



Plant Community Composition and Structure Monitoring Protocol for the Northern Great Plains I&M Network

Version 1.01

Natural Resource Report NPS/NGPN/NRR—2012/489



ON THE COVER

Photographs clockwise from top left:

1. Badlands at Theodore Roosevelt National Park, ND, July 2009
2. Deer exclosure at Devils Tower National Monument, June 2009
3. Post Rushmore 1 fire at Mount Rushmore National Memorial, SD, March 2006
4. American bison at Badlands National Park, June 2005
5. Riparian lowland at Fort Laramie National Historic Site, WY,
6. Spiderwort at Badlands National Park, SD, June 2009
7. (Center) Agate Fossil Beds National Monument, June 2003

Photographs 1-3, 5-7 by Amy Symstad

Photograph 4 by C. Jason Tinant

Plant Community Composition and Structure Monitoring Protocol for the Northern Great Plains I&M Network

Version 1.01

Natural Resource Report NPS/NGPN/NRR—2012/489

Amy J. Symstad¹
Robert A. Gitzen^{2,3}
Cody L. Wienk⁴
Michael R. Bynum³
Daniel J. Swanson⁵
Andy D. Thorstenson⁵
Kara J. Paintner-Green³

¹Northern Prairie Wildlife Research Center, U.S. Geological Survey
Wind Cave National Park, 26611 U.S. Hwy 385
Hot Springs, SD 57747

²Department of Fisheries and Wildlife Sciences, University of Missouri
302 Natural Resources building
Columbia, MO 65211

³Northern Great Plains Network, Inventory and Monitoring Program
National Park Service
231 East Saint Joseph Street
Rapid City, SD 57701

⁴Midwest Regional Office, National Park Service
601 Riverfront Drive
Omaha, NE 68102

⁵Northern Great Plains Fire Ecology Program, National Park Service
Wind Cave National Park, 26611 U.S. Hwy 385
Hot Springs, SD 57747

February 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal, high-level peer review based on the importance of its content. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Natural Resource Publications Management Web site (<http://www.nature.nps.gov/publications/nrpm/>) on the Internet.

Please cite this publication as:

Symstad, A. J., R. A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner-Green. 2012. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network: Version 1.01. Natural Resource Report NPS/NRPC/NRR—2012/489. National Park Service, Fort Collins, Colorado.

Revision History

Version numbers will be incremented by a whole number (e.g., 1.12 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Prev. Version	Revision Date	Revised by	Changes Made	Reasons for Change	New Version
1.00	Fall 2011	NGPN	Editorial, SOP revisions, new sample frame for FOUS. Separated SOPs from main narrative	Revisions based on the first field season and to better match sample frame of FOUS to vegetation management plan	1.01

Contents

	Page
Figures.....	ix
Tables.....	xi
Appendices.....	xiii
Acknowledgements.....	xv
1. Background and Objectives	1
1.1 The Northern Great Plains Inventory and Monitoring Network	1
1.2 Rationale for Monitoring Plant Community Composition and Structure.....	2
1.3 Goal of the Protocol.....	5
1.4 Historical Development of Plant Community Monitoring in Northern Great Plains Network Parks.....	5
1.4.1 <i>Prairie Cluster Prototype Monitoring Program (PCP)</i>	6
1.4.2 <i>Northern Great Plains Fire Ecology/Fire Effects Monitoring Program (NGP FireEP)</i>	10
1.4.3 <i>NGPN Monitoring in the Context of PCP and NGP FireEP Legacies</i>	10
1.4.4 <i>Measurable Objectives</i>	11
2. Sampling and Response Design.....	13
2.1 Response Design.....	13
2.2 Spatial Design.....	14
2.2.1 <i>Overview of Spatial Design</i>	14
2.2.2 <i>Defining the Sample Frame</i>	17
2.2.3 <i>Unequal Sampling within the Sample frame</i>	18
2.2.4 <i>Locating Sample Sites</i>	20
2.3 Temporal Design	21
2.3.1 <i>Revisit Design</i>	21

Contents (continued)

	Page
2.3.2 <i>Visit Schedule within Years</i>	24
2.4 Allocating Sample Sites.....	25
2.5 Rationale for choosing this design.....	26
2.5.1 <i>Rationale for Response Design</i>	26
2.5.2 <i>Statistical Power to Describe Status and Detect Trends</i>	28
3. Field Methods	31
3.1 Field Season Preparations and Training	31
3.2 Conducting Monitoring	31
3.2.1 <i>Intensive Plots</i>	34
3.2.2 <i>Extensive Woody Plots</i>	35
3.2.3 <i>All Plots</i>	36
3.3 End of Season Procedures	36
4. Data Management, Analysis and Reporting	39
4.1 Data Management.....	39
4.1.1 <i>Overview of Database Design</i>	39
4.1.2 <i>Data Entry, Verification, and Validation</i>	39
4.1.3 <i>Metadata, Data Archiving, and Editing Procedures</i>	40
4.2 Data Analysis and Reporting	41
4.2.1 <i>Annual Summaries and Reports</i>	42
4.2.2 <i>Status and Trends and Comprehensive Synthesis Reports</i>	42
4.2.3 <i>Variance Assessment and Report</i>	44
4.2.4 <i>Report Dissemination</i>	44
5. Personnel Requirements and Training	45

Contents (continued)

	Page
5.1 Roles and Responsibilities	45
5.2 Qualifications	46
5.3 Training Procedures	46
6. Operational Requirements	49
6.1 Annual Workload and Field Schedule	49
6.2 Facility and Equipment Needs	49
6.3 Startup Costs and Budget Considerations.....	49
6.4 Procedures for Revising the Protocol	50
7. Literature Cited	51

Figures

	Page
Figure 1. Parks and ecoregions of the Northern Great Plains Network.....	1
Figure 2. Layout for NGPN plant community composition and structure plots.....	15
Figure 3. Arrangement of nested quadrats along tape used for point-intercept sampling.....	16
Figure 4. [2-3] revisit design for intensive plant community composition and structure monitoring at most NGPN parks.....	22
Figure 5. [2-8] revisit design with [2-3] rollout for intensive plant community composition and structure monitoring at BADL and THRO.....	23
Figure 6. [(1-4) ¹] revisit design for extensive woody plots at appropriate parks.....	24
Figure 7. Comparison of revisit designs.	30
Figure 8. Outline of initial field procedures on the first visit to a potential monitoring plot.	32
Figure 9. Outline of procedures followed at a site after initial evaluation.....	33

Tables

	Page
Table 1. Size and visitation of parks in the Northern Great Plains Network (NGPN).....	2
Table 2. Summary of vegetation monitoring or related work in NGPN parks, 2004-2008.....	7
Table 3. Sample frame, park-specific areas excluded from this sample frame, and stratification of plant community sampling in NGPN parks.	19
Table 4. Within-season sampling plan for intensive plant community composition and structure monitoring in NGPN parks.	25
Table 5. Plot allocation among strata and parks in the NGPN.....	27
Table 6. Summary of sampling scheme for fire fuels.	35
Table 7. Condition categories and codes for standing trees.....	36
Table 8. Attributes to be summarized and reported in annual reports.	43
Table 9. Estimated annual budget for NGPN plant community composition and structure monitoring.....	50

