plantings at the Agate Springs Ranch.

AGFO is home to no federally threatened or endangered plant species or animals that depend on a particular plant species. A survey for species of state concern has not been done for the park, but 10 species on the Nebraska Plants of Concern list (http://www.natureserve.org/nhp/us/ne/plants.html) have been confirmed as occurring in the park. These are: limestone rockcress, narrowleaf goosefoot, smooth goosefoot, spotted mission bells, sidesaddle bladderpod, Nuttall desert-parsley, stemless nailwort, spearhead phacelia, small-flowered sand verbena, prairie ground cherry, and Huron green orchid. Finally, lesser yellow lady's-slipper is on the USDA Forest Service Rocky Mountain Region sensitive species list and is monitored in the Black Hills National Forest.

[1]Scientific names for all species mentioned in the text are listed in Appendix C.

Before its designation as a national monument, AGFO was cattle ranch land, with portions owned by the Agate Springs Ranch, Skavdahl, or Buckley families. Most of the area within the park boundaries was grazed, but flatter portions along the Niobrara River were hayed. A small portion of one river terrace was cultivated for one growing season in the 1950s, and other small areas in the park were used as corral areas. Although most of the previously cultivated areas have been seeded with native prairie species, formal corral areas remain in somewhat disturbed condition and are characterized by weeds. Except for the areas that were previously cultivated or used as corrals, the upland vegetation at AGFO is in relatively good shape, in that it is relatively free of invasive species. Some of the riparian vegetation is considerably compromised, however, by Canada thistle and yellow flag iris. The potential status of the yellow flag iris as a cultural resource (historical aspect of the Agate Springs ranch) needs to be considered, however. No prescribed fires have occurred at the park since its authorization (and probably before). This may have had a detrimental effect on the fire-evolved upland vegetation, but casual observation does not reveal a uniformly dense litter layer that would suggest this. A prescribed fire program is scheduled to be implemented in the near future.

Badlands National Park

Badlands National Park (BADL) is in west-central South Dakota. Three units comprise its 244,300 acres. The North Unit is the most heavily visited, and contains 64,250 acres of designated Wilderness Area. The Stronghold and Palmer Creek Units are in the Pine Ridge Indian Reservation. Although it was established primarily for its outstanding fossil resources and the badlands formations that contain them, BADL also contains the largest tract of mixed-grass prairie in National Park Service holdings. Some of this, particularly areas on flat tablelands, was plowed and/or hayed by homesteaders in the early 1900's, and the remainder was most likely grazed by cattle prior to the establishment of the area as a national monument in 1939. Areas of the prairie that were plowed recovered to mostly native vegetation, although the diversity of plant species in this vegetation is lower than that of unplowed areas. Cattle grazing continued in parts of the park until a fence was built in 1963 when bison were re-introduced to the western portion of the North Unit of the park (Butler and Batt, 1995). Cattle and horse grazing continue in the South Unit of the park. Black-tailed Prairie Dogs occur throughout the park.

BADL vegetation was classified and mapped into 32 vegetation types according to the National Vegetation Classification System in 1997 (Von Loh *et al.*, 1999; see Appendix A). Eighty-two percent of the park's area falls into two vegetation categories: Badlands Sparse Vegetation (46%) and Western Wheatgrass Herbaceous Vegetation Alliance (36%). Seven of the vegetation types mapped at the park are globally vulnerable or worse: Green Ash - Elm Woody Draw (G2G3), Sand Sage / Prairie Sandreed Shrubland (G2G3), Switchgrass Wet-Mesic Tallgrass Prairie (G2Q), Prairie Sandreed - Sedge Prairie (G3), Ill-scented Sumac / Thread-leaved Sedge Shrub Prairie (G3), Prairie Cordgrass - Sedge Wet Meadow (G3?), and Common Rabbitbrush / Bluebunch Wheatgrass Shrubland (G3Q). Five more vegetation types found in the park are ranked as G3G4, meaning they too may be globally vulnerable. Vegetation types that might be important park resources but are too small to be captured by the vegetation mapping effort include plant communities around the CCC springs on the west edge of the North Unit of the park, as well as juniper slumps, wooded areas that have been isolated from fire since they fell from eroding hillsides.

No federally threatened, endangered, or candidate plant species occur at BADL, but the park does house six species on the South Dakota rare plant list. These species are Barr's milkvetch, silver-mounded candle flower, Dakota buckwheat, sidesaddle bladderpod, Easter daisy, and largeflower Townsend-daisy. For the most part, these species generally occur in the Badlands sparse vegetation type, though Dakota buckwheat is an exception. Unlike most of the state rare plants found in the Northern Great Plains parks, two of these species are *not* considered globally secure. Barr's milkvetch and Dakota buckwheat are considered globally vulnerable (G3) and are endemic to the area, whereas most state-listed rare species occurring in the Network parks are simply at the edge of their range. A survey for locations and approximate population sizes of these and three other species for which BADL has the proper habitat is near completion, and its results (S. Dingman, pers. comm.) are reflected in this summary.

The majority of BADL's vegetation (98% of the park's area) is characterized by native species. However, previous land use, invasion by non-native species, and alteration of the grazing and fire regimes have taken their toll on the native vegetation. In particular, some non-native species – annual brome grasses and yellow sweetclover – are pervasive throughout many vegetation types in the park. In addition, approximately 8,000 acres of Canada thistle have been mapped in the park, and there is an active exotic plant management program to treat this weed. Despite these problems, much of the native vegetation at BADL is relatively intact.

<u>Devils Tower National Monument</u>

Devils Tower National Monument (DETO) is in northeastern Wyoming in the western-most part of the Black Hills. The small park is on the border of the Red Valley and Hobback geomporhic features and has the Belle Fourche River on its boundary. DETO was established in 1906 to protect the unusual geologic formation in the center of the park, but the 1,360 acres of the park contain some good examples of northern Black Hills vegetation, including ponderosa pine forests and mixed grasslands of more mesic nature than most represented in other NPS holdings in the Black Hills.

The vegetation of DETO was mapped according to NVCS standards in 1996-1997, yielding seventeen vegetation types in the park (Salas and Pucherelli, 1998a). Four of these are considered globally vulnerable or worse, but this ranking is certain for only one of the four. These types are: Ponderosa Pine / Bur Oak Woodland (G3), Ponderosa Pine / Oregon Grape Forest (G3Q), Ponderosa Pine / Bluebunch Wheatgrass Woodland (G3Q), and Prairie Cordgrass - Bulrush Wet Meadow (G3?). Five other vegetation types are ranked as G3G4 or G3G5, and therefore may also be considered vulnerable.

DETO has no federally listed threatened or endangered plant species or animals that depend on a particular plant species. Six species on the current Wyoming list of Plant of Special Concern (http://uwadmnweb.uwyo.edu/wyndd/Plants/plant_species.htm) occur at the park (Fertig, 2000). All of these are considered globally secure (G5) and state critically imperilled (S1) because they are on the periphery of their range at DETO. These species are: whorled milkweed, Emory's sedge, hairy wild-rye, Dakota mock vervain, plains frostweed, and prairie violet. Two of these (hairy wild-rye and Dakota mock vervain) were located in DETO historically but were not found in the most recent survey (1999). One of these (whorled milkweed) has its only known Wyoming occurrence in DETO.

The Black Hills Community Inventory (Marriot *et al.*, 1999) evaluated the condition of all seventeen vegetation types mapped in DETO. One of these (Black Hills Granite -

Metamorphic Rock Outcrop) was ranked as "A" (where A has the highest integrity on a scale of A to F), ten as "AB", two as "B", and the remaining four as "BC" or "C". Because of the good condition of many of the plant communities, DETO was considered a possible exemplary site in the Inventory. However, the small size of most of these communities and the poor condition of the riparian vegetation types precluded its inclusion as an exemplary site. In the riparian areas, a disrupted flood regime and possible herbicide residual have resulted in a lack of recruitment of cottonwood trees. Exotic species, particularly leafy spurge, are also a problem in the riparian zone. In the uplands, annual brome grasses, smooth brome, houndstongue, common mullein, bulbous bluegrass, and Kentucky bluegrass are problematic. Kentucky bluegrass is particularly widespread in grassland areas, and this species is the dominant in one of the vegetation types.

Fort Laramie National Historic Site

Fort Laramie National Historic Site (FOLA) lies in southeastern Wyoming at the confluence of the North Platte and Laramie Rivers and encompasses 833 acres. The natural vegetation of the area includes short- and mixed-grass prairie, sparse pine woodlands, and riparian floodplain forest and herbaceous vegetation. The park was established in 1938 to protect the ruins of the fort, which was an active trading post and military fort from 1834 to 1890. Between the abandonment of the fort in 1890 and the park's establishment, the area was essentially a country village (Mattes, 1980). The park has no native large ungulate grazers, but it does provide "winter" (September - April/May) pasture for pack horses from Rocky Mountain National Park. The herd size varies from 6 to 32 animals, depending on season and year.

FOLA's vegetation was mapped according to NVCS standards in 1996-1997 (Aerial Information Systems, 1998b). Thirteen vegetation types were identified in the park, two of which are considered globally vulnerable or worse. These are: Cottonwood / Western Snowberry Woodland (G2G3), and Prairie Cordgrass - Bulrush Wet Meadow (G3?). One additional vegetation type, Western Wheatgrass Mixedgrass Prairie, may be globally vulnerable but its current status is not well understood (G3G5Q).

Habitat for the federally threatened Ute ladies'-tresses may occur in or near the park, but the species has not been found within the park's boundaries (National Park Service, 2003). The majority of a plant species inventory for the park was completed in 2003, though more work will be done in 2004. This inventory (Heidel, 2003) provides the following information: Four species on the Wyoming Natural Heritage Species of Concern list have been documented within the boundaries of the park. These species are slender false-foxglove, shining flatsedge, great blue lobelia, and Indian grass. All of these species are globally secure (G5), and all are rare in Wyoming because they are at the edge of their range. One species of concern, showy prairie gentian, was previously collected in the vicinity of the park but its presence within park boundaries has not been confirmed. Two additional species on the state's list of concern (golden prairie-clover and six-angle spurge) occur in the northern BLM tract that the park patrols for law enforcement reasons only (i.e., no management involvement).

At least 25% of the park's area was classified as one of three disturbed vegetation types. Historical records and current vegetation suggest that the majority of the park's non-riparian acreage was cultivated and/or severely grazed at one time. Restoration efforts have been attempted in some of these areas, but the success of these efforts has not been quantitatively assessed. As a result, exotic and sometimes invasive species such as cheat grass, Japanese brome, smooth brome, kochia, and Canada thistle are common in the park. Riparian vegetation along the Laramie River is generally in better condition (less invasive plant presence, more cottonwood regeneration) than along the North Platte River.

Fort Union Trading Post National Historic Site

Fort Union Trading Post National Historic Site (FOUS) is the smallest of the parks in the Network at 450 acres. It was established in 1966 to preserve the site of an important trading post built in 1828 and active until the 1860's. After the fort building was removed in 1867, a Hidatsa band occupied the area for about 15 years. The fort is literally just meters from the edge of the historic Missouri River channel and straddles the North Dakota - Montana border. The natural vegetation of the area would be riparian floodplain forest and herbaceous vegetation, as well as northern mixed-grass prairie.

FOUS' vegetation was mapped according to NVCS standards in 2002-2003, yielding fourteen vegetation types (Salas and Pucherelli, 2003a). Only one of these types, Green Ash - Elm Woody Draw, ranked as at least globally vulnerable (G2G3). However, the vegetation mapping report notes that the understory forb layer in this community within the park has a considerable amount of exotics, including smooth brome, Kentucky bluegrass, alfalfa, and crested wheatgrass. The Cottonwood - Peachleaf Willow Floodplain Woodland might also be globally vulnerable, since its conservation ranking is G3G4. The understory of this community is also often dominated by exotics.

FOUS has no federally listed threatened or endangered plant species or animals that depend on a particular plant species. So far, only one species on the North Dakota Natural Heritage Rare Plants list has been confirmed in the park. This is white locoweed, which occurs in mixed-grass prairie. More information on rare species will be available when the plant inventory of this park is completed in 2004.

Much of the area within the park's boundaries was cultivated. This, combined with the long occupation and use of the site, has had serious impacts on much of the vegetation. Three of the park's vegetation types are semi-natural (dominated by non-native species) or recently planted prairie restorations. These three types comprise more than half of the vegetation in the park. Native vegetation occurs primarily in the Missouri River riparian zone, but small amounts (<25 acres) of natural prairie occur in the uplands. The restoration efforts, the earliest of which began in 1993, have planted primarily native grasses (very few forbs) in previously cultivated areas. Two invasive grasses, crested wheatgrass and smooth brome, are a problem in these restored areas. Leafy spurge and Canada thistle also occur in the park, and exotics are not uncommon in the understory of riparian woodlands.

Jewel Cave National Monument

Jewel Cave National Monument (JECA) was established in 1908 to protect Jewel Cave. The 1,355 acre park lies in the southwestern Black Hills near the border of the Limestone Plateau and Minnelusa Foothills formations in southwestern South Dakota. Ponderosa pine forest and woodland interspersed with mixed-grass prairie meadows dominate the landscape.

JECA's vegetation was mapped according to NVCS standards in 1996-97, yielding ten vegetation types in the park and two more in the park's surroundings (Salas and Pucherelli, 1998b). Only one of the vegetation types mapped as in the park's boundaries is considered globally vulnerable or worse – Ponderosa Pine / Mountain Ninebark Forest (G3). Three others might also be globally vulnerable, as their conservation ranking is G3G4. These are: Ponderosa

Pine / Sedge Woodland, Ponderosa Pine / Little Bluestem Woodland, and Northern Great Plains Little Bluestem Prairie.

In August 2000, the 83,503-acre Jasper Fire burned through the entire park, drastically changing the vegetation from how it was mapped in 1996-1997. Prescribed fires in some portions of the park prior to the Jasper Fire successfully reduced fuel loads so that the fire was cooler in these areas and tree mortality was relatively low. Higher fuel loads in the remaining majority of the park resulted in significant tree mortality, thereby changing forest and woodland structure and composition. Despite this disturbance, it is likely that most of the vegetation types mapped still occur at JECA, but their distribution has been altered. In general, ponderosa pine forest and woodland is now less extensive and herbaceous vegetation has increased. Vegetation types not mapped in the park prior to the fire may appear now that the canopy cover has been reduced.

JECA is home to no federally listed threatened or endangered plant species or animals that depend on a certain plant species. A 1986 vegetation survey (Marriott and Hartment, 1986) listed four South Dakota rare plant species (http://www.state.sd.us/gfp/DivisionWildlife/Diversity/rareplant2002.htm) that are either suspected to be or are confirmed as in the park: Hopi tea and Hooker's Townsend-daisy are confirmed in the park (though Marriott and Hartment suspected that Hopi tea had been planted near the visitor center), and the geography and habitat are correct for sleepy grass and Easter daisy. The park's plant list also includes smallflower columbine, a USDA Forest Service sensitive species monitored in the Black Hills National Forest. More information on rare species in the park will be available when the park's plant inventory is completed in 2004. The Nature Conservancy's Black Hills ecoregional conservation plan (Hall *et al.*, 2002) states that the area of the park and the surrounding Forest Service lands is known to house muskroot, or moschatel, a secondary plant target. This species has not been documented in the park, however. Black-backed Woodpeckers (TNC secondary animal target), which prefer recently burned conifer forest with abundant snags, and tawny crescent butterflies (TNC primary animal target), which may depend on the smooth blue aster as its host plant, are also known to occur in the area. Thus, these aspects of the vegetation might be considered for monitoring.

The current state of the vegetation is difficult to evaluate given the large disturbance of the Jasper Fire since the latest vegetation mapping effort. Invasive plants, primarily Canada thistle, do occur at the park, and other troublesome exotic species such as prickly lettuce seem to have increased since the Jasper Fire in some areas. Despite this disturbance, Marriot et al. (1999) considered Jewel Cave and surrounding Forest Service property in and around Hell Canyon as a potentially exemplary site in their evaluation of Black Hills plant communities due to the generally good condition of the ecosystem and the existing protection of the area. The condition of all but one of the native vegetation types was ranked as “B”, the exception being Ponderosa Pine / Common Snowberry Forest, which was ranked “AB”. Finally, some very small (<5 acres) areas of the park apparently were never logged, and therefore are unusual in the Black Hills for their old growth trees.

Knife River Indian Villages National Historic Site

Knife River Indian Villages National Historic Site (KNRI) straddles the Knife River just before it flows into the Missouri River in central North Dakota. The 1,758 acre park was established in 1974 to preserve certain historic and archaeological remnants of the culture and agricultural lifestyle of the Northern Plains Indians. The natural vegetation of the area would have been mostly floodplain forest and herbaceous vegetation in areas near the rivers and mixed-grass prairie in the uplands. Due to the long occupation and heavy use of this area by humans, much of this native vegetation is gone or heavily disturbed.