Appendices

	Page
Appendices.....	xiii
Appendix A: Power Analyses for Sampling Design.....	55
Comparison of revisit designs and sample sizes for the herb-layer component of plant community monitoring	56
Calculation of sample sizes necessary to estimate status or detect change in various components of forest structure in Black Hills ponderosa pine (<i>Pinus</i> <i>ponderosa</i>) forest	73
Calculation of sample sizes necessary to estimate status of forest structure in riparian lowlands	81
Appendix B: Sample Frame and Differential Allocation of Sampling Efforts by Park	93
Agate Fossil Beds National Monument (AGFO)	93
Badlands National Park (BADL).....	95
Devils Tower National Monument (DETO).....	97
Fort Laramie National Historic Site (FOLA)	99
Fort Union Trading Post National Historic Site (FOUS)	101
Jewel Cave National Monument (JECA)	103
Knife River Indian Villages National Historic Site (KNRI)	104
Missouri National Recreational River (MNRR).....	106
Mount Rushmore National Memorial (MORU)	106
Niobrara National Scenic River (NIOB)	108
Scotts Bluff National Monument (SCBL)	108
Theodore Roosevelt National Park (THRO)	110
Wind Cave National Park (WICA).....	114
Literature Cited.....	117

Appendices (continued)

	Page
Appendix C: Procedure/R code Used for GRTS Draws	119
Preparation of GIS files	119
Using spsurvey (version 2.0) to draw samples	122
Assigning drawn samples to panels.....	126
Customizing the FOUS Sample Frame.....	126
Literature Cited.....	129
Appendix D: Transition from PCP/HTLN to NGPN at AGFO and SCBL	131

Acknowledgements

Funding for the development of this protocol was provided through the National Park Service Northern Great Plains Inventory and Monitoring Network (NGPN), the NPS Northern Great Plains Fire Ecology/Fire Effects Monitoring Program (NGP FireEP), and the U.S. Geological Survey Northern Prairie Wildlife Research Center. Several standard operating procedures and parts of this protocol were derived from those written by other I&M Networks, especially HTLN, NCPN, and KLMN. We thank those networks who have gone before us and made our path easier. We also thank D. Licht for his early input into the protocol, S. Wilson and J. Brumm for GIS, GPS and data management input, T. Philippi for teaching us GRTS and early review of the protocol, J. Freeman and V. Hofman for input on sampling methodology, and S. Sanders, D. Shorrock, and J. Yeo for reviewing the manuscript. We thank the 2011 NGPN and NGP FireEP seasonal crew for implementing the protocol in 2011 and providing feedback on the methods. We thank I. Ashton, M. Prowatzke, S.K. Wilson, and T. Shepherd for revising the protocol and producing this version.

1. Background and Objectives

1.1 The Northern Great Plains Inventory and Monitoring Network

In 2001, the National Park Service (NPS) established the Inventory and Monitoring (I&M), or “Vital Signs Monitoring”, Program in Service units with significant natural resources. The NPS has organized more than 270 parks into 32 networks that are linked by geography and shared natural resource characteristics. The program of inventory and monitoring focuses on key indicators of ecological change, or “vital signs”, identified for each of the network’s parks.

The thirteen parks in the Northern Great Plains Inventory and Monitoring Network (NGPN) are located in five northern Great Plains states across six ecoregions (Figure 1) and vary widely in size, amount of visitor use, and management context (Table 1). Of particular note are the two river parks (MNRR and NIOB), whose land base is entirely or almost entirely owned by entities other than the NPS. Network-wide land cover is dominated by native grassland, but some small parks are dominated by old fields and recent prairie plantings. Other major land cover types include barren or sparsely vegetated areas (BADL and THRO) and ponderosa pine forests and woodlands in Black Hills parks. Riparian hardwood forests comprise a small portion of the area but have disproportionately large ecological significance because of their value to wildlife species.

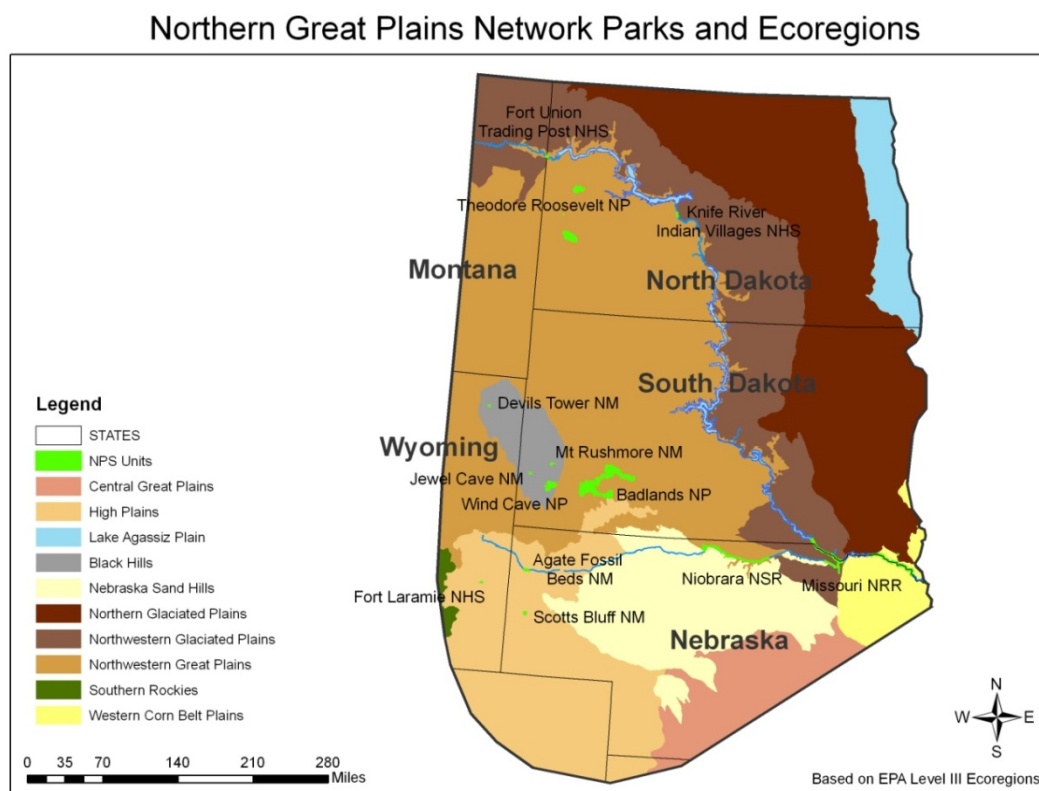


Figure 1. Parks and ecoregions of the Northern Great Plains Network. Based on the U.S. Environmental Protection Agency’s Level III ecoregions classes (Omernik 2007).

Table 1. Size and visitation of parks in the Northern Great Plains Network (NGPN).