KNRI's vegetation was mapped according to NVCS standards in 2002, yielding 14 vegetation associations (Salas and Pucherelli, 2003b). Only three of these are considered globally vulnerable or worse. Northern Plains Transition Bluestem Prairie (G2) is a western outlier of tallgrass prairie and occurs in the Big Hidatsa Pasture in the park. Green Ash - Elm Woody Draw (G2G3) is the most common woodland type in the KNRI area, but only one occurrence of this type in the park's boundaries has a shrub component. Cottonwood - Green Ash Floodplain Forest (G2G3) probably existed to a greater extent at one time at KNRI, but flood control on the Missouri River and heavy smooth brome cover in the understory has hindered cottonwood regeneration. Small stands may still exist, however. In addition to these vegetation types, four small areas of vegetation were noted in two previous vegetation surveys for their diversity or uniqueness. Clambey (1985) and Lenz (1993) noted a small collection of low stabilized dunes just east of the Knife River where sandy soils provided habitat for vegetation different from the rest of the park. Lenz (1993) also noted (1) a narrow woodland along the bottom of a low escarpment at the edge of the old river terrace where the trees were tall and well-formed (compared to stunted trees elsewhere in the park) and tree regeneration was occurring; (2) very steep wooded bluff of the Missouri River, which has some of the highest plant species richness in the park; and (3) at the bottom of this bluff, a mixture of communities that may represent relatively undisturbed floodplain vegetation.

KNRI is home to no federally listed threatened or endangered plant species or animals that depend on a certain plant species. A search for North Dakota-listed rare plant species at the park (Lenz, 1993) found none; this was expected due to the highly disturbed nature of most of the park's vegetation.

As suggested above, very little of the park's vegetation is in good condition. Three of the vegetation associations are characterized by invasive species (Smooth Brome, Canada Thistle, and Crested Wheatgrass Semi-Natural Herbaceous Vegetation Types), and four of the vegetation map units were planted with native or non-native perennial species when the park was established. Many of the areas planted with native species have been severely invaded by smooth brome and crested wheatgrass since then. Together, these units comprise 42% of the vegetated area of the park. Smooth brome and leafy spurge occur extensively in floodplain woodlands, and localized infestations of absinth wormwood are also problematic.

Missouri National Recreational River

Missouri National Recreational River (MNRR) consists of two reaches of the Missouri River along the South Dakota - Nebraska border. The downstream “59-Mile District” between Gavins Point Dam and Nebraska's Ponca State Park was set aside in 1978 to preserve the longest remnant of dam-free Missouri River outside of Montana. The upstream “39-Mile District” between Fort Randall Dam and Running Water, South Dakota, was set aside in 1991 because it resembles the natural landscape of pre-European settlement days. Together, these two districts encompass 33,839 acres, only a very small portion of which is owned by NPS.

Limited information on the vegetation specific to what falls within the boundaries of the park is available. The vegetation has not been mapped by the USGS/NPS vegetation mapping program yet, and a plant inventory specific to the park has not been completed. In general, the vegetation of the park is dominated by central plains riparian forest. Numerous other types of vegetation occur in the park, however, including native and restored tallgrass prairie, oak woodland and forest, pastures, plowed fields, and residential areas. The Network is currently working on determining which species, including rare species, occur within park boundaries.

Because the park encompasses such a long, narrow area, the condition of the vegetation varies considerably. In Ponca State Park, on the Nebraska side of the river at the furthest downstream-point of MNRR, native vegetation dominates. Outside of protected areas like this, however, much of the native vegetation has been impacted by agriculture, grazing, and especially alteration of the water flow regime of the river due to the dams. Invasive species such as Russian olive and purple loosestrife are problematic in areas.

Mount Rushmore National Memorial

Mount Rushmore National Memorial (MORU) is in the southwestern Black Hills of South Dakota. It was authorized in 1925 and transferred from the Mount Rushmore National Memorial Commission to NPS in 1939. The 1,238 acre park was created to "preserve and protect the memorial sculpture and the natural setting, and to provide for the access of the public and for the inspirational and educational appreciation of the cultural and natural resources of the memorial" (MORU FY 2001-2005 Strategic Plan). Its vegetation is primarily ponderosa pine forest and woodland interspersed by bare rock outcrops characteristic of the central crystalline core geological form in which it lies.

The vegetation of the park was mapped according to NVCS standards in 1996-1997 (Salas and Pucherelli, 1998c). Eight vegetation types were described for the park, two of which are globally vulnerable or worse. These are Paper Birch / Beaked Hazel Forest (G2G3) and Ponderosa Pine / Bur Oak Woodland (G3). The vulnerability of Ponderosa Pine / Little Bluestem Woodland (G3G4), Ponderosa Pine / Rough-leaf Rice Grass Woodland (G3G4Q) and Woolly Sedge / Bluejoint Herbaceous Vegetation (G3G5) is not certain because their global extent is unknown.

MORU is home to no federally listed threatened or endangered plant species or animals that depend on a certain plant species. A thorough inventory of the plants of the park has not been completed, so it is not certain to what extent it harbors species on the South Dakota rare species list.

The Nature Conservancy's Black Hills Community Inventory (Marriot *et al.*, 1999) considered all but one of the vegetation types in MORU to be in grade "B" condition, the exception being the Ponderosa Pine / Bearberry Woodland, which was given a grade of "AB." This generally good condition is reflected in the relatively low amount of invasive species, at least in intact vegetation. Disturbed areas such as roadsides and around developed areas have significant levels of annual brome grasses, as well as patches of Canada thistle, houndstongue, leafy spurge, and spotted knapweed. Much of the park appears to have been logged prior to its establishment, but portions of the Starling Basin and along an intermittent stream in the northern portion of the park may harbor old growth ponderosa pine. Recent thinning operations have reduced the density of young pine trees in some areas, but the long period of fire suppression in the area has undoubtedly affected the diversity and composition of the vegetation.

Niobrara National Scenic River

Two reaches totaling 76 miles of the Niobrara River east of Valentine, Nebraska, were designated as the Niobrara National Scenic River (NIOB) in 1991 to protect the unique biological, paleontological, and recreational resources of the area. The National Park Service does not own any of the park's 21,036 acres, but works through cooperative agreements with federal, state, and local governments, as well as private organizations and individuals, to protect the resources within its borders. At the northern edge of the Nebraska Sandhills, the park encompasses a wide variety of vegetation. The area is considered an ecological crossroads, where eastern, boreal, and Rocky Mountain forest meet sandhills, mixed-grass, and tallgrass prairie. Many species, particularly those associated with the forests, reach their western, southern, or eastern limits along this stretch of Niobrara River. The vegetation of NIOB has not been mapped according to the NVCS, but Kantak (1995) described the plant communities of the area and outlined the general position of the communities with respect to the river. These are summarized in Table 1.

The Fort Niobrara National Wildlife Refuge and The Nature Conservancy's Niobrara Valley Preserve, portions of which lie within NIOB's boundaries, have potential habitat for two federally threatened plant species: western prairie fringed orchid and Ute lady's tresses. Neither of these have been confirmed in the park, however. Twenty-eight plant species on the Nebraska Plants of Concern (http://www.natureserve.org/nhp/us/ne/plants.html) list have been found on TNC's preserve, but which ones fall within NIOB's boundaries is not clear. The Network is currently working on resolving this.

The condition of the vegetation varies drastically depending on the owner of the property, so generalizations are difficult to make. Invasive species, particularly purple loosestrife, and woody encroachment into prairie are problematic.

Scotts Bluff National Monument

Scotts Bluff National Monument (SCBL) lies in the west-central portion of the Nebraska panhandle on the southern bank of the North Platte River near the towns of Gering and Scottsbluff. The 3,003 acre park was established in 1919 to preserve and protect two large bluffs that rise from the surrounding prairie and the historical and cultural legacy attached to them and the trails that passed between them. The natural vegetation of the area is mixed-short grass prairie on the plains, pine/juniper woodland on portions of the bluffs, and sparse to no vegetation in an area of badlands between Scotts Bluff and the North Platte River. There is debate about the extent and density of trees in the riparian corridor prior to European settlement, but this area would have supported vegetation different from the other three geomorphologic features. A small but growing portion of the park houses black-tailed prairie dogs.

The vegetation of SCBL was mapped according to the NVCS by the NPS Vegetation Mapping effort in 1996-1997 (Aerial Information Systems, 1998c). This yielded 22 vegetation mapping units, most of which corresponded one-to-one with a vegetation type. Of these, two are considered globally vulnerable or worse: Central Wet-Mesic Tallgrass Prairie (G2G3) and Great Plains Natural Seep (G3). At SCBL, however, the former barely resembles the type description because of the high abundance of weeds (brome species, Canada thistle, reed canary grass, and Kentucky bluegrass) and the presence of some shrubs and trees. The latter occurs in only one very small location at SCBL, where it is dissected by an asphalt hiking path. Other vegetation types that may be globally vulnerable include Rocky Mountain Juniper / Little-seed Ricegrass

Woodland, Ponderosa Pine / Little Bluestem Woodland, and Cottonwood - Peachleaf Willow Floodplain Woodland, all categorized as G3G4.

SCBL is home to no federally threatened or endangered plant species or animal species that depend on a certain plant, but it does house at least 10 species on the Nebraska list of Plants of Concern (http://www.natureserve.org/nhp/us/ne/plants.html). These are: narrow-leaf milkvetch, Parry's rabbitbrush, spotted mission bells, stickseed, matted prickly gilia, Nuttall desert-parsley, stemless nailwort, spearhead phacelia, double twinpod, and flowering-straw. Two additional species, nodding buckwheat and whitestem stickleaf, have been recorded historically at the park but not recently found (DeBacker, 1997). Of these twelve species, only three are not considered globally secure: stickseed (G2G3), matted prickly gilia (G3G4), and Nuttal desert-parsley (G3).

Numerous past and recurring disturbances have taken their toll on much of the prairie and riparian-zone vegetation in SCBL. Parts of the property were previously cultivated or maintained as a golf course. Prairie plantings in these areas have met with varying success. Some prairie areas suffer from high annual brome grass abundance, and riparian areas have little native herbaceous vegetation. Vegetation on bluff sides and in areas away from recurring disturbances tends to be in better condition.

<u>Theodore Roosevelt National Park</u>

Theodore Roosevelt National Park (THRO) is comprised of three units in west-central North Dakota. All three units (North, South, and Elkhorn) are adjacent to or straddle the Little Missouri River. The two large North and South Units vary in topography and vegetation and have designated Wilderness areas. The small Elkhorn Unit lies entirely in the floodplain of the Little Missouri River. Together, the units comprise 70, 446 acres. The land that now comprises the park was acquired by the National Park Service between 1947 and 1978. From 1934 to 1947 some of the area was managed for recreational purposes by state and federal agencies. Prior to this, most of the land was used extensively (and in some cases intensely for cattle ranching. The natural vegetation of the area includes mixed-grass prairie, badlands sparse vegetation, woody draws, and riparian floodplain vegetation. Free-ranging herds of bison were re-introduced to the South and North Units in 1956 and 1962, respectively, and elk were reintroduced to the South Unit in 1985. The South Unit also houses a free-ranging herd of horses and the part of the North Unit houses a small herd (4 individuals) of long-horn cattle for historic demonstration purposes. Black-tailed prairie dogs also occur in the park.

The vegetation of the park was mapped using NVCS methods by the NPS vegetation mapping effort in 1997-1998 (Von Loh *et al.*, 2000). This resulted in 35 vegetation types. Six of these are considered globally vulnerable or worse. Of special concern is the Eastern Cottonwood / Rocky Mountain Juniper Floodplain Woodland (G1G2), which has been documented only in the THRO region. The other five vulnerable vegetation types are: Green Ash - Elm Woody Draw (G2G3), Prairie Sandreed - Sedge Prairie (G3), Ill-scented Sumac / Thread-leaved Sedge Shrub Prairie (G3), Prairie Cordgrass - Sedge Wet Meadow (G3?), and Common Rabbitbrush / Bluebunch Wheatgrass Shrubland (G3Q). Five other vegetation types are classified as G3G4, and therefore are also potentially globally vulnerable.

THRO is home to no federally threatened or endangered plant species or animal species that depend on a certain plant. A rare plant survey conducted at THRO in 1989 (Heidel, 1990) yielded 5 species currently on the North Dakota Rare Plants List: smooth goosefoot, nineanthered dalea, Rocky Mountain spurge, lanceleaf cottonwood, and alkali sacaton. Comparison of the park's plant species list to the current North Dakota Rare Plants List yielded one other rare species that has been confirmed to occur in the park, white locoweed. With the exception of smooth goosefoot, which is ranked as G3G4, all of these species are considered globally secure. smooth goosefoot, lanceleaf cottonwood, and alkali sacaton are also on the USDA Forest Service's sensitive species list for the region.

The lack of fire, previous overgrazing, and current concentration of large grazers (horses) in certain areas have contributed to the degradation of the vegetation at THRO. Numerous exotic species are found in the park, with leafy spurge being the most problematic. This species infests large portions of the park and is the focus of an intense control effort. Canada thistle is less widespread, but it is locally dense and problematic, particularly in more mesic areas. Non-native grasses and some legumes (alfalfa) were historically planted as pasture or in disturbed road rights-of-way. Some of these species have spread outside of their originally planted areas. For example, Kentucky bluegrass has been noted to occur extensively in the east side of the South Unit (Von Loh *et al.*, 2000). Other widespread problem species include yellow sweetclover and white sweetclover. Despite these problems, only 2% of the area of THRO is classified as a vegetation type dominated by non-native species (i.e., leafy spurge, Canada thistle, crested wheatgrass, smooth brome, or Kentucky bluegrass).

Wind Cave National Park

Wind Cave National Park (WICA) is on the southeastern edge of the Black Hills in southwestern South Dakota. Its 28,295 acres encompass all of the five major geomorphic divisions of the Black Hills (Central Crystalline Core, Limestone Plateau, Minnelusa Foothills, Red Valley, and Hogback), providing a diversity of habitats. The general vegetation of the park is northern mixed-grass prairie and ponderosa pine forest and woodlands. The park was established in 1903 to protect and preserve the park's namesake cave, but in 1912 the area was recognized for its potential for protecting wildlife as well. Consequently, Wind Cave National Game Preserve was established and bison, elk, and pronghorn were reintroduced. This Preserve became part of WICA in 1935, and management of these large mammals and their natural habitat has been an important part of the park's mission since then. As a result, WICA has been recognized as one of the few places where the major ecosystem processes that shaped the vegetation of the Black Hills before European settlement are relatively intact (Marriot *et al.*, 1999).

The vegetation of the park was mapped using NVCS standards in 1997-1999, yielding 24 vegetation types in the park (Cogan *et al.*, 1999). Three of these are ranked as globally vulnerable or worse: Cottonwood / Western Snowberry Woodland (G2G3), Box-elder / Choke Cherry Forest (G3), and Prairie Cordgrass - Sedge Wet Meadow (G3?). All of these are quite small, comprising less than 0.5% of the park's area. Seven other vegetation types are classified as G3G4 or G3G5, and therefore may be globally vulnerable.

WICA is home to no federally threatened or endangered plant species or animal species that depend on a certain plant. A rare plant survey conducted in 1998 (Marriot, 1999) confirmed the presence of four species on the South Dakota Natural Heritage Rare Plants list in the park. These are: nylon hedgehog cactus, Hopi tea, Easter Daisy, and Hooker's Townsend-daisy. All of these species are considered globally secure. Two other species (interrupted wild rye and sleepy grass) were previously recorded as in the park, but were not found in 1998 and vouchers need to be collected to confirm their presence. The park's plant list also includes smallflower columbine and American cranberrybush, USDA Forest Service sensitive species monitored in the Black Hills National Forest.

The Black Hills Community Inventory (Marriot *et al.*, 1999) evaluated the condition of 22 vegetation types at WICA at the time of the vegetation mapping effort. Of these, 10 were ranked as “A” (the highest integrity), 8 as “AB”, and 4 as “B”. As a result, the Inventory considered WICA to be one of eight “exemplary” sites in the Black Hills. Only two vegetation types classified by the mapping effort (Cogan *et al.*, 1999) were dominated by non-native species. These were Introduced Weedy Graminoid Herbaceous Vegetation and Kentucky Bluegrass Herbaceous Vegetation. The former, characterized by smooth brome, cheat grass, and Japanese brome, was mapped in only 2.7 hectares in the park, but the species that characterize this type are sometimes found in other vegetation types. The latter could not be separated from native grassland from aerial photograph interpretation, but is extensive in the eastern half and southwestern quarter of the park (Cogan *et al.*, 1999). Kentucky bluegrass also occurs in other vegetation types. Other non-native species of note are common mullein, yellow sweetclover, and Canada thistle. In general, these occur locally and are often associated with disturbance, such as dense patches of common mullein in area following high severity wildland fires. WICA personnel began a prescribed fire program in 1973 (Forde *et al.*, 1984). Although this has probably helped slow the spread of pine into grasslands, it probably does not mimic the pre-European settlement fire regime. As a result, plant communities, particularly those in the pine woodlands and forests, have probably been impacted. For example, comparison of aerial photos from the 1930's to current times suggests that tree density has increased (D. Foster, pers. communication).

Part B. Identify park management goals and objectives in regards to vegetation, authorities and policies affecting those resources and their management, and the role of park vegetation in overall park health.

This section will be completed after parks have provided the necessary documentation..

Objective 2. Provide a review, synthesis, and assessment of vegetation monitoring efforts being conducted by NPS and non-NPS entities in and around Network parks.

Part A. Vegetation monitoring efforts by NPS in Network parks.

Three NPS programs are the major avenues of current vegetation monitoring in parks in the Northern Great Plains Network. Briefly,

1. The Northern Great Plains fire effects monitoring (NGP Fire Effects) program was established in 1996 "to document baseline vegetation information, to detect trends in vegetation populations, to ensure that resource management objectives are met, and to aid in refining parks' fire management programs" (from NGP Fire Effects website http://www.nps.gov/fire/greatplains/). NGP Fire Effects has plots in forest stands, shrublands, and grasslands in 10 of the Networks' 13 parks. The exceptions are FOLA, MNRR, and NIOB.
2. The Prairie Cluster Prototype Long-Term Ecological Monitoring program (Prairie Cluster LTEM) monitors plant community structure, composition, and diversity in grasslands and woodlands at AGFO and SCBL. The goals of this monitoring are to gather baseline information for these parameters in remnant and restored prairies, detect trends in these parameters if they exist, and relate any trends to climatic variables or management activities, such as prescribed fire. Monitoring for this program began in 1997.
3. The Northern Great Plains Exotic Plant Management Team (NGP EPMT) serves the same 13 parks as in the NGP I&M Network. Although the primary duty of the team is to apply chemical, biological, and mechanical treatments to reduce the extent and density of exotic, invasive plants in the parks, the team does map areas of exotic plant infestations (often repeatedly in the same location) and records qualitative estimates of the density of these plants. These procedures are not formal monitoring, but do provide some recurrent information on park vegetation. The team began field work in 2002.

<u>NGP Fire Effects</u>

NGP Fire Effects is part of the NGP Fire Management Office at WICA. It is part of a national effort to assess the effectiveness and effects of fire management in NPS units. All monitoring teams in this national program follow the protocols described in the *Fire Management Handbook* ("FMH"; USDI National Park Service, 2003), which explains that the monitoring done for this program is designed to provide long-term, park-wide data on the effects of a park's fire management on vegetation. In other words, the data are meant to address the question of whether the goals and objectives of a park's Fire Management Plan are being met. However, at least in the NGP Fire Effects program, park resource management and administrative staff often want short-term, burn unit-specific information to determine whether the goals and objectives of a specific prescribed burn were met. Thus, although the NGP Fire Effects program's monitoring generally adheres to FMH guidelines, its design is oriented more towards providing the type of data requested by the parks it serves rather than the long-term, park-wide information described in the FMH.

With that in mind, a summary of the current protocols used by Fire Effects in the NGP for vegetation data collection follows. Detailed descriptions are in the FMH (USDI National Park Service, 2003).

1. One year prior to a prescribed burn, permanent plots are installed in the burn unit and

initial (pre-burn) vegetation data are collected. Vegetation data are then collected in these plots 1, 2, 5, and 10 years after the burn, then every 10 years thereafter, or until the unit is burned again. In this case, the sampling cycle starts again, but the same physical plots are used.

2. The number of plots per burn unit varies, depending on how many vegetation types are in the unit, the size of the unit, and the objectives of the burn. In general, there are 1-4 plots per vegetation type (grassland, shrubland, forest, non-native vegetation) per burn unit.
3. Plots are located randomly within burn units. Those not meeting the selection criteria (vegetation type, accessibility) are rejected and replaced by another randomly selected location.
4. Vegetation data collected varies by vegetation type, but all plot types follow essentially the same design. The greatest amount of data is collected in forest plots, a subset of that in shrubland plots, and a subset of shrubland plot data in grassland plots.
   - a. Forest plots are 20m x 50m in size, divided into for 10m x 25m quadrats.
     - i. On one of the 50m edges of the plot, point-intercept data is collected for all herbaceous and shrub species and all trees under 2m tall. Points are spaced at 30cm intervals, yielding 166 points per plot. All species that intercept the rod used as the pointer, or the substrate (rock, litter) if no plants are at that point, are recorded for that point in the order of decreasing maximum height. These data are used to estimate herbaceous layer cover, species richness, and composition. The height, in dm, of the tallest plant (<2m tall) at each point is recorded.
     - ii. Shrub stem density, by species, is recorded in a belt transect along the point-intercept line, inside the plot. Width of the belt varies from 0.5m to 5m depending on shrub species and vegetation type.
     - iii. Density of tree seedlings (DBH < 2.5 cm, where DBH is diameter at breast height), by species, is recorded in a 5m x 10m quadrat.
     - iv. Pole-size trees (2.5cm #DBH #15cm,) are identified, counted and their DBH measured in one of the 10m x 25m quadrats.
     - v. Trees (>15cm DBH) are tagged, and species identity, DBH, crown position in the canopy, tree condition (damage class), and whether it's alive or dead are recorded for each individual. This information is collected within the whole 20m x 50m plot. The combination of iii and iv gives basal area and tree density estimates.
     - vi. Fuel load data are collected on four 50ft or 100ft transects (also known as Brown's lines). Anchor points for these transects are evenly spaced along the 50m center-line of the plot, and the direction of each transect is determined randomly. Dead wood particles are recorded along this transect according to size class and integrity, and litter and duff measurements are recorded at 10 points, spaced at 5ft intervals, along the transect. Data are entered into calibrated equations (Brown, 1974; Brown *et al.*, 1982) to calculate fuel loads, and therefore to predict fire intensity.
     - vii. All species encountered in the plot or within 5m of its border are recorded.
   - b. Shrubland and grassland plots are actually 30m transects.
     - i. Point-intercept data are collected as described in i above, but due to the

difference in transect length, only 100 points are used.

        ii. When shrubs are present, shrub stem density is recorded in a 2m wide belt along the 30m transect.
        iii. Species presence data are collected as described in vii above.
        iv. In some grassland plots, nested frequency quadrats are spaced along the 30m transect at the 0m, 10m, and 20m points. At each of these points, three square sub-plots (0.01m^2, 0.1 m^2, 1.0m^2) are nested in a 10m^2 plot, similar to the layout of the Prairie Cluster LTEM sampling methodology (see Figure 1).
    c. One-nine photographs are taken at each plot from designated locations and facing designated directions (i.e. from the transect 0 point facing the transect in grassland plots).

5. Data are collected once during a growing season, from late May (southern parks) to mid August (northern parks).
6. Methods sometimes deviate from the standard protocols because of logistical considerations and/or burn or monitoring objectives. For example, a burn may not occur in the year in which it was planned. In that case, pre-burn data is acceptable if it is no more than two years old. Or, if the reaction of a certain species to a burn, such as reduction in cover of Smooth Brome, is part of a burn objective, cover of this and other species may be estimated using modified Daubenmire cover classes in quadrats along a transect in addition to the point-intercept method.
7. In addition to vegetation data, NGP Fire Effects collects information on fuel moisture before burns, fire behavior during burns, and fire severity immediately after burns.

The Fire Effects program also collects short-term data for specific projects, such as a mechanical thinning treatment at MORU. Protocols for these projects are tailored for the specific objectives and do not necessarily follow the FMH.

Data are stored and analyzed with software specifically designed for the nation-wide Fire Effects program. The software used is currently in transition from the DOS-based FMH software to the Microsoft Access/ArcMap-based FEAT (Fire Ecology Assessment Tool). Technicians and the assistant and lead fire effects monitors enter data. The lead fire effects monitor and the fire ecologist analyze the data and prepare reports of the results for the parks. The regional fire ecologist oversees the local program.

<u>Prairie Cluster LTEM</u>

The Prairie Cluster LTEM is located at Wilson's Creek National Battlefield in Republic, Missouri. It was established as part of the nationwide I&M program before the Natural Resource Challenge initiative and the establishment of monitoring networks. It was initiated to research, design, and test protocols for monitoring specifically in small prairie parks. Two of these parks are in the NGP I&M Network, whereas the remaining five are within the Heartland I&M Network. Before monitoring began, a rigorous process was used to determine specific objectives of the monitoring program within and across parks in the cluster, then choose specific ecological indicators to address those objectives. Grassland plant communities was one of the components chosen to monitor in this program, and the specific monitoring questions and approach for this component are as follows (from Thomas *et al.*, 2001)

Monitoring questions and approach

1. What is the current species composition, structure, and diversity of remnant and restored prairies?
   - Measure vascular plant species composition and foliar cover in permanent plots.
2. Is the structure, composition, and diversity of remnant and restored prairies changing? If so, is this change directional, cyclic, or random?
   - Monitor vascular plant species composition and foliar cover at regular intervals.
   - Initially, monitor for several consecutive years to assess inter-annual variability and obtain a multi-year baseline.
3. Are trends in species composition, structure, and diversity correlated with climatic variables or management activities, such as prescribed fire?
   - Record management actions and acquire climatic data for correlation with monitoring results.

An initial protocol was developed for gathering the vegetation data necessary to answer these questions (Willson *et al.*, 2002). The protocol was adapted from that used by the National Science Foundation-funded Konza Prairie long-term ecological research program in the Flint Hills of Kansas, where tallgrass prairie is the overwhelmingly dominant vegetation. Some modifications have already been made to the initial protocol, and the protocol is currently going through extensive revision to conform to new NPS standards. The summary description of the protocol that follows incorporates the modifications that have been used so far, as described by the current Prairie Cluster LTEM coordinator (M. DeBacker, pers. comm). Only the protocols used in the NGP Network Parks are described here.

1. Permanent study sites in grasslands and woodlands were established in 1997. Permanent study sites associated with a prairie restoration at SCBL were established in 1998.There are no plans to establish more study sites as part of this program. In grassland study sites, data were collected in 1997, 1998, 1999, and 2003. In woodland study sites, data were collected in 1997, 2000, and 2003. Data in the restoration sites were collected 1998-2001 and 2003. The current revisit plan is to measure these sites for two consecutive years, followed by a three year non-visit interval.
2. The many different vegetation types, management practices and park specific information needs, as well as the logistical constraints related to field work and personnel costs, prohibit comprehensive sampling at each park. In other words, these constraints prevent simply treating the park as the study unit. In choosing smaller subsets of the park as study units, park-specific resource management issues and/or the desire to capture landscape and community heterogeneity guided the selection. The study unit is the reference frame for which statistical inference is made. In general, study units that represent a range of community types (prairie, woodland), conditions (high-quality remnants, restored areas), and/or management strategies were selected. Study sites within study units were located randomly, using soil type, slope, and aspect to stratify into approximate plant communities when more than one community type occurred within a study unit.
3. The program attempted to locate two or more study sites per community type per study unit, depending on the size of the unit and community type. The number of sample sites

to be deployed within a study unit is made on a case by case basis. Factors include field work logistics, expense and professional judgment regarding the adequacy of a particular sample size in capturing the diversity inherent in the study unit. After collecting pilot data, the adequacy of the sample size is explored using power analysis and sample sizes modified where necessary. Actual number of study sites per community type at AGFO and SCBL ranges from two to four.

4. Vegetation data collected is basically the same in all three community types (grassland, woodland, and restoration), but additional data are collected in woodland sites.
    a. A study site consists of two 50m parallel transects separated by 20m. Five $10m^2$ circular plots are located along each of the transects. The ends of each transect are permanently marked, but the plot locations are refound each time with a tape. Within each $10m^2$ plot, three smaller round plots ($0.01m^2$, $0.1m^2$, and $1m^2$) are nested. Figure 1 depicts the layout of plots at a study site.
    b. Species presence is recorded in successively larger plots for each $10m^2$ plot. Canopy cover of all individual herbaceous and shrub species and ground-level cover of vegetation (basal area), bare soil, bare rock, tree leaf litter, grass litter, and woody debris are estimated for each $10m^2$ plot using modified Daubenmire cover classes.
    c. In woodland areas, small seedlings (< 0.5m tall), large seedlings (∃ 0.5m tall and DBH < 2.5cm), and saplings (2.5cm # DBH # 5.0cm) of woody species are identified to species and counted within each $10m^2$ plot. In addition, the species identification, DBH, and condition (dead or alive) of each tree are recorded. Trees are not tagged.
5. Study sites are sampled twice in the growing season, once in May or June and once in August.
6. Methods are strictly adhered to in all situations.

In addition to monitoring plant community composition as described above, the Prairie Cluster LTEM monitors grassland birds and water quality at AGFO and black-tailed prairie dog colony density and size at SCBL.

The Prairie Cluster LTEM database infrastructure is composed of multiple project databases developed and managed in Microsoft Access. ArcView, and ArcInfo are used for GIS purposes, and data are analyzed with a variety of statistical programs (NCSS 2000, Pass 6.0, PC-Ord 4.0, SAS 8.2). A technician enters data with some help of the botanist, who also verifies the data. The project manager (plant ecologist for vegetation monitoring) oversees data entry and verification, and validates, summarizes, analyzes, and reports the data in coordination with the program coordinator. The program employs a full-time, permanent data manager, who is responsible for data archiving and dissemination, database development, report automation, and overall quality assurance. Data management protocols for the Prairie Cluster LTEM are fully described in DeBacker et al. (2002).

A recent review of the Prairie Cluster LTEM (Williams, 2002) recommended that, when it is up and running, the NGP I&M Network should take over monitoring the exact same plots, using the same protocols, as the Prairie Cluster LTEM. Funding would be transferred from the Prairie Cluster LTEM to the NGP Network for this purpose.

NGP EPMT

The NGP EPMT is headquartered at THRO but has seasonal offices at BADL and WICA. It is part of a national program of 16 networks funded by the Natural Resources Challenge. The NGP EPMT was first funded in fiscal year 2002, and is therefore a very new program. The original intent of the national program was that an EPMT would work in a region for a short time (5 years) to reduce invasive plant infestations within the parks in that region to a maintenance level, i.e., one that the individual parks could maintain without the extra help of the EPMT. After that time, the EPMT would move to a different region. Whether this model will be followed is not yet determined.

The NGP EPMT does not currently do monitoring in the strict sense ("the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective"; Elzinga *et al.*, 1998). However, some of the information that the NGP EPMT collects in the course of its treatment work might be used as part of a monitoring program, so it is summarized here:

$ The location and size of infestations of target species in each park are mapped with a GPS unit, and an essentially qualitative estimate of the density of the target in each infestation is recorded.
$ The target species vary among parks and generally include only those species that the EPMT will treat.
$ The target species include leafy spurge, Canada thistle and other non-native thistles if encountered, houndstongue, spotted knapweed, black henbane, Russian olive, and purple loosestrife.
$ Exotic species that are treated in only very select areas of certain parks include annual brome grasses and smooth brome.
$ Problematic invasives that have not been treated to date include bindweed, yellow sweetclover, crested wheatgrass, and salt cedar.
$ Approximately one month of each field season is devoted to mapping these target species. Additional occurrences are mapped if they are encountered during treatment activities. In smaller parks, such as FOLA and FOUS, this effort is sufficient to accurately map the target species in the whole park every year. In larger parks, however, only a small portion of the park is mapped (or treated) each year, and the areas are not necessarily revisited.

NGP EPMT operations are data intensive. In addition to collecting the information described above, team members record information about treatment (herbicide name and amount used, plus weather at time of spraying; mechanical control method; name and number of biological control agents released) and the amount of time spent and number of people treating an area. The NGP EPMT has its own permanent, full-time data manager, who is responsible for verification and compilation of data entered in the field by seasonal technicians. The team leader analyzes and reports the data to the parks and the national program.

The leader of the NGP EPMT does not feel that their current efforts/methods are sufficient to statistically test for changes in either density or extent of infestations (C. Prosser, pers. comm.). Consequently, and due to other priorities of EPMT staff, no attempt has been made to analyze their data for vegetation monitoring purposes such as treatment effectiveness and effects on non-targets, annual variation in spatial extent or density of infestations, and so forth.

Other NPS Monitoring

In addition to the three programs mentioned above, some limited monitoring efforts with respect to vegetation have been done by park staff in individual parks. As would be expected, they are more common in larger parks with more natural resource staff. AGFO, FOLA, FOUS, JECA, MNRR, MORU, NIOB, and SCBL reported no park-led vegetation monitoring outside of casual observations regarding invasive plant species or known plant pests.