Park	Boundary Acres (2008) ^a	NPS Fee Acres (2008) ^a	Visitors ^b
Agate Fossil Beds NM (AGFO) ^c	3,058	2,270	13,991
Badlands NP (BADL)	242,756	110,498	892,987
Devils Tower NM (DETO)	1,347	1,347	353,542
Fort Laramie NHS (FOLA)	833	832	45,252
Fort Union Trading Post NHS (FOUS)	444	307	16,062
Jewel Cave NM (JECA)	1,274	1,274	103,496
Knife River Indian Villages NHS (KNRI)	1,758	1,457	29,510
Missouri NRR (MNRR)	53,775	62	106,358
Mount Rushmore NM (MORU)	1,278	1,238	1,980,393
Niobrara NSR (NIOB)	23,074	0	63,369
Scotts Bluff NM (SCBL)	3,005	2,951	104,381
Theodore Roosevelt NP (THRO)	70,447	69,551	464,934
Wind Cave NP (WICA) ^d	28,295	28,292	600,141
Total	411,728	220,078	4,774,413

^aFrom <http://www.nature.nps.gov/stats/acreagemenu.cfm>, NPS Public Use Statistics Office.

^bAnnual average for 2004-2007. From <http://www.nature.nps.gov/stats/park.cfm>, NPS Public Use Statistics Office.

^cFour-letter codes in parentheses following park names are abbreviations used throughout the rest of this document.

^dWICA acquired an additional 5,555 acres in 2011.

1.2 Rationale for Monitoring Plant Community Composition and Structure

Vegetation is one of the major geographical features of almost all parts of the earth's surface...In major ecosystems, at least, it is an essential component, as it includes the primary production apparatus that fuels the system by capture of solar energy. Practically every terrestrial view that man has of his environment, outside his own constructions, ... is almost sure to be primarily of vegetation. It is the most obvious surface feature of the land. On it depends the existence of all animal life. Most human activities deal in some respect with vegetation or its products. In other words, vegetation is an inescapable fact of life. As such, it is one of the most important of all subjects for investigation and study.

- F.R. Fosberg, Foreword to Mueller-Dombois and Ellenberg's seminal volume, *Aims and Methods of Vegetation Ecology* (1974)

Plant community composition and structure monitoring comprises the core of the vegetation monitoring effort for the NGPN, covering the “Riparian Lowland Plant Communities” and “Upland Plant Communities” vital signs (Gitzen et al. 2010). Knowing the status and trends in plant communities of any terrestrial ecosystem is critical to understanding the status and trends in most other biotic components of that ecosystem. Not only are plants the ultimate source of food for all other organisms, but they also provide other organisms cover from enemies and the elements, structure for basic life-history processes (e.g., nest sites), and substrate on which to grow. Plant communities influence local, regional, and global climate through evapotranspiration, albedo, and greenhouse gas emissions and absorption (Smith et al. 1997). Fire regimes (D'Antonio and Vitousek 1992) and flood behavior (Anderson et al. 2006) are in part mediated by the species that comprise plant communities and the structure that they create. Plants are the major source of organic inputs into soil and aquatic systems. Finally, as noted in the quotation above, vegetation is a large part of the scenery that visitors to NPS units come to enjoy.

Plant communities also are sensitive to many stressors (Symstad 2004), and vegetation monitoring is critical for alerting park managers to any degradation occurring in them. Current and potential stressors on plant communities in the northern Great Plains include invasive species (Reed et al. 2005, Vaness and Wilson 2008), habitat fragmentation (Samson and Knopf 1994), river flow management (Scott et al. 1997), climate change (Mitchell and Csillag 2001), atmospheric nutrient deposition (Clark et al. 2007), pollution (Temple and Miller 1994), and altered fire and grazing regimes (Licht 1997, Brown and Cook 2006). In addition, park management activities affect plant community composition and structure through herbivore management (e.g., bison and elk culling, prairie dog control), prescribed fire programs, and exotic species control. Ecological models describing the effects of these stressors and activities on a variety of vegetation types in the northern Great Plains were completed as part of the Network's Vital Signs planning process (see Appendix B in Gitzen et al. 2010).

Plant community composition and structure include the number, identity, and relative abundance of plant species, as well as their horizontal cover and vertical structure. Monitoring these requires a relatively small number of procedures, yet it yields information about a large number of parameters. Specific parameters measured in this protocol are defined and justified in this section.

- *Foliar cover of individual species:* Foliar cover is the estimate of abundance for herbaceous and small woody species. It is defined as the percentage of ground covered by a downward projection (perpendicular to the ground) of the aerial portion of plant foliage (USDA-NRCS 1997). The protocol described in this document is unlikely to precisely describe the status and trends of even the most abundant individual species (Appendix A). However, the protocol is designed to describe the status and trends of cover of ecologically meaningful functional groups, the cover of which can be calculated from the cover of their individual species. Examples of categories and their relevance to stressors and management actions include: (1) short vs. tall grasses, whose relative abundance reacts to grazing intensity (Smith 1940, Uresk 1990, Sedivec and Barker 1998); (2) shrubs vs. forbs vs. grasses, whose relative abundance is important for forage quality for a variety of animals (Singer and Norland 1994, Sjodin 2007); (3) warm- vs. cool-season (C4 vs. C3) graminoids, whose relative abundance is affected by climatic conditions and atmospheric carbon dioxide concentrations (Owensby et

al. 1999, Mitchell and Csillag 2001); and (4) exotic species, whose abundance relative to native species indicates the integrity of the plant community.

- *Herb-layer height*: Information on the vertical structure of vegetation in the herb layer (≤ 2 m in height) complements the information on horizontal cover. Vegetation height influences the use of an area by some animal species (e.g., ground-nesting birds), and is influenced by other animal species (e.g., prairie dogs and large herbivores), edaphic conditions, and weather.
- *Species richness*: Species richness is the number of species encountered in a given sample. A large body of literature (summarized in Hooper et al. 2005) suggests that greater species richness may contribute to greater plant biomass production, nutrient retention, and stability of these ecosystem functions, particularly in grassland ecosystems. In addition, species richness in grassland ecosystems often declines in response to atmospheric nitrogen deposition (Clark et al. 2007), invasion by exotic species (Butler and Cogan 2004, Vaness and Wilson 2008), and high-intensity grazing (Fuhlendorf and Smeins 1997). On the other hand, an increase in native species richness is one indicator of the success of a prairie restoration. Finally, as the prime directive of the NPS is to maintain the resources for the enjoyment of future generations, maintaining the diversity of native plant species is a direct management goal.
- *Ground cover*: Ground cover is the percentage of material other than bare soil covering the land surface and may include live vegetation, litter (dead vegetation), cobble, gravel, stones and bedrock (USDA-NRCS 1997). The abundance of some of these different types of cover (e.g., bedrock) influences the type of vegetation that can grow at a site. Litter and vegetation cover influence the space available for recruitment of individual plants. Litter cover also influences fire behavior. Ground cover of live vegetation (also known as basal cover) reflects long-term trends in precipitation and grazing intensity (Biondini et al. 1998) and affects soil erosion rates (Neave and Rayburg 2007).
- *Tree stem density and basal area*: Stem density is the number of stems per unit area, and basal area is the area covered by the stem (major axis or bole) of a tree. Both of these are measured on an individual species basis, but they can be combined over all species to describe forest structure. For example, the basal area of a forest stand is the combined cross-sectional area of all tree stems per unit area of ground. The abundance of individual species and all live trees in different size classes influences understory vegetation, defines habitat types for animals, and indicates the amount of tree regeneration occurring in a wooded area. Density and size of standing dead trees are important as measures of habitat and food availability for certain wildlife species such as cavity-nesting birds. Density and size of live and dead trees in different size classes also influences fire behavior.
- *Live and dead tree condition*: Condition of standing trees reflects the health of living trees and the suitability of live and dead trees as wildlife habitat.
- *Fire fuel loads*: Fuel loads are the amount of combustible material in an area, usually expressed on a weight per area basis. Fuel loads are measured according to different size classes because of the time it takes for the moisture content of these classes to equilibrate

with the moisture content of the environment; therefore, each class exhibits a difference in flammability. Fuel loads determine fire behavior, which in turn determines the effect of different fire types on vegetation.