At BADL, the park's vegetation crew does noxious weed mapping beyond what the NGP EPMT does, and has done range evaluation sampling using the Natural Resources Conservation Service (NRCS) double-sampling protocol (USDA-NRCS, 1997). Three exclosures each were constructed at three locations in the Sage Creek Wilderness Area in 1994. At each location, two exclosures were within an active prairie dog colony, and one was outside the colony. On the colony, one exclosure excluded bison only, and the other excluded both bison and prairie dogs. Off the colony, the exclosure excluded bison only. An additional plot with no fencing served as a bison-grazed plot. These exclosures were set up by a park wildlife ecologist with the intention of long-term monitoring of the vegetation in these various situations. Some research was done in the plots by non-NPS investigators (Fahnestock and Detling, 2002; Fahnestock *et al.*, 2003), but the long-term monitoring never materialized. The exclosures will be removed in the spring of 2004 due to park concerns about having structures in the wilderness area and because the original design of the monitoring has fallen apart (prairie dog towns expanded into the plots previously outside of the towns; prairie dog exclosures didn't keep prairie dogs out for long). The materials from these exclosures may be used for building other exclosures for Network monitoring, however.

At DETO, the park's staff maps exotic plants beyond what the NGP EPMT does. They also recently repeated an evaluation of the impact of rock climbers on the flora, fauna, and soil on the top of the tower, which was previously done ten years ago. The park plans to repeat this evaluation every ten years.

At KNRI, park staff GPS the boundaries of major invasive plant infestations and plant communities each year. The goal of this mapping is to determine whether exotic infestations, particularly Smooth Brome areas, are increasing or decreasing in size. They have also been monitoring the infection of trees by *Prenoporia fraxophelia*, a heart-rot fungus, in a treated plot (in which fungicide was sprayed and fruiting bodies are removed from trees) and a paired control plot for approximately 10 years. Thirty-six photo-points in areas where leafy spurge biological control agents were released may also be useful for qualitative vegetation monitoring.

At THRO, a former biological technician installed 85 Modified Whittaker plots (Stohlgren *et al.*, 1998) in 12 vegetation types in the South Unit of the park in 2002. Data (cover of individual plant species in ten $1m^2$ subplots per plot, presence/absence of individual plant species in larger subplots and the entire 1000 m^2 plot) data plant cover were collected from a subset of these plots in 2002, but the program was not continued after the technician left in early 2003. The objectives of the plots are many (P. Andersen, pers. comm.):

- Monitor species richness and diversity by vegetation type
- Develop a species list for each vegetation type
- Monitor the frequency, distribution and density of invasive species and rare plants

- $ Monitor the effects of various disturbances, such as invasive species, biological control, herbicides, fire, and wildlife, on vegetation
- $ Monitor wildlife habitat, large ungulate forage conditions and trends in particular
- $ Use data to ground-truth vegetation types due to inaccuracies of the USGS-NPS veg map
- $ Photographically record visual change over time
- $ Meet Inventory and Monitoring goals of the Natural Resource Challenge

It is not clear that these plots could actually be used to meet all of these objectives.

At WICA, park staff GPS the boundaries of prairie dog colonies biennially, annually map exotic plants beyond what the NGP EPMT does, and casually watch for populations of species on the South Dakota rare plant list. They also map some native species of concern (quaking aspen) and have established photo-points in an exclosure constructed in 2003 to protect quaking aspen from deer and elk. Other exclosures to protect some hardwoods have plots in them in which a "scorecard" methodology of assessing the seral stage of a stand (D. Uresk, unpublished) has been used. Finally, a range assessment program, using the NRCS double sampling method used at BADL, was begun in 2003. Park staff plan to continue the last two monitoring projects in some form in the future, but no definite plans have been established.

Part B. Vegetation monitoring efforts by non-NPS entities in and around Network parks.

Efforts by non-NPS entities of interest to the Network for vegetation monitoring purposes fall into two basic categories. First, there are past or current research projects in the parks conducted by outside, often academic, investigators, since no true vegetation monitoring by outside entities has occurred in any of the Network's 13 parks (with one exception, see WICA below). These research projects often have permanently marked plots and information about the vegetation from years to decades ago. The second category is true vegetation monitoring done by non-NPS entities outside, but in the vicinity of, the Network's parks. These efforts, generally by federal or state agencies, are of interest because of the opportunities of using similar protocols, and therefore the potential for collecting comparable data.

<u>Non-NPS Entities in Network Parks</u>

Nearly all parks in the network (AGFO and FOLA being the possible exceptions) are monitored for gypsy moths each year either by the USDA or by a state agency. Other relevant efforts by park are:

- ! BADL
    - " The South Dakota Department of Agriculture watches for Tamarisk invasion along the White River (which barely touches the park at the southern tip of the South Unit) and the Cheyenne River (north of the park).
    - " Plots used in the early 1990's for vegetation mapping prior to the USGS-NPS vegetation mapping effort (Butler and Batt, 1995) were permanently marked with wooden stakes, but not GPS'd. If these plots could be relocated, they might be used for long-term plant community monitoring.
    - " Laura Van Riper and Diane Larson of the University of Minnesota have an ongoing research project on Yellow Sweetclover. Begun in 2000, the project has randomly located plots in Badlands Sparse and Western Wheatgrass vegetation

types in the North Unit of the park. Plant community composition, cover, and biomass data have been collected annually.

! DETO

" Evelyn Merrill of the University of Wisconsin-Stevens Point established six deer exclosures and paired plots outside the exclosures in wooded areas in 1989 and sampled understory woody and herbaceous vegetation in them at approximately 3-year intervals from 1989 to 1996. Additional exclosures and paired plots were established at six new sites in 1996 and the vegetation was sampled (http://science.nature.nps.gov/research/ac/iars/search/iarView?reportId=3109). These exclosures are still in place, but have not been maintained since 1996.

! MNRR

" The Army Corps of Engineers monitors willow and cottonwood regeneration on sandbars in order to track nesting site availability for the federally endangered Piping Plover and Interior Least Tern (W. Werkmeister, pers. comm.).

! NIOB

" Part of The Nature Conservancy's Niobrara Valley Preserve lies within the boundaries of NIOB. TNC conducted a Natural Heritage-style inventory of all major life forms, including plants, just after the preserve's establishment in1981-1983, and again in 1996-1998. The plan is to repeat this inventory approximately every 10 years. A more concentrated plant inventory is conducted approximately every 3-5 years in 13 to 20 spring branch canyons on the south side of the Niobrara River, east of TNC headquarters on the preserve. TNC also has photo points in the preserve, as well as plots along the Niobrara River for monitoring purple loosestrife and its biocontrol agent (A. Steuter, pers. comm.).

" Tom Bragg of the University of Nebraska-Omaha established two sets of monitoring plots on the Niobrara Valley preserve. The first, established in 1984, is in an ungrazed area and the sample sites are stratified into north-facing, south-facing, and hilltop locations; four of the 12 original sites are still sampled on an annual basis. The second set of plots, established in 2000, is in two, adjacent pastures, one in which bison were introduced the year after sampling and another in an area recently excluded from cattle grazing. Continuous data are available from 2000 to present for twelve monitoring sites (three in each of upland, north-facing slope, south-facing slope, and depression). Plot setup is the same in both sets of plots: At each sampling site, 10 1m x 5m subplots are systematically located along a 21 m transect (endpoints GPS'd and permanently marked) and evaluated for canopy cover of all species and species groups (T. Bragg, pers. comm.).

! THRO

" A fairly large number of autecological and phytosociological studies were conducted in western ND starting in the early 1960s and many completed in the early 1980s. These were done both in park and in the National Grasslands surrounding the park. GPS coordinates for many of the plots from these studies have been developed from the original legal descriptions of the plot locations. Harold Goetz, formerly of North Dakota State University and currently retired from Colorado State University directed the majority of these projects (J. Butler, pers. comm.).

- Jack Butler, USDA Forest Service Rocky Mountain Research Center, established a series of permanent, 20cm x 50cm plots on several leafy spurge infested sites on the Petrified Forest plateau in 1992. The sites were aerially sprayed with herbicides in 1993 and again in 1995. Plant community data were recorded from the plots in 1992, 1993, 1994, 1996, 1999, 2000, and 2003. The plots are permanently marked with barn nails driven into the soil. He, along with a graduate student, also has Modified Whittaker plots in silver sagebrush, green ash, and needle-and-thread communities (J. Butler, pers. comm).
- Diane Larson, USGS Northern Prairie Wildlife Research Center, inventoried the park for invasive plant species in 1996-97. The sampling scheme was designed to sample each vegetation type (from a 1980's vintage veg map) in proportion to its area within rectangular strata overlayed on the park. The strata ensured that the entire park was covered. Random sample points were selected within each vegetation type. These points marked the beginning of vegetation transects along which all species were identified within a series of equidistant 0.5m x 2m plots. Data were expressed as frequency/transect. Transect endpoints were not permanently marked, although GPS coordinates were recorded, so they could be approximately relocated. She also has plots from a leafy spurge research project in 1999-2002. Plots were located only within vegetation types that contained leafy spurge. These 4m x 6m plots were randomly located within vegetation types and the park has GPS coordinates for them, although the markers have mostly been removed (P. Andersen, pers. comm.). Data from these plots include frequency of individual species, biomass of leafy spurge and functional groups, and biocontrol insect abundance (D. Larson, pers. comm.).

- WICA
  - Tom Stohlgren, USGS Fort Collins Science Center, established seven randomly located Modified-Whittaker plots in grassland areas of the park in 1996. The plots are not permanently marked, but GPS coordinates for the park are available. Data were collected only in 1996 (Stohlgren *et al.*, 1998; S. Simonson, pers. comm.; Stohlgren *et al.*, 1999).
  - Francis Singer and Linda Zeigenfuss, USGS Fort Collins Science Center, established seven large mammal exclosures in hardwood stands in 1995 as part of a browse-fire interaction study. Location, height, and stem counts of eight hardwood tree and shrub species were recorded in 1995 and 1996, and twig browse data were collected in 1995-1997, inside and outside of the exclosures (Singer and Zeigenfuss, 1998). The exclosures are still intact (M. Curtin, pers. comm.).
  - One or two Phase 2 plots of the USDA Forest Service Forest Inventory and Analysis (FIA) program fall in WICA (D. Haugen, pers. comm.). These plots are described in the following section

Non-NPS Monitoring around the Parks

The major entity involved in monitoring in the vicinity of Network parks is the USDA Forest Service. This agency manages the Black Hills National Forest, which surrounds or is near to DETO, JECA, MORU, and WICA; the Buffalo Gap National Grassland, which surrounds BADL and is relatively close to WICA; the Ogalala National Grassland and Nebraska National Forest, which are in the vicinity of AGFO; the Little Missouri National Grassland, which surrounds THRO; and Thunder Basin National Grassland and Medicine Bow National Forest, which are in the vicinity of FOLA. Vegetation monitoring methods used by the Forest Service are summarized below.

1. *The Forest Inventory and Analysis (FIA) program* is a national continuous forest census. The Forest Service has collected, analyzed, and reported information on the status and trends of America's forests – how much forest exists, where it exists, who owns it, and how it is changing – since 1930. In the last decade or so, the program has been modified to provide more and more current information. This program involves three sampling "phases", the third of which was formerly the Forest Health Monitoring (FHM) program. More detailed information about this program can be found at http://fia.fs.fed.us/about.htm. Other useful documents include Stolte et al. (2002), DeBlander (2002), and http://fia.fs.fed.us/library.htm#Manuals.
    - Phase 1 is a remote sensing phase aimed at classifying the land into forest and non-forest and taking spatial measurements such as fragmentation, urbanization, and distance variables. Sampling points are distributed in a honeycomb grid, every 1000m, across an entire state. Each point is assigned ownership and vegetative cover (forest, non-forest) attributes using aerial photography and, more recently, satellite imagery.
    - Phase 2 consists of field plots located every 5000m on the Phase 1 grid. Phase two plots are stratified based on Phase 1 ownership and vegetation information, and weights are assigned to each stratum based on the proportion of Phase 1 points in that stratum.
        - Forested sample locations are visited by field crews who collect a variety of forest ecosystem data. This includes forest type; size distribution of trees; number and basal area of live trees; number and weight of dead trees; wood volume, biomass, and basal area of live trees; stocking category; tree growth; tree mortality; and visual estimates of crown canopy coverage for four plant groups in the understory — tree seedlings/saplings, shrubs, forbs, and graminoids. Additional information recorded for each plot includes accessibility (distance to road), cutting and burn history, and anthropogenic disturbance.
        - Non-forest locations are visited as necessary to quantify rates of land use change.
        - There are 205 Phase 2 plots in the Black Hills National Forest: 173 forest, 22 forest and non-forest, and 10 non-forest (DeBlander, 2002).
        - Figure 2 shows the plot design of a Phase 2/Phase 3 sample point.
    - Phase 3 consists of a subset of the Phase 2 plots (one for every 16 Phase 2 plots, approximately 1 every 96,000 acres).
        - These plots are visited during the growing season in order to collect an extended suite of ecological data including that listed for Phase 2 plots; a full vegetation inventory (all plants in subplots are identified to species

level and the height zone that the species occupies in the stand); tree regeneration (seedling and sapling counts); soil data (basic soil parameters, pH, and aluminum); lichen diversity; coarse woody debris; and ozone damage using bioindicators in or near the plot.
    - Two or three of these plots are in the Black Hills National Forest.
  - Table 2 describes the FHM indicators, which Phase 2 and Phase 3 encompass, in more detail.
  - In the FIA's North-Central Region, which encompasses all but the Wyoming parks in the Network, sampling is done every five years, with the sampling staggered so that some samples are taken each year. Other Forest Service regions work on a ten-year rotation.
  - The estimated cost of following FHM protocols is about $800 - $1200 per plot in the continental US, depending on housing, travel costs, and region of the country.
  - In some regions, the Forest Service has increased the density of FIA sampling in cooperation with other agencies.
2. The monitoring attention that *Forest Service Regional Sensitive Species and Watch List Species* receive varies among regions and Forest Service units. Network parks fall within two different Forest Service Regions (which, by the way, are different from the regions used by the FIA program). FOUS, KNRI, and THRO are in the Northern Region and the remainder are in the Rocky Mountain Region.
  - In the Rocky Mountain Region, the Black Hills National Forest appears to be the only Forest Service unit that currently has an inventory or monitoring program for sensitive species (B. Burkhart, pers. comm.), although a protocol for monitoring Barr's milkvetch in Forest Service properties in the region is currently being developed. The Black Hills program will expire in June 2004 unless renewed. This unit has designed monitoring protocols for the 14 sensitive species that occur within its boundaries.
    - Four of these species occur in Network parks, as described in the individual park vegetation descriptions in Objective 1, Part A above.
    - Methods for monitoring these species vary depending on the number and density of populations. Methods range from annual mapping of known patches to annual checks for presence of the species in known locations (R. Crook, pers. comm.).
  - In the Northern Region, botanists in the Little Missouri National Grassland keep track of 12 sensitive species and 23 watch list species. Three of these sensitive species (smooth goosefoot, lanceleaf cottonwood, and alkali sacaton) and three of the watch list species (cutleaf evening primrose, many-flowered broomrape, and white locoweed) occur in THRO, and one of the sensitive species (sand lily) is expected in that park. Monitoring efforts vary among species, but generally consist of completing or updating a Natural Heritage Element Occurrence Record for new or known populations on a regular basis (J. Washington, pers. comm.).
3. A variety of other sampling/monitoring methods have been used in Forest Service lands for different objectives. These include:
  - Fire effects monitoring plots (M. Lata, pers. comm.) using NPS FMH protocols
    - 23-24 grassland plots in the Western Unit of Buffalo Gap National

   - Grasslands, plus some small nested plots using Daubenmire quadrats in the same areas
   - 6 forest plots on the Pine Ridge escarpment in Nebraska National Forest
- Range evaluation/monitoring sampling sites
   - 8 permanent ocular plots (NRCS methods) in Buffalo Gap National Grasslands, 2-5 miles from the South Unit of BADL (G. Kostel, pers. comm.)
   - standard NRCS range evaluation sites in all national grasslands, but these do not use permanent plots (M. Lata, pers. comm.)
   - hundreds of permanent transects used for determining grassland seral stage; the data collected on these transects is strictly structural (plant height and litter depth), with no composition information (G. Kostel, pers. comm.)
- Timber information (size distribution and density of trees, tree species composition) using Common Stand Exams (http://www.fs.fed.us/r10/ro/business/fsveg/) in forested areas. These do not involve permanent plots.
- Ocular Plant Composition plots for describing vegetation types (G. Kostel, pers. comm.)
   - There are more than 300 of these in the approximately 300,000 acres of Buffalo Gap National Grasslands.
   - Canopy cover and shrub vigor are visually estimated by species in plots ranging in size from 10m x 10m to 20m x 50m, depending on the vegetation type.
   - Plots were placed subjectively to represent vegetation types. Multiple plots were placed in each vegetation type.
   - Baseline data collection occurred in 2001-2003. Some plots will be revisited, especially those with rare species or communities, but the return interval has not yet been determined.
- Long-term monitoring of vegetation inside and outside a few scattered exclosures in the Little Missouri National Grassland, primarily in woody draws.
- Specific monitoring methods for answering questions posed in the Land & Resource Management Plans for Forest Service grassland units in the northern Great Plains are being developed (Forest Supervisor, 2001a, 2001b; Grassland Supervisor, 2001). Monitoring questions particularly relevant to vegetation in the Network include:
   - To what extent are perennial streams in proper functioning condition and riparian areas and wooded draws self-perpetuating? Possible units of measure: Percent of riparian areas and wooded draws that are regenerating or making measurable progress towards regeneration.
   - To what extent is the Dakota Prairie Grasslands contributing to the viability of rare plant communities? Possible units of measure: Results from targeted botanical surveys, implementation of conservation strategies.
   - To what extent is the Dakota Prairie Grasslands contributing to the

viability of sensitive plant, animal, and fish species? Possible units of measure: Implementation of conservation strategies, acres of habitat improvement accomplished, population and distribution information from surveys, number of reintroductions and transplants.

" To what extent are noxious weeds, invasive species, and animal damage expanding or being reduced? Possible units of measure: Species, location, and acres of noxious weeds, invasive species, and animal damage.

" To what extent are rangeland vegetation structure objectives being met? Possible units of measure: Location and percent of rangeland area meeting or making measurable progress towards desired vegetation structure.

" To what extent are rangeland vegetation composition objectives being met? Possible units of measure: Location and percent of rangeland area meeting or making measurable progress towards desired vegetation composition.

" To what extent are desired vegetation conditions in wetlands being met? Possible units of measure: Location and percent of wetlands meeting, making measurable progress making measurable progress towards, or not meeting desired structural stages.

" How valid are composition and structure in managing for desired vegetation and habitat? Possible units of measure: Correlate composition and structure with species trends.

! So far, the Forest Service does not follow a nationally standardized protocol for monitoring invasive/exotic plants, but they do have an extensive mapping program using a data dictionary similar to that used by the NGP EPMT (C. Beckner, pers. comm.).

In addition to the Forest Service monitoring, some smaller efforts in the vicinity of Network parks include:

! Custer State Park (South Dakota Department of Game, Fish and Parks), which is on the north boundary of WICA, began range evaluations using NRCS protocols, in 1998. Park staff plan to continue sampling biennially (B. Hall, pers. comm.).

! The Nature Conservancy's Whitney Preserve, southwest of WICA, is developing a vegetation monitoring program for its rare plants (none of which occur in Network parks) and grazing effects on riparian and upland habitats.

! Fort Niobrara and Valentine National Wildlife Refuges (near NIOB) are developing a grassland vegetation monitoring protocol to evaluate plant community composition with respect to management goals. The pilot protocol, tested in 2003, includes Daubenmire cover estimates of all species in three 1m x 0.5m plots along 30m transects, as well as identification of the dominant plant group or species in each half meter interval within a 0.1 m belt along the 30-m transect to estimate frequency of major species (K. McPeak, pers. comm.). The refuges are very interested in coordinating monitoring efforts, but stress that the resources they have for monitoring are very limited (one staff person per refuge).

Part C. Assessment of vegetation monitoring efforts in and around Network parks.

To summarize the information above, there are basically four kinds of true monitoring occurring in and around Network parks. The first kind includes The Prairie Cluster LTEM and Fire Effects programs within NPS, the small number of fire effects plots established by the Forest Service in Buffalo Gap NG and Nebraska NF, and Phase 3 of the Forest Service's FIA. These are the most comprehensive and generally share the objective of tracking the overall state of the vegetation as indicated by plant community composition and structure. Specific objectives vary, however, and protocols vary even more so. The Modified-Whittaker plots established at THRO might also belong to this category, but there are no resources dedicated to this monitoring and many of the objectives set for the plots are unlikely to be met with the current design. The second type of monitoring is the range monitoring that the Forest Service and Custer State Park do using both NRCS and Forest Service methodology. These efforts also provide information on plant community composition and structure, but their emphasis is on what that means for cattle and other ungulates. The third type of monitoring, at least potentially, is the mapping of invasive species infestations by the NGP EPMT, individual parks, and at least some Forest Service districts. The final type is that dedicated to species of concern. So far, only the Forest Service has a program dedicated to this, but efforts vary among Forest Service units.

All of these types of monitoring could potentially be used by the I&M program, since they address issues of concern to at least some of the parks. Because specific vital signs have not yet been chosen for the Network, a true assessment of current monitoring efforts with respect to the monitoring goals of the Network cannot be made at this time. Because it was designed for similar purposes as the I&M program, the Prairie Cluster LTEM plant community monitoring has objectives and sampling schemes closest to what the Network will probably eventually shoot for. However, it is the Prairie Cluster program, and therefore its sampling methods, including choice of sampling locations, have so far been limited to prairies. In addition, the protocols may be more than needed in the mixed-grass prairies (M. DeBacker, pers. comm.). Similarly, the Fire Effects monitoring has been limited to areas that have been burned, which in many of the larger parks accounts for a small percentage of the total area. Users of this protocol have expressed some dissatisfaction with the methods they use, as well. The FIA program, on the other hand, collects detailed information only in forests, and the scale of the program is humongous compared to what the I&M program will be dealing with. However, due to the national scope of the FIA program, the Network should seriously consider adopting its methodology, or some subset of it, in order to tap into a broader framework. As far as I can tell, there is no equivalent for grasslands, however. The closest would be the NRCS range evaluation protocols, but these are designed for short-term evaluation, not long-term monitoring.

In their current state, the invasive species mapping efforts are probably not sufficient to provide a statistically analyzable data set to determine the trend of invasive species in most locations or over a landscape. This is because areas are not sampled according to a random or systematic design. Instead, efforts are concentrated in areas where treatment can, will be, or have been applied. Difficulties in defining the borders, densities, etc. of infestations also make the data collected so far not very standardized. Because invasive plants are bound to be an important indicator of ecosystem health, however, these issues must be tackled if this type of monitoring is incorporated into the I&M program.

Finally, preliminary discussions with staff of Network parks indicate that species of concern (rare, sensitive, etc.) are unlikely to be high on the monitoring priority list. However, the Network should consider methods used by the Forest Service, which are relatively fast assessments of population or subpopulation existence, to ensure that these species are not disappearing from or declining in its parks, since other monitoring protocols would be unlikely to be able to detect this.

<u>Objective 3</u>. Provide a detailed review, synthesis and assessment of past, present, and future stressors affecting park vegetation.

All parks in the Network suffer from multiple stressors, both natural and anthropogenic. Table 3 shows a comprehensive list of past, present, and potential future stressors on park vegetation and a tentative evaluation of whether each of those stressors are likely to affect individual park's vegetation currently or in the future. (Therefore, although natural drivers such as fire and grazing undoubtedly affected the vegetation of small parks in the past, these drivers have been eliminated or replaced by park natural resource management.) The list was compiled through consultation with park staff (see Table 5 and Appendix D) and through reference to Prairie Cluster LTEM and Heartland I&M Network documents.

This is a first attempt at an evaluation of whether each natural driver or anthropogenic stressor is likely to affect a park's vegetation. It is based on consultation with park staff and my own "expert" opinion. Refinements will be made through continuing work with the Network technical committee and scientific advisory board. At this stage, a detailed explanation for the evaluation of each stressor for each park is probably overkill, but some notes are warranted:

- Any park with a river was considered potentially affected by erosion and altered hydrology. Also, although the forested parks in the Black Hills do not have rivers, the low water flow in many streams in the area attributed to high tree density around the parks was considered altered hydrology that could have significant effects on the streamside vegetation.
- In almost all parks, whether or not surface and ground water pollution are sufficient to affect the park's *vegetation* is questionable. The fact that surface and ground water pollution could affect other aspects of park ecosystems will be evaluated by other subject matter experts. JECA and MORU are not considered affected by these stressors at all because of the small amount of water at each of these parks.
- The relative importance of the stressors to each park's vegetation (indicated by bold type in Table 3) is based on my personal opinion and priorities of monitoring given by park staff.
- Although climate change is undoubtedly going to affect many aspects of all the parks' vegetation, I thought that the impact it would have on natural disturbance regimes would be relatively small compared to other things (fragmentation, internal management) that affect disturbance regimes. Hence, I did not consider this a stressor likely to affect park vegetation.
- For MNRR and NIOB, I considered actions within their boundaries but outside of their control as "management of adjacent land" instead of internal natural resource management. However, the staff of these parks may have a different opinion as to what is outside of their control than I did.

Although the evaluation of stressors will undoubtedly change somewhat, the major messages of it are unlikely to change. These messages are:

1. Because all rivers in the northern Great Plains are impacted by dams and/or irrigation withdrawals, all parks that have riparian vegetation are affected by altered hydrology. At many parks, this is impact is significant, and therefore it is a major concern.
2. Exotic, invasive plants and park efforts to control them will have major impacts on park

vegetation everywhere.

3. The alteration of fire regimes caused by fragmentation and fire suppression has and will continue to impact park vegetation everywhere, even in the relatively large parks where non-human-lit fires are still possible. The park prescribed fire programs are generally not replicating the fire regimes that shaped the vegetation before European settlement, and are therefore themselves “stressors.”

<u>Objective 4</u>: Conduct a decision-making process that ranks potential floral indicators and identifies those specific indicators that should be monitored.

The first step in achieving this objective is to develop a list of potential indicators of vegetation health and condition. Using information from discussions at individual park scoping meetings, I compiled a preliminary list of potential monitoring projects. In January 2004, I submitted this list to the natural resource staff of each park, asking that they indicate the importance and priority of each monitoring project to their individual park. Appendix D shows this list and the supporting documentation, and Table 4 summarizes the results of the survey. Perhaps because of the wording of the document ("Ecosystem Health" measured as plant community composition and diversity), plant community composition and diversity was the highest priority for vegetation monitoring for ten of the twelve parks that responded.

After completing this exercise, I used the list of stressors in Table 3 and the format of the conceptual model developed by the Heartlands I&M Network for its parks in the Tallgrass Prairie eco-region (Eckhoff *et al.*, 2002) to develop a list of potential floral indicators of ecosystem health for the Northern Great Plains Network. Table 5 is this list. It describes the expected effect of each stressor in Table 3 on vegetation resources and potential indicators for tracking those effects. Although there are 39 stressors, I came up with only 17 potential indicators. Some of these indicators, such as seed production of a rare plant population and specific symptoms on species sensitive to air pollution, are very specific to the stressor. Others are much more general and could be used to track the effects of a wide variety of stressors. Many of the more frequently occurring indicators basically boil down to two indicators: plant community composition, structure, and biomass (or cover), and distribution and diversity of plant community types. Another important indicator may be rare plant population size and distribution.

At this point, it should be noted that these two approaches to choosing indicators are not the same. The potential indicators determined by going through the conceptual ecological model are strictly indicators of ecosystem health. The potential monitoring projects proposed to the parks cover more than ecosystem health (e.g., early warning of new invasive species; assessment of invasive species treatment) and were proposed to get a better feeling for what park staff desire to be incorporated into a long-term vegetation monitoring program. Although the I&M program is specifically charged with devising a monitoring protocol that will track ecosystem health, it must be acknowledged that these other issues are important to at least some parks.

Despite their differences, the two approaches did yield some similarities. Plant community composition and diversity was chosen to represent ecosystem health in the park prioritization exercise because it was chosen to do so by the Prairie Cluster LTEM program, and probably consequently was ranked highly by the parks. Distribution and diversity of plant communities probably should have been on the prioritization exercise, but was not. Rare plant populations were generally ranked somewhere in the middle by parks, perhaps because few of the rare plants in Network parks are globally threatened. Specific monitoring projects dealing with invasive species (mapping, treatment assessment, and early warning) were, on average, second only to plant community composition and diversity. This, combined with the possibility of joining efforts of the I&M and EPMT programs, suggests that monitoring protocols to address these additional aspects of invasive species (additional, because the monitoring of plant community composition and diversity will give a general idea of the proportion of a park's vegetation that is native or exotic) be a high priority even though they do not specifically come out as an indicator of ecosystem health.

<u>Objective 5</u>: Develop monitoring protocols for selected floral indicators that are scientifically defensible and can be implemented within the logistical, fiscal, and administrative constraints of the I&M Program and Network parks.

Based on the information compiled so far, I will propose a monitoring protocol for the highest priority (so far) indicator: plant community composition, structure, and biomass. This proposed protocol is very preliminary and is meant to serve as a "straw dog" – a design that is to be questioned, pulled apart, and reconstructed. After this, I'll simply record some of my thoughts on protocols for the other high priority indicators: plant community distribution and diversity; invasive species mapping, treatment assessment, and early warning; and rare plant populations.

Part A: Plant Community Composition, Structure, and Biomass

Designing a monitoring protocol for this indicator requires answers to the basic questions faced in designing any monitoring protocol. They are:

1. What do you sample?
2. Where do you sample?
3. When do you sample?
4. How frequently do you sample?
5. How many samples do you take?
6. How do you sample?
7. What do you analyze?

The preliminary answers to these questions will be the straw dog.

A major assumption of the design of this protocol is that vegetation sampling efforts will be very coordinated, if not fully integrated, between the Fire Effects program and I&M Network. Thus, the needs of the Fire Effects program have been integrated into the answers to each of the questions below. The degree to which EPMT invasive plant mapping, and potentially treatment effectiveness monitoring, will be coordinated with these other two vegetation sampling programs is yet to be determined. Thus, no effort has been made to incorporate these aspects of the EPMT program into sampling for this first indicator. Indeed, these aspects of invasive plant management are probably served better with very different monitoring protocols that would have to be developed separately. However, as will be discussed in the final section (in answer to question 7), the plant community composition indicator will give important information about how much of the total vegetation of a park is comprised of non-native species.

1. <u>What do you sample?</u>

In order to capture plant community composition (including diversity), structure, and biomass, I propose the following list of items to sample at each sample site:

- Cover of all individual vascular plant species
- Cover of bare ground, litter, rock, lichens, and non-vascular plants
- Canopy cover (in forest)
- Tree, pole, shrub, and seedling density

- Basal area of trees
- Fuel load
- Standing herbaceous biomass: This could be separated into live and dead biomass to get an estimate of above-ground productivity of the season in which it was sampled. I also recommend archiving at least a portion of each sample for potential later analyses on chemical contents. This can be done by grinding dried vegetation to a fine powder, then storing a small portion of the powder in small glass vials in a dry place.
- Appearance: Photographs of each sampling site cannot be used to quantitatively track most changes in vegetation (at least with current technology)

This list is very similar to the data currently collected by the Fire Effects program, and it completely encompasses the data collected by the LTEM program at AGFO and SCBL. It would also probably provide the information needed for determining Fire Regime Condition Class (FRCC), an interagency scheme for describing the degree of departure from natural vegetation, fuels and disturbance regimes in an area (http://www.frcc.gov/). FRCC is used in fire and natural resource management planning by NPS and other agencies. The only item in this list not currently collected by Fire Effects as part of their normal vegetation monitoring is the standing herbaceous biomass, but this data is collected immediately prior to a prescribed burn in order to estimate fuel loads and predict fire behavior. Thus, collecting standing biomass data as part of the normal monitoring protocol will provide this fuel load/fire behavior information in addition to some data on forage availability and productivity. I recommend using cover, as opposed to biomass, of individual species for estimating their abundance because the methods are quicker and may (depending on how cover is estimated) cover a larger area than clipping and sorting biomass by species.

Items considered, but so far rejected, for the list include:

- vegetation height or height-density: This information is collected by range managers in the Forest Service using methodology developed by Benkobi et al. (2000). This type of measurement would be one estimate of plant community structure (in addition to horizontal measurements of bare ground, litter, plant, etc. cover) not captured by any of the other measurements. It did not appear as a floral indicator of ecosystem health in the preliminary conceptual model presented in Table 5, but that model was concerned solely with vegetation. Because this type of measurement is considered an excellent method of determining habitat suitability for certain wildlife species, particularly grassland birds (Herkert *et al.*, 1993), it may be considered important when the conceptual model is broadened to capture other components of the ecosystem. If the Fire Effects method of estimating plant cover is adopted, vegetation height would be captured (see Objective 2, Part A, Fire Effects section, above, and question 6, below), although the methodology is not as well accepted for wildlife habitat evaluation as the Robel pole methodology used by the Forest Service.
- crown condition and canopy structure: This information is gathered by Fire Effects in forest plots and is an indicator of windthrow and tree pathogens. At first cut, I thought the time it would take to compile this information would not be worth the output. The exception might be at KNRI, where pathogen infection of hardwood trees is a major concern.
- ozone damage: This information is collected in Phase 3 of the Forest Service's FIA and

has been brought up repeatedly by park staff as a concern. However, risk of ozone damage to vegetation in the Network parks is considered low (R. Kohut, draft report to T. Maneiro). Also, the probability of an ozone-sensitive species occurring in a plant community composition sampling site is low in many circumstances, particularly in grassland parks. Therefore, if ozone damage is still a concern despite the low risk assessment, a separate sampling protocol would probably have to be developed to achieve adequate sample sizes.