Quantitative values of these parameters that constitute ecological or management decision thresholds are relatively rare, but some guidelines for deciding whether status values estimated or trends detected warrant expanded monitoring, research, or management attention are available. These are thoroughly reviewed and incorporated into the ecological models completed during the Network's Vital Signs planning process (Appendix B in Gitzen et al. 2010).

1.3 Goal of the Protocol

Consistent, well-planned monitoring of the status and trends of these parameters ideally would provide park managers with early warning of undesirable change, measure digression from or progress towards a desired state, and evaluate effectiveness of management programs. In addition, when combined with monitoring of environmental factors (NGPN Weather and Climate, Wet and Dry Deposition, Ozone vital signs), wildlife species (Prairie Dogs and Land Birds vital signs, park ungulate monitoring), specific disturbances (Fire and Fuel Dynamics and Extreme Disturbances vital signs), and park management practices, it would increase the fundamental understanding of these ecosystems. No single monitoring protocol, or even a whole monitoring program, can do all these things thoroughly within the bounds of fiscal resources available. Thus, the monitoring strategy described in this protocol attempts to balance the immediate needs of managers for current information for evaluation and the need for insight into the changes occurring in plant communities over time.

The broad goal of plant community composition and structure monitoring for most NGPN parks is to make park-wide inferences about the status and trends of the health of vegetation. However, plant community composition and structure monitoring in two parks in the Network, MNRR and NIOB, will not have park-wide inference but will instead focus on limited areas because multiple ownership of the properties within their boundaries is not conducive to long-term, park-wide, land-based vegetation monitoring. Plant community monitoring in these parks will likely focus on specific management issues (e.g., birch or aspen at NIOB, prairie restoration at MNRR).

1.4 Historical Development of Plant Community Monitoring in Northern Great Plains Network Parks

Since they were established, most NGPN parks have had some level of vegetation monitoring, but the extent and type vary greatly. Extent ranges from single-season evaluations for planning purposes, to short-term (1-3 year) research projects, particularly at the larger parks (BADL, THRO, and WICA), to monitoring programs in place for more than a decade. Types of monitoring include mapping of targeted invasive species, range/forage evaluations, ecosystem health monitoring, and fire effects monitoring. The Northern Great Plains Exotic Plant Management Team (NGP-EPMT) has been mapping the locations and general densities (low, medium, high) of target invasive species, as well as the treatment applied to those species, in all NGPN parks except AGFO since 2002, and in AGFO since 2006. Intensity and extent of mapping and treatment vary substantially from year to year and have generally been decreasing over time. Ecosystem health and fire effects monitoring have been conducted by the Prairie Cluster Prototype Long-Term Ecological Monitoring Program (PCP) and Northern Great Plains

Fire Ecology/Fire Effects Program (FireEP), respectively, and are summarized below. Symstad (2004) describes other vegetation monitoring in NGPN parks up to January 2004, and Table 2 summarizes relevant vegetation sampling/monitoring in parks since then.

1.4.1 *Prairie Cluster Prototype Monitoring Program (PCP)*

In the early 1990s, the NPS established prototype monitoring programs to evaluate monitoring at different spatial scales and to develop field sampling methods and accuracy assessment protocols for parks in each of 10 major biomes. Prototype programs established more in-depth monitoring than the subsequent I&M programs, and have performed research and development to benefit monitoring in all natural resource parks. The PCP was established in 1994 to address monitoring concerns in small NPS prairie parks in the Great Plains. From 1994 to 1999 this program, in collaboration with the U. S. Geological Survey-Biological Resources Division, initiated pilot studies in six geographically distinct parks to develop a long-term vegetation monitoring protocol appropriate for the program's objectives and parks' information needs. Two of the PCP parks, AGFO and SCBL, are part of the NGPN.

Briefly, PCP vegetation monitoring in these two NGPN parks consists of the following: Within each park, one or more subsets of the entire park was chosen to be a study unit based on management issues or the desire to capture landscape and community heterogeneity. Where more than one plant community occurred in a study unit, soil type, slope, and aspect were used to identify approximate plant communities. Two or more monitoring sites were then located randomly within each plant community (Willson et al. 2002). At AGFO, this practice yielded 10 sites across 5 plant communities in one study unit (i.e., University/Carnegie Hill). At SCBL, this method yielded 9 sites across 3 plant communities in the South Bluff study unit and 4 sites in and adjacent to a restoration site in a separate study unit. At each monitoring site, two permanently marked, parallel, 50 m transects were located 20 m apart from each other. Species presence in nested, circular plots (sizes are 0.01m², 0.1m², 1m², and 10 m²) and species cover class (7 classes) in the 10 m² plots are recorded at 5 evenly spaced locations along each transect. Sites are generally measured for 2 successive years, then rested for 3 years. Monitoring was initiated in 1997, although not all sites were established in that year. Some modifications to the protocol have been made since then; the current protocol is documented in DeBacker et al. (2004).

The Heartland Network of the NPS I&M program was established in 2001. Initially co-located with the PCP program, the two programs were further integrated in 2003 to become the Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program (HTLN). Since then, HTLN has been monitoring PCP vegetation sites at AGFO and SCBL. All PCP monitoring at these two parks was transferred to NGPN in 2010.

Table 2. Summary of vegetation monitoring or related work in NGPN parks, 2004-2008. Does not include FireEP or PCP monitoring, which are described in detail in the text.