! lichen community composition: Although lichens are not plants, they are often lumped into the vegetation monitoring category so I address them here. This information is also collected in Phase 3 of the Forest Service's FIA protocol as a biodindicator of changes in air quality, climate, and forest structure. However, there is concern that the susceptibility of lichens to other factors, primarily fire, makes them unreliable indicators of ecosystem health. If there is interest in monitoring specific lichen communities (such as those that comprise part of cryptogamic crusts), a separate monitoring protocol, and different expertise, would be needed.

2. Where do you sample?[1]

Where sampling sites are located depends on a major issue not yet addressed by the Network: How much of the emphasis will be put on making inferences across an entire park vs. monitoring plant community composition, etc. in areas of special interest (e.g., riparian zones, specific management units)? The answer to this question will determine how sampling sites are allocated.

The basic framework for a sampling site design is a dense grid of points (spaced 50-150m apart, for example) spread out evenly over the target population. Assuming a park decides that all vegetation in the park is a target, this would be the entire vegetated area of the park. This might not be the entire park area, however. For example, roads in any park or un-vegetated badlands formations at BADL would be excluded. Alternatively, in those parks where the Forest Service does the FIA in their vicinity, the FIA grid could be used as the basic sampling frame.

Using this frame, sample points could be chosen randomly or placed systematically over the entire vegetated area of a park, called level 1 sampling. Although random allocation of sampling sites has been the mantra of sampling for a long time, statisticians are now recommending systematic placement for the type of sampling that would be done in the I&M program. This is because random points tend to be clumped, leaving large portions of an area under- or un-sampled. Also, because nature generally is not systematic (grid-like), systematically placed points are essentially random with respect to the target population. The only exception would be if there were some type of regular pattern on the landscape, such as sand dunes and swales along a lake shore, river terraces that run parallel to a river, or previous land use (plowing). In this case, systematic sampling could still be used, but care must be taken to insure that the sampling grid does not mimic the landscape pattern. Although a systematic

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[1]The discussion in this section is drawn heavily from guidance documents provided by the national I&M office. The documents can be downloaded from the "Sampling Design Considerations: Where and When to Sample" section of the guidance posted at http://science.nature.nps.gov/im/monitor/vsmTG.htm#Introduction.

sample is essentially random with respect to the target, there should be a random component to the placement of the sampling points. Recommendations for achieving this include choosing a compass direction and establishing one set of grid lines on this direction, plus randomly locating actual sample locations within the grid cell chosen by the systematic allocation.

In addition to this overall extensive framework, sampling could be intensified in areas of special interest (e.g., riparian areas or rare habitats), meaning that certain areas are sampled disproportionate to their availability (i.e., level 2 sampling). This is done to achieve adequate sample sizes in these special interest areas, since this would probably not be achieved with the basic framework. There are a variety approaches to this intensified sampling. Stratification is probably the most familiar of these approaches, but there are some drawbacks to this approach, as described by Fancy (2000):

- $ Strata boundaries may change over time (e.g., a pool may become a run after a flood, or vegetation map boundaries change as classification models change or as additional ground-truthing data becomes available).
- $ Stratification can be optimized for only one variable at a time. If multiple measurements are taken at each site, or multiple species are sampled, stratification for one measure may do a very poor job for another measure.
- $ If everyone stratifies separately, collocation of sites is not possible, and correlations over space cannot be easily made or design based.
- $ Sites are often misclassified in the office and must be reclassified into the proper stratum after site visits.
- $ Stratification and misclassification of sites leads to unequally weighted data which must be released to the public and critics who may not understand or properly use the weights when considering the data.

If stratification is used to develop a sampling design for a long-term program, the strata boundaries must be fixed forever. Thus, even though increasing the sample size in smaller vegetation types may be the reason for stratification, un-changing attributes such as terrain, soils, or distance from a river channel should be used to define the strata. Because strata will always be mixtures of vegetation communities, they cannot be used to make estimates for communities. Procedures for domain (subpopulation) estimation should be used instead.

Data collected from the two different sampling levels can be analyzed separately relatively easily. Analysis of combined data is slightly more complicated, but still relatively straight-forward. Complications arise, however, if this two-level sampling design is combined with a complex rotating panel design for determining when (how frequently) each site is sampled.

One other aspect of sampling site location needs to be considered. In some circumstances, adjustments to sampling plans must be made because of difficulty in accessing plots. For example, in large parks with mountainous terrain, it may take days to reach a sampling site. This is generally not an issue in NGP Network parks, although some overnight camping trips may be necessary in the wilderness areas of BADL and THRO. However, individual sample sites may be too steep to be safely sampled (e.g., at JECA or MORU). These sites are simply excluded from the sampling design, but it makes it impossible to make any inferences about the condition of the vegetation that grows in such sites.

To summarize and put this discussion in the context of the plant community composition, structure, and biomass indicator for NGP Network parks, at this point I recommend the approach described above: two-level sampling, where the second level of sampling is assigned using stratification and sampling sites are located systematically from a random start. Whether the FIA grid is used as the basic frame for sampling in the relevant parks will depend on whether this grid is fine-scale enough to accommodate the number of sampling sites that will be in each of these parks.

More discussion regarding the relative amount of emphasis on level 1 vs. level 2 sampling is needed. Only two parks (NIOB and THRO) rated rare plant communities as "very important" in their preliminary evaluation of potential monitoring projects. There may have been some misunderstanding about what was meant by this, however, and I anticipate that many parks will be interested in having adequate sample sizes for tracking trends in smaller vegetation types.

3. <u>When do you sample?</u>

When, in terms of what time in the season, samples are taken for this indicator is relatively straight-forward. I recommend following the example of Fire Effects, in which a plot is sampled once during the growing season from mid-June to early August. Generally, parks in the southern part of the network are sampled first, and sampling efforts move north as the season progresses. This timing is geared at capturing the majority of the diversity of the plant communities, which tends to manifest itself sooner, rather than later, in the climate experienced by Network parks (majority of annual precipitation in spring, summer generally dry). This sampling time may underestimate the biomass of the community, particularly if there is a strong warm-season component. In order to capture the true species diversity of a community and the late-season biomass component, sampling twice during a growing season would be necessary. The reduction in sample size necessary to accommodate this would probably not be worth the information gained. Since biomass production is very sensitive to the precipitation of a given year, it is not a very sensitive indicator of ecosystem health.

Once a sampling time is chosen for each sample site, that time during the growing season must be adhered to throughout the monitoring because the phenological stage of a community can significantly impact its composition.

4. <u>How often do you sample?</u>

The decision on the temporal pattern of sampling sites depends on many factors. First, since the number of sites that can be sampled each year is limited, there is a tradeoff between ability to estimate the status of a parameter (value of that parameter throughout the monitoring period) vs. the ability to estimate trends in that parameter (how it is changing over time) (McDonald, 2003). The less frequently each site is sampled, the more sample sites can be included in the monitoring design. Greater frequency of sampling leads to greater ability to detect a trend. Thus, if detecting trends in a parameter is of the utmost importance, annual sampling would be called for. However, annual sampling can lead to investigator impacts on the parameter of interest, such as trampling. Greater number of samples in the whole design leads to more precise estimation of status. Therefore, if knowing the status of a parameter over the whole time that things are sampled is of utmost importance, a new set of sites would be sampled each year.

Given this tradeoff, there is still an infinite number of ways to sample multiple sites over time. A useful scheme for determining the revisit design of any sampling program is the panel diagram, used in Figure 3. In this scheme, a “panel” is a group of sample sites that are always all sampled during the same sampling occasion (McDonald, 2003). Thus, in Figure 3a, there are two panels, one sampled in even years and one sampled in odd years. The two main components of a revisit design are (1) how many years in a row a site is sampled, and (2) how many years of non-sampling occur between sampling occasions. In Figure 3b, a panel is sampled for two years in a row, then not sampled for three years. This type of revisit design might be used if objectives include understanding interannual variability (from the two years in a row) plus trends over a longer time. Note that this is the current revisit design of the Prairie Cluster LTEM program. Another approach is to use a split-panel design (Figure 3c), in which different parts of the total population are sampled on different revisit schedules. For example, some sites would be sampled every year (which would be excellent for detecting trend), whereas other sites would be sampled only every fifth year (thereby increasing status estimate precision).

Despite the appeal of some of these more elaborate revisit designs, they have some serious drawbacks. First, the logistical coordination of sampling is more difficult the more complicated the revisit design. Second, combining a revisit design with the spatial allocation of samples, particularly when the recommended two-level sampling is used, can be complicated. Finally, procedures for the statistical analysis of data from many of these more complicated designs have not yet been developed.

Given these drawbacks and based on preliminary advice of a statistician (D. Johnson, pers. comm), I recommend a relatively simple revisit design, in which all panels are sampled using the same revisit design and each site is sampled for only one year at a time. This design will not capture interannual variability for individual plots (which can be substantial in the grasslands common in Network parks due to variation in precipitation) as well as an annual revisit. However, because one of the main goals of the I&M program is to detect trends in the parameters it measures, and because of the desire to combine efforts with the Fire Effects program, the return interval between sampling occasions should be relatively short. Specifically, a preliminary discussion on how Fire Effects could work with I&M and still meet the needs of that program produced the following guidelines (C. Wienk, pers. comm.):

! Fuel load data must be collected no more than two years prior to a prescribed burn and must be collected immediately (within 1 year) after a burn.

! Other data (as described in Objective 2, Part A above) must be collected no more than two years prior to burn and no more than two years after a burn.

Given these guidelines, and assuming that immediate post-burn sampling of fuel load would be outside of the normal revisit pattern, the only revisit design outside of annual sampling that would work would be sampling a panel every other year. By increasing the return interval to every three years, 50% more sample sites could be included in the design, but problems would occur when a prescribed burn is done in the same year as the sampling: depending on the season of the burn, either pre- or post-burn data would be too far from the burn (Figure 3d). These problems could be overcome either by the Fire Effects program's accepting information further from a prescribed burn or by the fire program's coordinating its burns around the sample design. Because a relatively small portion of a park is burned each year, the latter seems to be a reasonable solution. Thus, for the straw dog's sake, I recommend a one-year on, two-years off, revisit design as illustrated in Figure 3d.

5. <u>How many samples do you take?</u>

The answer to this question depends entirely on the resources available for monitoring this indicator, and this, of course, will depend on the relative importance of this indicator compared to others. However, some back-of-the-envelope calculations were done to get some ballpark figures as to how many sites could be sampled each year. These calculations assume:

! The Network will contribute $250,000/year to vegetation monitoring.

! All funding that Fire Effects currently uses for sampling its plots is contributed to the combined vegetation monitoring.

! With these funds, a vegetation field crew consisting of 12 people is available annually.

! Vegetation monitoring consists entirely of monitoring this plant community composition, structure, and biomass indicator.

! Sampling one site with the I&M protocol will take the same amount of time to sample one Fire Effects plot.

Based on these assumptions [which are probably unrealistic (the fourth being the most so)] and the three-year revisit design recommended above, 759 sampling sites would be available to allocate among the Network parks. How to allocate them among parks depends on too many undecided things to make any recommendations at this point. One thing is certain, however. Allocating the number of plots to a park based on its area as a percentage of the area owned by Network parks will not work. If this were done, only the three largest land-owning parks (BADL, THRO, and WICA) would have enough sampling sites to make any inferences about status or trends (Table 6). In addition to making the assumptions above more realistic, the number of burn units, and the frequency at which they will be burned, in each park will factor into deciding how many sites will be located in each park.

6. <u>How do you sample?</u>

This question is basically asking what methods will be used to estimate the parameters suggested in the answer to question 1. For some of these parameters, there are fairly standard methods for collecting the relevant data. These include:

! canopy cover (in forest): spherical densiometer (Lemmon, 1957) or canopy cover tube; number of locations would need to be determined.

! tree, pole, shrub, and seedling density; tree basal area: as done by Fire Effects (Objective 2, Part A, Fire Effects section 4.a.ii.-v.) ; number, size, shape and location of plots would need to be determined; Fire Effects and FIA arrangements are good models to work from or adopt.

! fuel load: Brown's lines as done by Fire Effects (Objective 2, Part A, Fire Effects section 4.a.vi.) ; number, length and location of transects would need to be determined; Fire Effects and FIA arrangements are good models to work from or adopt.

! standing herbaceous biomass: clip herbaceous biomass as close to ground level as possible; oven dry until at constant mass, then weigh; number, size, shape and location of clipping areas would need to be determined; in general, long, narrow clips are better than square or circular clips.

- appearance: Depending on the layout of other sampling methods, photographs could be taken as by Fire Effects.

There is no standard or preferred method for estimating cover of individual species, bare ground, etc. In addition to determining the number, size, shape, and layout of plots or transects, the method for actually estimating cover needs to be decided. Unfortunately, the two monitoring programs currently in place in Network parks use two entirely different methods. Fire Effects uses point-intercepts along a transect, whereas LTEM uses a visual estimate in plots. Both of these methods have advantages and disadvantages. The point-intercept method is firmly grounded in sampling theory and is relatively repeatable by different observers, but (1) it samples only a very small portion of the vegetation at any one site (and therefore is generally useful only for estimating cover of the most common species); (2) it is highly susceptible to wind blowing the vegetation; and (3) it is difficult to have truly permanent sample units because the dimensionless sample unit (point) is very easy to move (Elzinga *et al.*, 1998). The visual estimate method samples a larger portion of the vegetation and is generally faster, but estimates can vary considerably among observers, especially when large plots are used. However, there are training procedures that can successfully reduce differences among observers.

The variations on the theme of these two general methods are nearly infinite. Consequently, devising a whole new sampling design is not recommended. Instead, I recommend field work to compare the efficacy of a limited number of currently existing sampling protocols for meeting the objectives of the monitoring program. For reasons of continuity, the Fire Effects and LTEM methods should clearly be two of these methods. Other possibilities, based on their use in other monitoring or research programs in and around Network parks are:

- Forest Service FIA Phase 2 and Phase 3 (which has specific methodology for almost all the suggested parameters, not just cover)
- NRCS double sampling (ocular and clipping) range evaluation method
- Modified Whittaker plots
- small (20cm x 50cm or 1m^2) plots along transects in which cover is visually estimated (this is more common than the large plots currently used by LTEM).

These methods should be tried in the four major vegetation categories that occur in Network parks:

- native grassland[1]
- badlands sparse vegetation
- conifer forest/woodland
- riparian hardwood forest/woody draw

The efficacy of meeting the objectives of the monitoring program should be judged by (Elzinga *et al.*, 1998; Coulloudon *et al.*, 1999):

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[1]Restorations and non-native grasslands are generally less complex and diverse than native grasslands. Therefore, any method that is deemed sufficient in native grasslands would be adequate in these other types.

- the coefficient of variation (CV) of the response variables
  - CV = standard deviation/mean
  - the lower the CV, the better
  - suggested response variables will be discussed in section 7, “What do you analyze?”
- the number of species captured by the sampling method
  - the higher the better
- the amount of person-hours needed to accomplish acceptable CV and species numbers
  - Note that there are no hard and fast rules for determining what is acceptable.
  - When determining how many plots or points within a sample site to use, CV, mean, standard deviation, and species number can be plotted against plot/point number, and an “acceptable” number of plots/points chosen based on where the curve levels off (approaches a constant value).
  - Numbers of plots/points or specific methods that achieve an acceptable CV will probably differ among response variables; therefore, priorities among response variables must be made.

Whatever method is chosen for sampling, I highly recommend that the same method be comprised of nested modules applicable in different vegetation types. For example, the Fire Effects methodology is close to this in that the point-intercept transect for cover is used in grassland, shrubland, and forest; a shrub belt is added to the transect in shrubland, and a plot for tree and fuels data is added in forest plots. This is recommended because the vegetation type of an individual sampling site may change over time, particularly between forest and grassland. The continuity of the data would be compromised if it were necessary to change methods when the vegetation type changed.

7. <u>What do you analyze?</u>

There is a wide variety of specific response variables that can be used to describe and analyze plant community composition status and changes through time. The specific variables analyzed can be chosen at the time of analysis and will depend on what information is needed for natural resource staff to make management decisions, but the types of information available from the parameters suggested in section 1 include:

- cover (and frequency, if visual cover estimates are used) of individual species and classes, e.g., native species, exotic species, and cool-season grasses
- species richness, diversity (H’), and evenness (E) of all species, native species only, or exotic species only
- ratio of exotic to native species cover and richness

Descriptions of plant community structure include:

- cover of bare ground, litter, rock, lichens, and non-vascular plants
- total vascular plant cover
- forest canopy cover
- tree, pole, shrub, and seedling density, and relative amounts of each
- visual appearance from photographs

Descriptions of plant community biomass include:

- fuel load
- tree basal area
- herbaceous standing biomass

Because of high variability in precipitation in this region, and the resulting effects not only on vegetation biomass but also plant community composition, all of these parameters should be evaluated with respect to climate data.