Park	Description	Responsible Party	Extent	Duration
AGFO	Wetland delineation study (Sundermann 2004)	Geologist in the Park Intern	Niobrara River in fee-title areas of park	1 year (2004)
BADL	Research project on Canada thistle and associated vegetation	Amy Symstad (USGS)	32 sites in bison range	2005-2007
	Research projects on yellow sweetclover and assoc. veg.	Diane Larson (USGS)	20 sites in eastern portion of North Unit	2001-2008
DETO	Invasive species mapping	Park resource management division	Whole park	Continuing
	Sensitive plant species inventory	Bonnie Heidel (Wyoming Natural Diversity Database)	known sites of rare plants, plus entire river corridor	1 year (2008)
FOLA	Cottonwood regeneration survey (Jones 2007)	George Jones (Wyoming Natural Diversity Database)	Woodlands on the Laramie and North Platte Rivers	1 year (2006)
FOUS	Prairie restoration assessment	Greg Eckert (NPS WASO Natural Resources)	Planted areas	1 year (2008)
JECA	Invasive species occurrence and treatment mapping	Park resource management division	Whole park	Continuing
KNRI	Forest Inventory and Analysis	USDA Forest Service	One plot	2004-continuing
	Heart rot and DBH measurements on green ash trees	Park resource management division	Four stands	Erratic
	Re-survey of rangeland plots established in 1984	E. Shawn DeKeyser (North Dakota State University)	Whole park	2006-2007
MNRR	Missouri River cottonwood study (Dixon et al. 2009)	Mark D. Dixon (U. of South Dakota)	104 cottonwood stands sampled on ground; entire park examined with remote imagery	2007-2008

Park	Description	Responsible Party	Extent	Duration
MORU	Cedar County cedar thinning study	Adam Benson & Mark Dixon (University of South Dakota), Stephen Wilson (NPS-MNRR)	26 plots in ~40 ha in woodlands and hillside prairie of Bow Creek Recreational Area	2008-2010 or 2011
	Old-growth inventory (Symstad and Bynum 2007)	Amy Symstad (USGS)	Undeveloped areas of park	1 year (2004)
	Thinning and chipping research project	Kate Cuneo (Colorado State University) & Cody Wienk (NPS MWRO)	36 plots in ~25 ha south of park housing	2008-2012
NIOB	Paper birch decline research project	Esther Stroh (USGS)	Selection of birch stands within park boundaries	2005-2008
SCBL	Aspen stand mapping and health evaluation	Timothy Downing (Missouri River Institute), Scott Schlarbaum (University of Tennessee), Wayne Shepperd (Consultant)	Selection of aspen stands within park boundaries (varied among efforts)	short, one-time visits in 2007, 2008
	none			
	Seral stage monitoring for elk EIS	Park resource management division	76 plots in South Unit, needle-and-thread and threadleaf sedge vegetation types	2006-continuing (some plots visited annually, others every 3 years)
WICA	Range condition monitoring	Park resource management division	~37 transects in whole park	2004-2008
	Hardwood scorecard monitoring	Park resource management division	3 plots	Established in 2000; 10-year revisit schedule
	Forest Inventory and Analysis	USDA Forest Service	3 plots	Established in 2001; 5-year revisit schedule

Park	Description	Responsible Party	Extent	Duration
	Hardwood recruitment study (Ripple and Beschta 2007)	Bill Ripple (Oregon State University)	Hardwood exclosures (3) and surrounding areas	1 year (2005)
	Thinning and chipping research project	Kate Cuneo (Colorado State University) & Cody Wienk (NPS MWRO)	18 plots in ~21 ha west of Hwy 87 near Pigtail bridge	2008-2012
	Vegetation mapping/Black Hills Community Inventory plot revisits	Park resource management division	~ 65 plots throughout park	Established 1998; revisit 2009 or 2010

1.4.2 Northern Great Plains Fire Ecology/Fire Effects Monitoring Program (NGP FireEP)

The Northern Great Plains Fire Ecology/Fire Effects Monitoring Program was established in 1996 as part of the Northern Great Plains Fire Management Office at WICA. The purpose of the program is to document baseline vegetation information, to detect trends in vegetation populations, to ensure that resource management objectives related to fire management are met, and to aid in refining parks' fire management programs. Since 1996, over 200 monitoring plots have been established in forest stands, shrublands, and grasslands in ten of the NGPN parks. In addition to monitoring vegetation, the program monitors fuel moisture throughout the summer season in selected parks and fire behavior in prescribed and wildland fires.

The NGP FireEP is part of a national program established to assess the effectiveness and effects of fire management in NPS units. National-level program protocols are contained in the *Fire Monitoring Handbook* ("FMH"; USDI National Park Service 2003), which explains that the program's monitoring is designed to provide long-term, park-wide data on the effects of a park's fire management program on vegetation. The FMH gives very specific instructions on data collection at sites once the sites are located, and the NGP FireEP has generally followed these, but protocols for the location of sampling sites are less specific because of the broad nature of the national program. In most instances, resource limitations have resulted in sampling designs oriented towards short-term, burn unit-specific information to determine whether the objectives of a specific prescribed fire or mechanical treatment project have been met.

Briefly, standard NGP FireEP monitoring has consisted of the following: Permanent monitoring sites are located randomly within specific vegetation types in a prescribed fire unit one year prior to the scheduled fire. The number of sites per unit and per vegetation type depends on the number of vegetation types in the unit, the size of the unit, and the objectives of the fire, with 1-4 sites per vegetation type per unit being the norm. The type of vegetation data collected and the arrangement of subsamples within a site depends on the vegetation type. In all instances, cover of all individual species is measured using a point-intercept method along a single transect (30 m long in grasslands and shrublands, 50 m long in forests). In shrublands, shrub stem density is measured in a 2 m wide belt along the 30 m transect. In forests, density of shrub stems, tree seedlings, and trees are measured in a subset of or the entire 20 m x 50 m plot, and fuel load is measured on four 50 ft or 100 ft transects following Brown's method (Brown 1974, Brown et al. 1982). Diameter and condition class are recorded for individual trees in forest sampling sites. Sites are sampled in the year of establishment, 1, 2, 5, and 10 years after the prescribed fire, then every 10 years thereafter, or until the unit is burned again, in which case the sampling schedule is reset. Deviations in methodology at individual sites have occurred recently in efforts to streamline data collection and in preparation for merging monitoring efforts with the NGPN.

1.4.3 NGPN Monitoring in the Context of PCP and NGP FireEP Legacies

It was determined early in the development of NGPN monitoring protocols that park-wide plant community composition and structure monitoring would be fully integrated between NGPN and NGP FireEP. The reasons for this decision are many. First, the geographical overlap of the two programs is complete, with NGPN encompassing all ten of FireEP's parks and three others that have not yet had any fire monitoring (FOLA, MNRR and NIOB). Second, the overlap of the objectives of the programs is very high, particularly because fire is a natural process in all of the vegetated area within NGPN's parks. Finally, because of this overlap, the efficiencies gained by

combining resources of the two programs would produce a much stronger vegetation monitoring program for the NPS northern Great Plains units than would two separate programs.

NGP FireEP protocols primarily have followed those described in the NPS Fire Monitoring Handbook (USDI National Park Service 2003). However, program staff members were willing to shift to different methods to foster full cooperation of the two programs. The development of this protocol was a combined effort of the NGPN and the NGP FireEP. All aspects of the protocol were evaluated in the context of the goals, objectives, and requirements of each program.