Issues that need to be resolved

As mentioned at the outset, the preliminary suggestions made here for this monitoring protocol are merely that. Numerous issues regarding various aspects of this sampling protocol have already been mentioned. Others that also need to be considered include:

- At this time, the assumption is that monitoring of this indicator will *not* be done at MNRR and NIOB. This is because almost all of the property within the boundaries of these parks is outside of the control of NPS. Because access to all the property within these boundaries is not guaranteed, this makes it difficult to distribute sample sites so that the entire park is truly represented. However, this type of monitoring may be exactly what is needed for NPS to ensure that land-management agreements (e.g., conservation easements) with land-owners within and surrounding park boundaries are adhered to. Also, much of the land within NIOB falls within TNC's Niobrara Valley Preserve, which is under very stable management. Although sampling sites within this preserve would not be representative of the park as a whole, the rare plant communities within these boundaries may warrant some kind of quantitative monitoring. Finally, if either of these parks instigates a prescribed burning program (as NIOB is currently planning), Fire Effects monitoring may be required.
- If MNRR and NIOB are field sampled, and aquatic vegetation (actually in the river) is chosen as an indicator, different methods would have to be used for sampling. One possibility is the protocol used by the USGS Long Term Resource Monitoring Program in the Illinois and Upper Mississippi River basins (Yin *et al.*, 2000).
- Will the proposed systematic sampling layout meet Fire Effects needs? In other words, can these programs be fully integrated so that there are adequate samples in each burn unit?
- Can those sample sites already established by Fire Effects and LTEM continue to be used in the new monitoring program? Although this would be optimal, the different criteria used to establish those sites from what may be used for the I&M program make this difficult. One option for Fire Effects plots could be to phase out established plots as a new burn cycle begins. If it is decided *not* to continue using the same sites and protocols as LTEM does currently, an effort should be made to overlap methods for a few sampling periods in order to integrate the data already collected by LTEM.

Part B. Thoughts on protocols for other indicators

Due to the early stages of design of the NGPN monitoring plan, it is not currently worth while to come up with monitoring protocols for other vegetation indicators. However, in the process of compiling the information for this report, I have had various thoughts about other aspects of monitoring that may be useful for determining priorities and protocols. I have every intention of remaining an active player in the design of the vegetation component of the monitoring plan, so these thoughts are mostly recorded for the sake of articulating them while all the information in this report is fresh in my mind.

Plant Community Distribution and Diversity

Changes in the distribution and diversity of plant communities, a.k.a. vegetation types, can be gradual and subtle (e.g., grasslands becoming more homogeneous as historic grazing-induced vegetation differences fade after removal of domestic livestock) or sudden and dramatic (an intense wildfire turning a uniform, closed-canopy pine forest into a mosaic of grassland, woodland, savanna, and forest). Such changes can be captured to some degree by the on-the-ground sampling suggested for the plant community composition, structure, and biomass indicator. However, this type of sampling would not adequately describe the status and change of the overall landscape structure and composition defined by the patch size, shape, and distribution of different vegetation types. Consequently, this indicator is measured on a much larger scale than the plant community composition, structure, and biomass indicator, and would best be done by some kind of remote imagery.

The USGS/NPS vegetation mapping program and the protocols developed to implement it are the standard to work from for this type of monitoring. A repetition of the vegetation mapping effort in each park, with one modification, at a designated time interval, would be a reasonable protocol for this indicator. The designated time interval could be rather long, such as 10-20 years, since this would be a major effort and many changes on this scale are expected to be quite gradual (though there are many exceptions to this expectation). The modification to the vegetation mapping effort already done in most Network parks is that sites used for ground-truthing maps created based on remote imagery would not be chosen to be “representative” of each vegetation type. Instead, the ground-truthing sites would be the sample sites used for monitoring plant community composition, structure, and biomass, with additional samples as necessary. Ideally, the ground-truthing sites of the original vegetation mapping effort would have been allocated similarly to as has been suggested for the first indicator, but this was not done in Network parks.

Invasive Species Mapping, Treatment Assessment, and Early Warning

The data collected for the plant community composition indicator would provide an indicator of the *general* extent, density, and overall success of treatment efforts of invasive plant species. However, they would neither describe boundaries, densities, or treatment effects of specific infestations nor capture the appearance of small infestations. This type of information is not necessarily an indicator of ecosystem health, but it is the type of information that park natural resource managers and the EPMT are particularly interested in. Whether these more specific invasive species monitoring tasks are taken on by the I&M program depends on the direction that EPMTs take and whether an EPMT will always serve the parks in the Network. Discussions regarding the interface and coordination of the EPMT and I&M programs are currently taking place. Ideally, the EPMT could continue to concentrate its efforts on treating invasive species, but funding from the EPMT program would be contributed to the I&M Network to take on invasive species monitoring tasks. This would be an efficient use of funds because of the different expertise needed by the two different efforts.

Regardless of the outcome of those discussions, I see a potential role for the I&M program as coordinator of a volunteer effort for detecting new infestations of exotic, potentially invasive species. Efforts of volunteers could be concentrated in areas where new infestations are likely to take place, such as construction sites, trails, campsites, parking lots, borders with infested areas, and riparian corridors. This volunteer effort would be particularly useful in small parks with limited natural resource staff and activities. In the larger parks, volunteer efforts might not add much to work done by park staff.

Rare Plant Population Density and Distribution

Park and Network staff need to discuss the importance of individual species as indicators of ecosystem health and how important species considered rare by states (or the Forest Service) are to each park. Not all states list the reason for a taxon[1] being rare, but for those that do, the vast majority of the rare taxa that occur in Network parks are on a state list because they are at the edge of their range. For these taxa, there are two ways the argument for their being indicators of ecosystem health could go. Taxa at the edge of their range tend to be rare because environmental conditions are sub-optimal for the taxon and/or there has been insufficient time for dispersal past that range. Thus, on the one hand, these populations may be more sensitive to, and therefore a better indicator of, changes in the environment (and possibly ecosystem health) than the more common species that are presumably not at the edge of their range. On the other hand, if these rare taxa have small populations, they are very susceptible to stochastic events (late hard freeze, drought, severe fire) that do not necessarily indicate a change in ecosystem health. Which of these arguments is appropriate will probably depend on the taxon. For example, those rare plants in the relict communities at NIOB could be excellent indicators of global warming. In contrast, I would guess that the population of whorled milkweed at DETO is rare (in Wyoming) because a small portion of the Black Hills (and their associated climate) extends across a state line.

Of the 55 rare taxa that occur or might occur in Network Parks, only 11 are not ranked as globally secure (Appendix E). Some of these (e.g., sidesaddle bladderpod at BADL and slender false foxglove at FOLA) are on a state list because they reach the edge of their range in that state, but are still at some peril throughout their range. Others, however are endemic to a region (e.g., Barr's milkvetch and Dakota buckwheat at BADL) or tend to be rare throughout their range (e.g., smooth goosefoot at AGFO and THRO). Despite their slightly to greatly more imperiled state than the peripheral species, the same debate about the usefulness of these species as indicators of ecosystem health can be argued.

Given the limited resources of the Network, I recommend that the most serious consideration for monitoring rare taxa be given to those for which there is strong information about what causes their rarity in each location (e.g., specific soil conditions, temperature regimes, or pollinators). This information is necessary to determine how indicative of overall ecosystem health these taxa are. This recommendation is clearly based on the assumption that all monitoring done as part of the I&M program will be for the purpose of tracking ecosystem

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[1]I use "taxon" here instead of species because many of the listed rare plants are subspecies or varieties.

health. Some argument could be made, however, that monitoring these rare taxa is necessary simply for their own sake – making sure that they don't disappear from a park.

If some of these taxa are chosen to be monitored, whether as indicators of ecosystem health or for their own sake, specific methods will need to be developed for each park. Given the relatively stable status of most of the rare taxa, I do not recommend quantitative sampling of population densities each year, but rather a protocol similar to what the Forest Service uses in the Black Hills for its sensitive species – regular visits to known population locations with qualitative estimates of population size and density.

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Table 1. Terrestrial Plant Communities of the Middle Niobrara River Valley, Nebraska, according to Kantak (1995). Communities were determined by Two-Way Indicator Species Analysis on field data collected in 1983.

Plant Community	Location	Characteristic Species
Sandhill Communities	South side of river	
Prairie	Plains above valley	sand bluestem, prairie sandreed
Upland thicket	slopes between plains and pine forest on bluffs; isolated slopes in plains above valley	shrubs
Blowout	wind-eroded areas of plains above valley	blowout grass
Mixed Prairie		
Upland	dune-mantled alluvial terraces on either side of river	varies
Lowland transitional	low terraces on either side of river	varies; mixture of upland mixed prairie, lowland mesic prairie, and ruderal species
Tallgrass Meadows	floodplain flats and lower terraces	
Transitional	previously hayed/cultivated areas	weedy forbs and grasses
Prairie	undisturbed areas (very rare)	tallgrass prairie species
Wetlands	stream-side locations flooded for at least part of the growing	
Upland Pine Communities	upper canyon slopes on both sides of river and tributary canyons	
Forest	canyon rim and south-facing slopes of river and tributaries	ponderosa pine
Savanna	south side of river, transition to sandhills	ponderosa pine
Juniper Communities	slopes between pine and hardwood communities	
Pine/Juniper	upper middle slopes	ponderosa pine, eastern redcedar
Hardwood/Juniper	lower middle slopes	ponderosa pine, bur oak

Plant Community	Location	Characteristic Species
Hardwood Communities	river floodplain and south wall of valley	
Eastern deciduous	south side of river, lower slopes where water seeps from aquifer	green ash, bur oak, American basswood
Boreal relict	south side of river midway up north-facing slopes where cold springs and seepages keep	paper birch, quaking aspen-big-toothed aspen hybrid
Streambank communities	fringes along banks of river and tributaries, stabilized sand bars	cottonwood, peachleaf willow, sandbar willow

Table 2. Summary of USDA Forest Service Forest Health Monitoring (FHM) indicators, including the parameters measured to assess the indicator, and the Phase in which the parameters are measured. For crown condition, some of the parameters are measured for Phase 2 sampling, but the complete list is measured for Phase 3 sampling.

Indicator	Parameters	Phase
Crown Condition	crown diameter, live crown ratio, crown density, crown dieback, foliage transparency, crown vigor	2, 3
Tree Damage	presence of decay, disease, breakage, discoloration	2
Tree Growth	DBH of saplings and trees	2
Tree Mortality	DBH of trees that have died since last plot visit	2
Tree Regeneration	seedling and sapling counts by species	2
Ozone damage	% of damaged foliage on indicator plant species	3
Lichens	abundance as bioindicator of changes in air quality, climate, forest structure	3
Soils	soil erosion, soil nutrients (carbon storage, N, P, Ca, Mg, K)	3
Vegetation Diversity and Structure	nested plots; number and density by species, height; % groundcover; presence/density of exotic species	3
Down Woody Debris	number and volume of dead tree parts	3
Fuel Loading	% cover and depth of grass, shrubs, slash & litter for fuel models	3
Wildlife Habitat	snags, plot composition and structure	3

Table 3. A comprehensive list of natural drivers and anthropogenic stressors for parks in the Northern Great Plains I&M Network. For each stressor, an "x" in the park's column indicates that this stressor is likely to impact park vegetation. Bold **x**'s are the stressors of highest concern (most likely to affect vegetation) in each park, as assessed so far. This may change with further consultation with more subject matter experts.

Stressor	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA
Natural Drivers													
Succession[1]			x	x	x	x	x	x	x	x		x	x
Disturbance													
drought	x	x	x	x	x	x	x	x	x	x	x	x	x
floods	x		x	x	x		x	x		x	x	x	
wind-throw			x	x	x	x	x	x	x	x	x	x	x
insect/Pathogen outbreaks	x	x	x	x	x	x	x	x	x	x	x	x	x
fire	x	x	x		x	x	x		x		x	x	x
grazing	x	x	x									x	x
other herbivory	x	x	x			x	x	x	x	x		x	x
animal soil disturbance	x	x	x				x				x	x	x
erosion	x	x	x	x	x	x	x	x		x	x	x	x
Anthropogenic Stressors													
Internal, adjacent and regional development													
surface water pollution	?	?	?	?	?		?	?		?	?	?	
ground water pollution	?	?	?	?	?		?	?		?	?	?	
alteration of hydrology	x		**x**	**x**	x	x	**x**	**x**	x	**x**	**x**	**x**	x
disturbed sites	x	x	x	x			x	x	x	**x**	**x**	x	x
Adjacent and regional development													
pesticide drift				x	x						x	x	
air pollution (including CO_2)[2]	x	x	x	x	x	x	x	x	x	x	x	x	x
herbivore composition & abundance[3]	x		x			x	**x**	x	x	x	x	x	x

[1]This is basically woody encroachment into grassland, as well as changes in forest composition and structure due to lack or reduction of natural disturbance (fire, flood).

[2]While all indications suggest that potential for damage from ozone is low in all parks, there is a potential for altered plant community composition due to nitrogen fertilization. More information regarding this is necessary to better assess this risk.

[3]The best example of this is overabundance of deer due to increased habitat and lack of predators.

Stressor	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA
Management of adjacent lands													
timber harvest and forest thinning			x			x			x	x			x
rail/road construction		x				x		x	x	x	x	x	x
recreational use								x		**x**		x	
grazing	x		x			x		x		**x**	x	x	x
agriculture				x	x		x	x		**x**	x		
canal seepage				x							x		
Invasive exotic species													
animals								?[1]	x[2]	?[3]		**x**[4]	
plants	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Fragmentation													
loss of colonization sources			x	**x**	**x**		**x**	x		x	x		
limited genetic exchange among populations			x	x	x		x	x		x	x		
fire suppression	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Internal natural resource management													
prescribed fire	**x**	**x**	**x**	**x**[5]	**x**	**x**	**x**	**x**[5]	**x**	**x**[5]	**x**	**x**	**x**
exotic species control (chemical, mechanical, biological)	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
mechanical woody plant thinning			x	x		**x**	**x**		**x**	x			**x**
stream bank stabilization					x			**x**					
restoration plantings	x	x	x	**x**	**x**		**x**	x	x		**x**	x	x
grazers		**x**		**x**								**x**	**x**
lack of grazers	**x**		x		**x**		x				**x**		
water developments (for grazers)		x										x	x
Visitor use													
trails	x	x	x	x		x	x		x	**x**	x	x	x
camping/campgrounds		x	x					x		x		x	x
pack animals/trails		x							x			x	x
road maintenance		x	x						x		x	x	x
rock climbing			x						x	x			
collection		x											

[1]aquatic invasive animals can significantly affect vegetation within the river

[2]mountain goats

[3]aquatic invasive animals can significantly affect vegetation within the river

[4]wild horses

[5] if/when prescribed fire program begins

Stressor	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA
Paleontological/archaeological digs	x	x					x			x			x
Climate change													
changing temperature regimes	x	x	x	x	x	x	x	x	x	**x**	x	x	x
changing precipitation regimes	x	x	x	x	x	x	x	x	x	**x**	x	x	x
changing natural disturbance regimes													

Table 4a. Preliminary park staff evaluation of importance of proposed monitoring projects to their park. The importance scale is as follows: 0 = not important at all, 1 = minimally important, 2 = somewhat important, 3 = important, 4 = very important.

Potential Plant Monitoring Project	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA	mean
Ecosystem Health/Fire Effects (plant community composition and diversity)	4	4	4	4	4	4	4	4	4	4	4	4	4	4.0
Invasive species early warning	0	4	4	3	4	4	2	4	4	4	4	4	3	3.4
Invasive species treatment assessment	0	4	3	4	4	4	2	4	4	3	4	4	3	3.4
Grazing effects (exclosures)	0	2	0	2	0	0	2	1	0	3	0	3	3	1.2
Air pollution effects	0	3	4	2	1	3	3	2	3	2	3	3	4	2.5
Rare plant communities	0	3	2	3	3	3	0	3	2.5	4	3	4	3	2.6
Restoration assessment	1	3	3	4	4	2	4	4	3	2	4	3	3	3.1
Effects of complete absence of fire	0	3	0	3	0	0	2	3	4	4	2	3	0	1.8
Invasive species mapping	1	3	4	4	3	4	3	4	4	4	4	4	4	3.5
Browse rates/Deer effects	2	1	1	2	0	2	3	2	2.5	2	1	3	3	1.9
Riparian tree recruitment	0	1	4	1	2	0	4	4	2	4	0	3	4	2.4
Rock-climbing impact	0	0	4	0	0	0	0	0	3	2	0	0	0	0.5
Canal seepage effects	0	0	0	3	0	0	0	0	2	0	1	0	0	0.5
Pathogens/pests on plants	0	2	2	1	2	0	4	2	4	1	0	2	2	1.7
Woody encroachment into prairie	0	2	4	2	2	0	1	2	0	3	1	1	4	1.7
Rare plant population(s)	0	3	1	3	2	3	0	3	3	4	4	3	2	2.4
Flood regime change effects								4						
Woody increase in forest understory								4						
Mean	0.6	2.4	2.5	2.6	2.0	1.8	2.1	2.8	2.8	2.9	2.2	2.8	2.6	

Table 4b. Preliminary park staff ranking of proposed monitoring projects to their park, where 1 is the most important.