Because of the legacy of the PCP monitoring at AGFO and SCBL, as well as the fact that prototype monitoring parks were promised that the transition to I&M monitoring would result in equal or better monitoring at those parks compared to the rest of the parks in the network (S. Fancy, NPS National I&M coordinator, personal communication), strong consideration was given to simply continuing to follow the HTLN protocol in AGFO and SCBL, as well as expanding it to the other parks in the NGPN. This was decided against for the following reasons:

- Exact methodology for determining monitoring site locations is unclear in the published protocol under which AGFO and SCBL monitoring sites were established (Willson et al. 2002), and notes from this time (M. DeBacker, HTLN coordinator, 29 June 2007 email) do not provide sufficient information for NGPN to replicate the process with confidence.
- The stratification approach used by PCP in establishing monitoring sites at AGFO and SCBL does not follow current I&M program guidance (Geissler and McDonald 2003).
- Cover classes, which are used by PCP/HTLN for recording plant and ground cover, tend to overestimate the cover of small or rare species (Floyd and Anderson 1987) and have large boundary errors (Helm and Mead 2004).
- Plant cover estimates on continuous numerical scales are difficult to replicate among observers in the large (10 m²) plot sizes used by HTLN.

NGPN acknowledges the value of the data collected by both of these established programs. Therefore, this protocol has been designed to make as smooth a transition as possible from these two programs by including elements of both but improving on them by incorporating recent developments in sampling design and results of pilot study work conducted specifically for this program. Appendix D describes this transition in detail.

1.4.4 Measurable Objectives

In collaboration with these existing programs, the NGPN has developed the following monitoring objectives for this protocol:

1. In all NGPN parks except MNRR and NIOB, determine park-wide status and long-term trends in vegetation species composition (e.g., non-native vs. native, forb vs. graminoid vs. shrub) and structure (e.g., cover, height) of herbaceous and shrub species.

2. Determine park-wide (DETO, JECA, and MORU) or targeted area (WICA) status (at 5-yr intervals) and long-term trends of tree density by species, height class, and diameter class, and of fuel loads by fuel classes in Black Hills parks.
3. Determine status (at 5-yr intervals) and long-term trends of tree density by species, height class, and diameter class in lowland areas near targeted perennial streams in selected parks (FOLA, SCBL, DETO, KNRI, and THRO).
4. Determine trends in plant species composition and community structure in selected areas of NGPN large-river parks (NIOB and MNRR).
5. Improve our understanding of the effects of external drivers and management actions on plant community species composition and structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control.

2. Sampling and Response Design

The sampling design for a monitoring protocol specifies the procedures by which members of a population are selected and the spatial arrangement and schedule for measurement of these members (Thompson 2002). The response design describes what variables will be measured and how they will be measured when a sample unit is surveyed (Stevens and Urquhart 2000). Together, these designs must address the problems associated with sampling numerous parameters through space and time using approaches that are efficient and effective at accomplishing the objectives of the monitoring program.

Sample size analyses based on pilot sampling implemented specifically for development of this protocol and on data collected in NGPN parks by other programs (described in detail in Appendix A; summarized below in “Rationale for choosing this design”) indicated that two types of sampling units are needed to accomplish the objectives stated above. The primary sampling type is the “intensive plot” and the secondary is the “extensive woody plot.” These two plot types represent alternative trade-offs in the relative amount of effort allocated to measuring each plot vs. adding and measuring additional plots. As described below, intensive and extensive woody plots are chosen as part of the same random draw of sampling locations in each park. In some cases, an extensive woody plot is at the same location as an intensive plot; such plots are referred to as “dual plots”. In dual plots, which measurements (extensive woody only vs. the more thorough intensive) are done in a given year is determined by the separate intensive and extensive revisit schedules. This is described in more detail below.

2.1 Response Design

The primary sample unit for intensive plant community composition and structure monitoring in the NGPN consists of a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 2a). These are hereafter referred to as “intensive plots”. Data on ground cover and herb-layer (≤ 2 m height) height and foliar cover are collected on two 50 m transects (the long sides of the plot) using a point-intercept method.^a Species richness data from this point-intercept method are supplemented with species presence data collected in five sets of nested square quadrats (0.01 m², 0.1 m², 1 m², and 10 m²; Figure 3) located systematically along each transect.^b Tree regeneration and tall shrub density data are collected within a 10 m-radius, circular subplot centered at the center of the 50 m x 20 m plot. In this subplot or a subset thereof, tree and targeted tall shrub species with diameter at breast height (DBH, where breast height = 137 cm) < 2.54 cm (“seedlings”) are tallied by species, and DBH, status (live or dead) and species are recorded for all pole-size ($2.54 \text{ cm} \leq \text{DBH} \leq 15 \text{ cm}$) trees and targeted tall shrubs. Trees with $\text{DBH} > 15 \text{ cm}$ within the entire 0.1 ha plot are mapped and tagged, and species, DBH, status, and condition (leaf-discoloration, insect-damaged, etc.) are recorded for each tree. Where appropriate (i.e., in ponderosa pine forest or woodland in Black Hills parks), dead and downed woody fuel load data are collected on two perpendicular, 100-ft (30.49 m) transects centered at the center of the plot.

^a This is an adaptation of the NGP FireEP monitoring protocol.

^b Plot size and nested subplots for species richness/frequency are consistent with the PCP and HTLN vegetation community monitoring protocol.

For analysis of data from intensive plots, the plot is used as the unit of replication and quadrats or transects are pooled or averaged. Data from each plot are summarized for a variety of variables including: relative cover of growth forms (shrubs, grasses, forbs), absolute cover of bare soil, total herb-layer foliar cover, density and basal area of trees, species richness and diversity, relative abundance of functional groups, and proportions of foliar cover and species richness that are non-native.

The extensive woody plot uses the same methods for collecting data on tree and tall shrub species, as well as dead and downed woody fuel (where appropriate), as in the intensive plot, but tree and tall shrub sampling is limited to a 10 m-radius, circular plot (Figure 2b) and trees are not mapped or tagged. No herb-layer data are collected. The smaller area and limited amount of information collected in these plots allows for more of them to be deployed across a park, increasing the precision of measurements on tree densities in smaller size classes. As with the intensive plot, information from transects is averaged to obtain one value for the plot, which is the sample unit.

Data collection methods are summarized in Section 3. Field methods are described in detail in Symstad et al. 2012 in SOP Plant Sampling, SOP Trees and Shrubs, and SOP Surface Fuels. Analyses of data for both annual status and temporal trends are summarized and discussed in Section 4 and described in detail in SOP Data Analysis (Symstad et al. 2012).

2.2 Spatial Design

2.2.1 Overview of Spatial Design

NGPN plant community composition and structure monitoring uses a probability sampling approach. With probability sampling, all potential sample units in the population of interest have non-zero probabilities of being selected; each possible sample of n units has a definable probability of selection; and a sample is selected based on a random draw or process according to these probabilities (Cochran 1977, Särndal et al. 1992). In this situation, when the sampling frame and sampled population overlap completely with the target population, direct statistical inference about the population of interest can be made. In the absence of significant measurement error, as is possible with vegetation sampling, status and year-to-year changes of measured parameters can be estimated with no additional assumptions about the population. From this limited sample and the probability design, it is possible to estimate the uncertainty in estimates caused by sampling error, which is the variation between the parameter's estimate from the sample and the underlying population parameter resulting from measuring only a random subset of the target population. Because samples are selected based on pre-defined rules of probability rather than individual opinion, probability sampling is often seen as objective. This is an important advantage when results may lead to contentious management decisions (Thompson 2002).