Potential Plant Monitoring Project	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA	mean
Ecosystem Health/Fire Effects (plant community composition and diversity)	1	1	1	1	1	3	1	1	1	3	1	1	1	1.3
Invasive species early warning		2	2	8	3	4	9	7.5	3	5	4	5	3	4.6
Invasive species treatment assessment		3	3	3	4	1	10	7.5	2	7	3	4	3	4.2
Grazing effects (exclosures)		10		13			11	16		11		8	3	10.3
Air pollution effects		7	5	11		7	7	13	12	13		6	2	8.3
Rare plant communities		6	11	6	6	5		10	6	1	6	3	4	5.8
Restoration assessment		4	9	2	2	9	2	5.5	4	12	5	12	3	5.8
Effects of complete absence of fire		8	14	7			8	9	13	8		9		9.5
Invasive species mapping		9	7	4	5	2	5	4	8	6	2	2	3	4.8
Browse rates/Deer effects	2	14	12	15		8	6	15	11	15		10	3	10.1
Riparian tree recruitment		13	4	10	7		4	3	10	9		7	4	7.1
Rock-climbing impact			8	17					6	10				10.2
Canal seepage effects				9					9					9.0
Pathogens/pests on plants		12	10	16			3	14	5	14		13	4	10.1
Woody encroachment into prairie		11	6	12			11	12		4	7	14	2	8.8
Rare plant population(s)		5	13	5		6		11	7	2	8	11	3	7.1
Flood regime change effects								2						
Woody increase in forest understory								5.5						

Table 5. Potential floral indicators of ecosystem health for parks in the Northern Great Plains I&M Network, given the stressors listed in Table 3. This table is based on the conceptual model developed by the Heartlands I&M Network for its parks in the Tallgrass Prairie eco-region (Eckhoff *et al.*, 2002) (http://www1.nature.nps.gov/im/units/htln/pdf/HTLN.2002.PhaseIMonitoring.pdf).

STRESSOR	RESOURCE	EFFECT	INDICATOR
		Natural Drivers	
Succession	herbaceous forest understory forest composition & structure grasslands	changes in composition change in forest type increased woody component	plant community composition; distribution of community types; beta diversity
Disturbance			
drought	plant communities	mortality of woody species; reduced, patchy vegetative cover; reduced seed production; shifts in species composition	plant community biomass and composition
flood	riparian plant communities	recruitment of phreatophytes; change in vegetation type	phreatophyte regeneration; plant community composition
wind-throw	forest composition & structure	deformation and mortality of woody species; change in forest type; change in understory composition	forest structure and composition
insect/pathogen outbreaks	plant communities	deformation and mortality of individual species; reduced vegetative cover	crown condition in forest; plant community biomass and composition
fire	plant communities	prevention of woody species establishment; temporary decreased productivity (mixed-grass prairie); increased landscape heterogeneity when fire regime variable; interacts with grazing	plant community composition; distribution of plant community types; beta diversity
grazing	plant communities	reduced, patchy vegetative cover; increased landscape heterogeneity and species diversity when grazing regime variable and sufficiently light; interacts with fire	plant community biomass and composition; distribution of community types; beta diversity
other herbivory	plant communities	changes in structure and composition	plant community biomass and composition; browse rates; prairie dog colony size
animal soil disturbance	plant communities	increased habitat for ruderal species; altered nutrient availability	plant community composition and cover

STRESSOR	RESOURCE	EFFECT	INDICATOR
erosion	plant communities in erodable zones rare plant species	altered size and distribution of habitat altered size and distribution of habitat	distribution of plant community types size and distribution of populations
		Anthropogenic Stressors	
Internal, adjacent and regional development			
surface water pollution	riparian/temporary pond vegetation	shifts in community composition and productivity (from fertilization); decreased vigor or mortality (from toxicity)	plant community composition and biomass
ground water pollution	riparian tree species	decreased vigor, lack of recruitment	phreatophyte regeneration
alteration of hydrology	riparian plant communities	shifts in community composition and productivity; lack of phreatophyte recruitment	plant community composition and biomass; phreatophyte regeneration
disturbed sites	plant communities	increased ruderal plant component	plant community composition
Adjacent and regional development			
pesticide drift	plant communities pollinators	decreased vigor or mortality reduced seed production	plant biomass or cover seed production
air pollution	sensitive species plant communities	toxicity shifts in community composition; increased productivity (from fertilization)	specific symptoms on sensitive species plant community biomass and composition
herbivore composition & abundance	woodland plant communities	altered community composition and understory structure	understory plant community composition and structure
Management of adjacent lands			
timber harvest & forest thinning	plant communities	shift in fire regime; exotic species source	plant community composition; distribution of plant community types
rail/road construction	plant communities	exotic species source	plant community composition
recreational use	plant communities	exotic species source	plant community composition
grazing	plant communities	exotic species source	plant community composition
agriculture	plant communities	exotic species source	plant community composition
canal seepage	plant communities	increased habitat for wet/mesic species and communities	plant community composition; distribution of plant community types
Invasive exotic species			
animals	plant communities	shifts in community composition and biomass	plant community composition and biomass

STRESSOR	RESOURCE	EFFECT	INDICATOR
plants	plant communities rare species	displacement of native species; alteration of community composition, structure and diversity	plant community composition and structure; rare species population size and distribution
Fragmentation			
loss of colonization sources	plant communities rare species	loss of diversity as populations lost to stochastic events are not replaced	plant community composition; rare species population size and distribution
limited genetic exchange	rare species	reduced reproduction due to lack of pollen and/or inbreeding effects	rare species population size, distribution and genetic diversity
fire suppression	plant communities	succession	plant community composition; distribution of plant community types; woody species composition and age distribution
Internal natural resource management			
prescribed fire	plant communities	prevention of woody species establishment; temporary decreased productivity (mixed-grass prairie); increased landscape heterogeneity when fire regime variable; interacts with grazing	plant community composition; distribution of plant community types; beta diversity
exotic species control (chemical, mechanical, biological)	target species	population density and distribution reduction or elimination	target species population density and distribution
	non-target species in infestations	population density changes	non-target (including rare) species population density in treated areas
	plant communities	return to pre-invasion conditions (hopefully)	plant community composition, diversity and structure
mechanical woody plant thinning	forest communities	lower intensity fires leading to maintenance of woodland/forest communities	forest/woodland plant community composition and structure; fuel load structure and distribution
stream bank stabilization	riparian plant communities	plant communities static or succeeding	distribution of community types; plant community composition
restoration plantings	restored plant communities and landscapes	increased diversity and abundance of natives; decreased abundance of non-natives	plant community composition and diversity approaching that of reference/desired condition

STRESSOR	RESOURCE	EFFECT	INDICATOR
grazers	grassland plant communities	increased landscape heterogeneity; decreased plant cover and biomass in grazed areas; decrease in palatable species; increase in grazing-tolerators	plant community composition, diversity and structure; distribution of plant community types; beta-diversity
lack thereof	grassland plant communities	decreased landscape heterogeneity; increase in grazing sensitive/intolerant species	
water developments for grazers	grassland plant communities	concentrated areas of low or no vegetation cover; ruderal species habitat increased	plant community composition and cover
Visitor use			
trails; camping/camp-grounds; pack animals; road maintenance; rock climbing	plant communities	corridors of exotic and ruderal species spread; soil compaction and erosion	plant community composition
	unique habitats	fragmentation of remnant communities	
plant collection	edible species	decrease in collected species	population size and distribution of target species
Paleontological/archaeological digs	plant communities	temporary elimination of plant community	plant community composition in disturbed areas
Climate change			
changing temperature and precipitation regimes	plant communities	shift in composition	plant community composition
	rare species	shift in population size and distribution	population size and distribution

Table 6. Crude estimate of sample sites that would be allocated to each Network Park based on park-owned acreage alone. Total acres and NPS-owned acres are approximations from various sources, since no two sources I consulted agreed for most parks.

Park	Total acres	NPS-owned acres	% of Network area	# of sites based on area
AGFO	3,055	2,270	1.06	8
BADL	244,300	100,000	46.63	354
DETO	1,360	1,360	0.63	5
FOLA	833	831	0.39	3
FOUS	450	410	0.19	1
JECA	1,355	1,355	0.63	5
KNRI	1,758	1,600	0.75	6
MNRR	33,389	250	0.12	1
MORU	1,238	1,200	0.56	4
NIOB	21,035	0	0.00	0
SCBL	3,003	2,930	1.37	10
THRO	70,446	69,250	32.29	245
WICA	28,295	33,000	15.39	117
Total		214,456		759

Figure 1. Prairie Cluster LTEM plot layout within a study site.

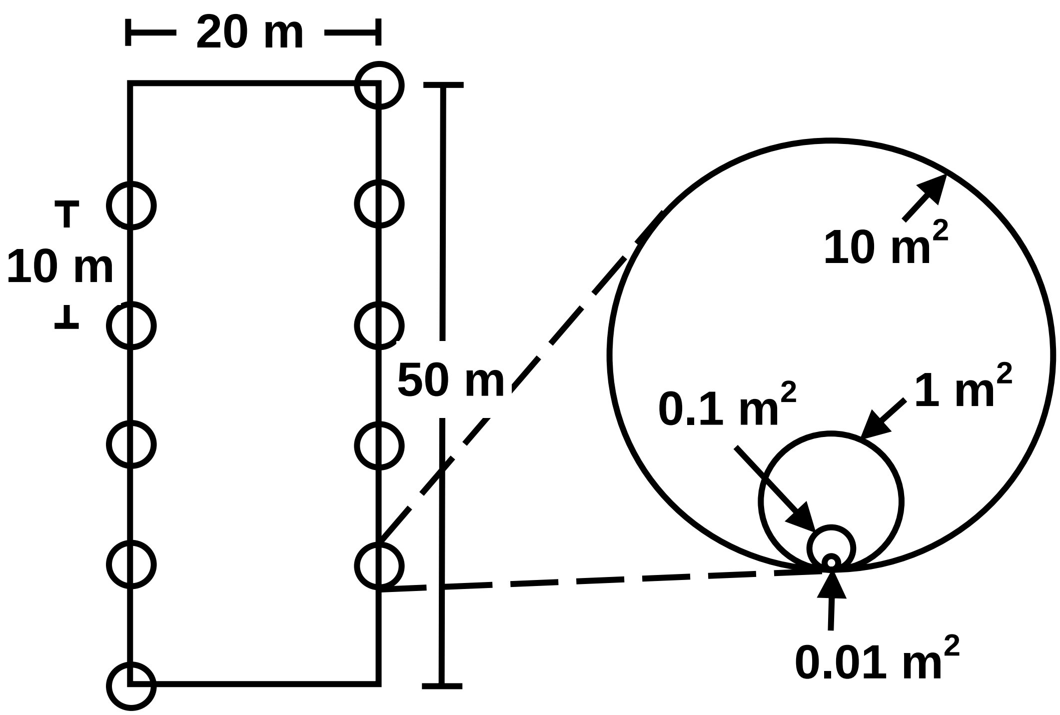

Figure 2. Diagram of USDA Forest Service Forest Inventory and Analysis (FIA) Phase 2/Phase 3 plot design. A fuller description of the data collected in each plot type is in Table 2. From http://fia.fs.fed.us/library/FIA_Demo_Plot_Handout.doc.

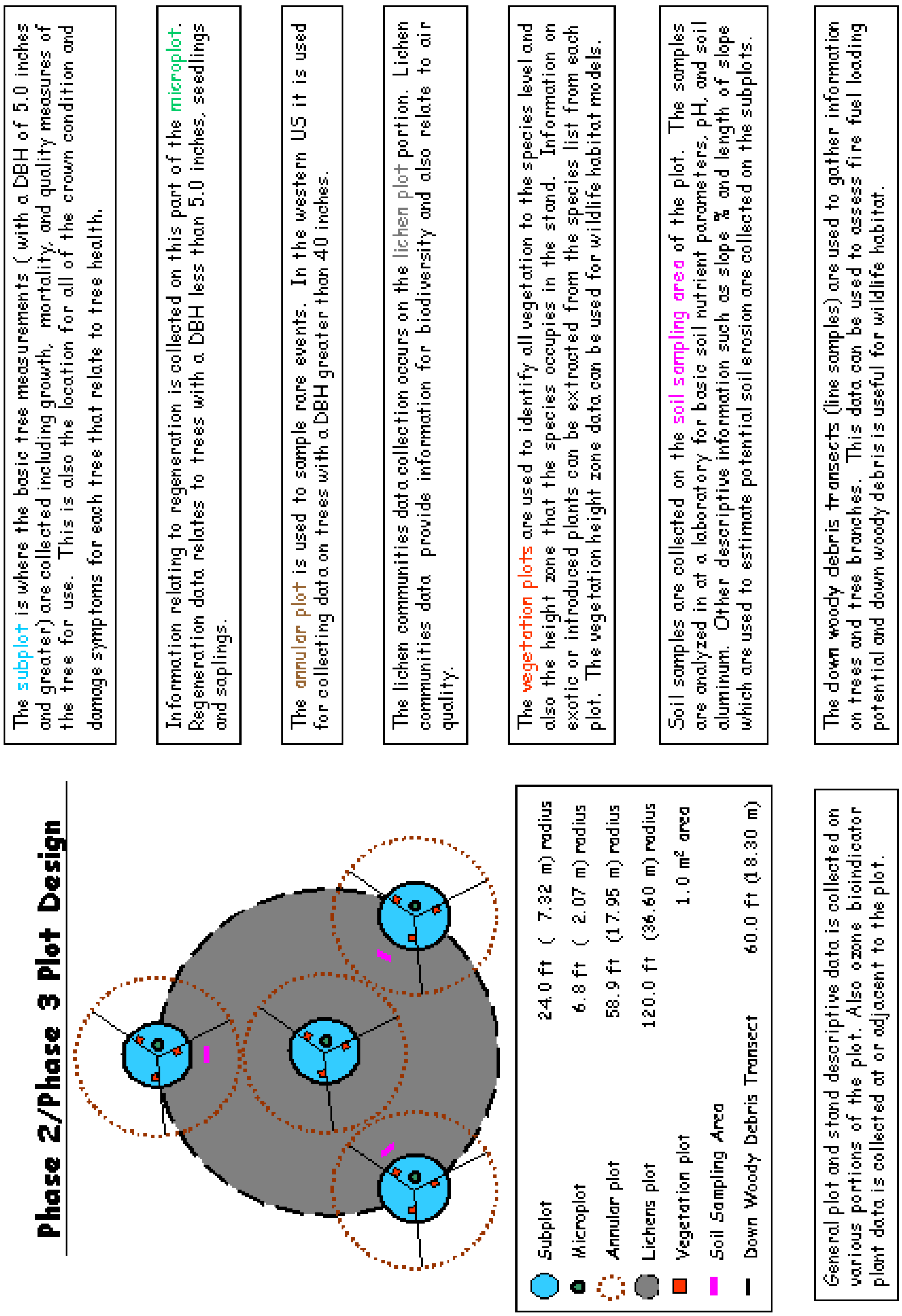

Figure 3. Revisit designs for sampling sites through time. X delineates a year in which all sites within a panel are sampled. In part d, B indicates a prescribed burn, where BX indicates a spring burn and XB indicates a fall burn. Two rows for each panel in (d) are shown to illustrate that not all sample sites within a panel would necessarily burn in the same year.

(a) Two-panel design: one on, one off revisit schedule

	Year							
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
A	X		X		X		X	
B		X		X		X		X

(b) Five-panel design: two on, three off revisit schedule

	Year							
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
A	X	X				X	X	
B		X	X				X	X
C			X	X				X
D				X	X			
E	X				X	X		

(c) Split-panel design: panel A sampled annually; panels B-F one on, four off revisit schedule

	Year									
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A	X	X	X	X	X	X	X	X	X	X
B	X					X				
C		X					X			
D			X					X		
E				X					X	
F					X					X

(d) Three-panel design: one on, two off revisit schedule

	Year							
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
A	XB			X		B	X	
A	X		B	X			X	B
B		BX			X		B	X
B		X		B	X			X
C	B		X			BX		
C			X		B	X		

List of Appendices

A. Vegetation types mapped in each park
B. Description of Natural Heritage status rankings
C. Scientific names for common names used in text
D. Memo sent to parks for ranking and prioritizing suggested monitoring projects
E. State-listed rare species or species of concern occurring in Network parks
F. Contact information for individuals providing information through personal communication