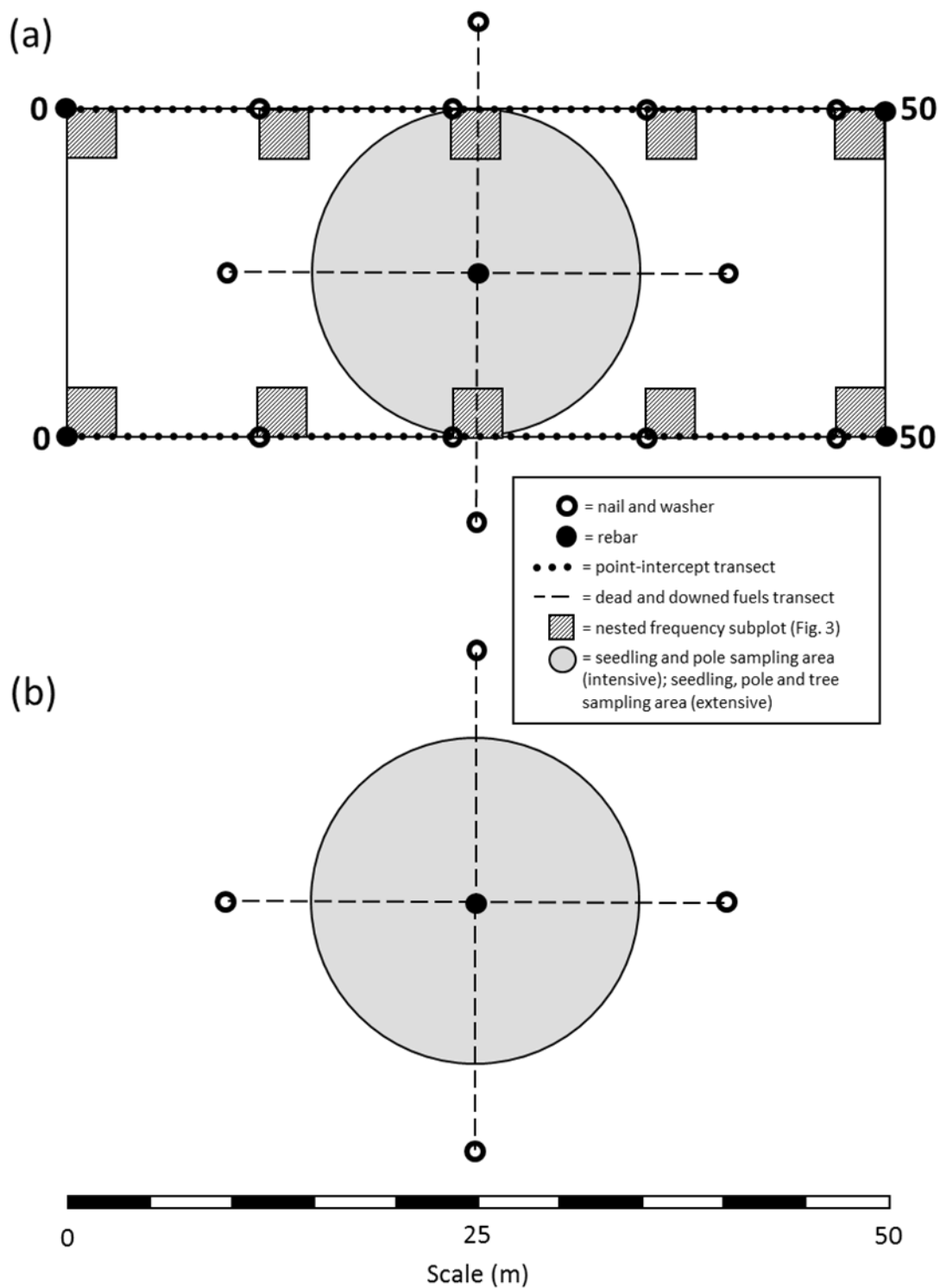


Figure 2. Layout for NGPN plant community composition and structure plots. (a) Intensive plots; (b) Extensive woody plots. In cases where fewer than 5 trees or poles occur in the 10-m radius of an extensive plot, the radius is extended to 20 m.

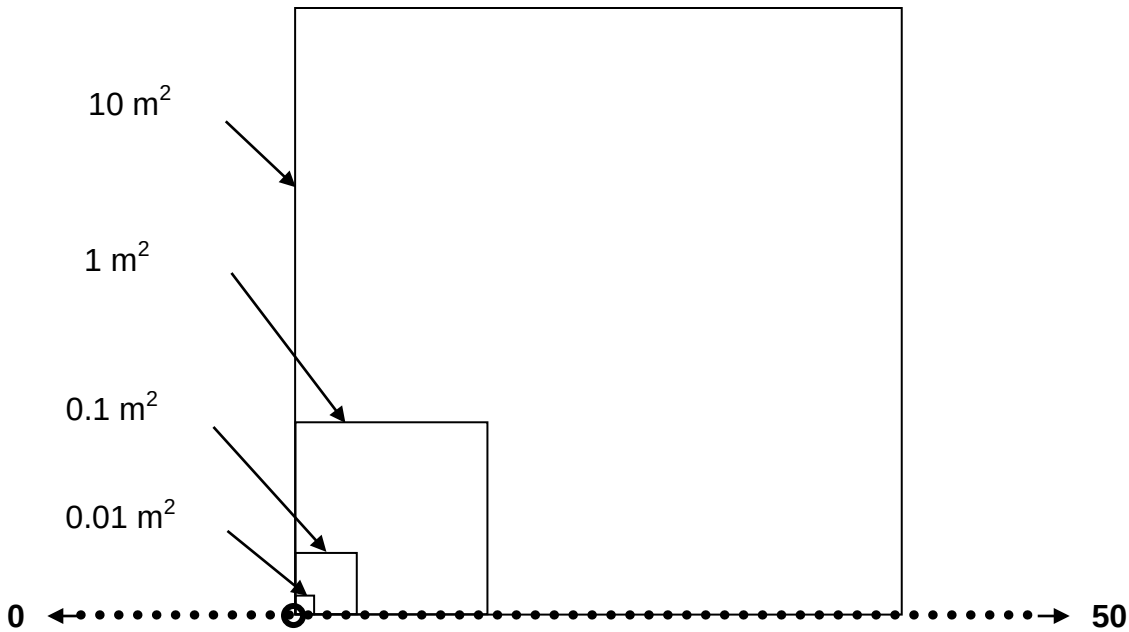


Figure 3. Arrangement of nested quadrats along tape used for point-intercept sampling. Open circle indicates permanent marker (nail and washer or, at 0 end of transect, rebar). The general NGPN approach to defining a sample frame is to tile the continuous target population for each park into a set of discrete, sampleable units. For plant community composition and structure monitoring, these units are defined by a grid of 53.85 m x 53.85 m cells that encompasses the entire park and areas that may become part of the park in the future. This cell size allows any orientation of the rectangular 20 m x 50 m intensive plot with respect to the grid with no overlap between plots if two adjacent cells are selected (Appendix C). Within this sample frame, samples are selected using the generalized random tessellation stratified (GRTS) design (Stevens 1997, Stevens and Olsen 2004). This design produces samples that are more spatially balanced than those from simple random sampling. Unlike systematic sampling (in which one unit is randomly selected, and then every k th unit is selected so that the sample is spread equally across the population), the GRTS design has a well-defined variance estimator (Stevens and Olsen 2003). One of the primary benefits of the GRTS design is its flexibility, particularly in situations where some selected samples may not be suitable for monitoring but it is difficult to determine that before they are visited. GRTS sampling produces an ordered list of sampling locations and can select more locations than are actually needed for a given protocol (i.e., an oversample can be included). If a particular location cannot be sampled, then the next location on the list can be used instead; the approximate spatial balance of the sampling design will be maintained and inclusion probabilities for each sample unit remain simple to compute. This maintains our ability to do valid design-based analyses of status. The GRTS design also allows flexibility in altering sample sizes after the initial sample has been established. For example, if funding increases or decreases in the future, sample size can be increased or decreased without compromising the spatial balance or statistical validity of the sample. Or, if the need arises for a one-time high-intensity sampling effort (e.g., to estimate status in a given year very precisely to address a management information need), a larger supersample of sites can be used by combining the selected sample and oversample units, resulting in the long-term sampling sites being nested within this supersample.

2.2.2 Defining the Sample Frame

The approach of the NGPN is to be able to make park-wide inferences from its sampling. Thus, in most cases the target population encompasses the entire park, and the sample frame overlaps this target population as closely as the GIS database allows. This is subject to the following exceptions:

1. Administrative areas, including but not limited to maintenance “bone yards”, campgrounds, buildings, lawns, and sewage treatment lagoons, plus a 25 m buffer are excluded. Vegetation in these areas is not managed for ecosystem health.
2. Roads, railroads, canals, utility corridors and other highly disturbed linear features, plus an appropriate buffer, are excluded. These features are represented by lines in GIS, which do not adequately capture the width of the disturbed area affected by these features. The appropriate buffer for each feature is determined by the width of the feature. For example, a two-lane road with minimal shoulder has a 5 m buffer on each side of the center line, whereas the portion of Highway 244 at MORU that has three lanes and wide margins and guardrails on each side has a 10 m buffer on each side of the center line.
3. Areas within 10 m of a park boundary are excluded. This is because boundaries are subject to management activities (e.g., fire break construction, law-enforcement traverses, fence repair vehicle traverses) in a greater concentration than, and therefore not representative of, the rest of the park. Samples that fall in this area are expected to increase variability among samples, and therefore reduce precision of estimates. The disadvantages of this added variability are not expected to be overcome by the potential advantage of having information about the impact of these activities or other processes that affect vegetation adjacent to borders. This potential is expected to be quite small because of the low number of samples that would fall in this exclusion zone. An exception to this rule is made in areas where the boundary of the park is the middle of a river. In this case, boundaries are not subject to the management activities described above. Thus, no buffer is used on river boundaries.
4. Paved (surface material not from immediate surroundings) trails, plus an appropriate buffer, are excluded. The reason for this exclusion is similar to that as for near park boundaries, with mowing being the major management activity. Paved trails in NGPN parks are rare; thus, a very small area is excluded. Unpaved trails are not excluded from sampling, as human traffic on these is generally light and impacts are expected to be less than or equal to trails created by large animals other than humans (particularly bison and horses).
5. Areas with little or no potential for terrestrial vegetation (e.g., large areas of bare rock at MORU) are excluded.
6. Areas that are dangerous or prohibitively difficult to access or work on (e.g., the top of Devil’s Tower) are excluded for safety reasons.

7. Except at MNRR and NIOB, areas within the administrative boundaries of a park but not owned in fee-title by the park will be considered “dormant” – they are included in the sample frame but will not be sampled unless they are acquired. At MNRR and NIOB, some portion of state-, federal-, or The Nature Conservancy-owned property within the administrative boundaries may be sampled.
8. The sample frame for extensive woody sampling varies among parks. Three parks (AGFO, BADL, and FOUS) have no extensive woody sampling because of their limited number and/or scattered distribution of trees. At FOLA, SCBL, and THRO, extensive woody sampling is done only in the riparian area. At DETO, JECA, KNRI, MORU, and WICA, the same sample frame is used for both intensive and extensive woody sampling. However, at WICA, extensive woody sampling is currently limited to areas mapped as forest, woodland, or tall shrubland or within a 100 m buffer around those areas in the 1999 vegetation mapping report (Cogan et al. 1999, see Appendix B).

Some modifications of these general rules are made on a park-by-park basis. These are summarized in Table 3 and detailed in Appendix B.

2.2.3 Unequal Sampling within the Sample frame

Stratified sampling divides the target population into discrete, non-overlapping subpopulations (strata), samples each stratum separately, estimates the attributes of interest separately for each stratum, and then combines the strata estimates and variances into estimates for the entire target population. We considered using stratification for NGPN plant community composition and structure monitoring for five reasons. First, stratification is appropriate when sampling methods differ, and separate estimates of the attribute must be generated for each stratum and then combined. Second, stratification can be advantageous when variability among strata is expected to be much greater than variability within strata. This is because stratification removes differences among strata from the variance estimate for the entire population; thus, it provides more precise estimates for the entire population compared to simple random sampling (Cochran 1977). For example, in many parks, exotic species comprise a substantially higher proportion of total cover in riparian areas than in upland areas, possibly because of higher disturbance or greater moisture availability. Third, stratification is often used because estimates for specific subpopulations of interest are desired. Fourth, stratification allows differential allocation of sampling effort among strata, a form of unequal probability sampling, producing stratum sample sizes that are not proportional to stratum size. For example, riparian areas comprise a relatively small fraction of the area in most NGPN parks. However, due to their importance as wildlife habitat and high sensitivity to certain stressors, proportionately more samples would have to be allocated to these corridors to ensure adequate sample size to draw inferences about this special subset of the park. Finally, if a spatially balanced sample is desired within such high-priority subpopulations, rather than simply at the whole-park level, separate GRTS draws within strata may be necessary.

Table 3. Sample frame, park-specific areas excluded from this sample frame, and stratification of plant community sampling in NGPN parks.

Park	Sample frame	Areas Excluded from Sample frame ^a (rationale)	Strata (rationale)
AGFO	Whole park	Mowed trails (disturbance similar to a lawn)	None ^b
BADL	North Unit	(Stronghold and Palmer Units not in target population because NPS does not manage and access is limited)	None
DETO	Whole park	Top of Devils Tower rock formation (inaccessible)	Riparian Lowland vs. Upland (management importance of riparian lowlands disproportionate to area)
FOLA	Whole park	None	Riparian Lowland vs. Upland (management importance of riparian lowlands disproportionate to area)
FOUS	Whole park	None	Bodmer Unit vs. Fort Unit (achieve adequate sample size in distinct management unit – Bodmer)
JECA	Whole park	None	None
KNRI	Whole park	high-density cultural sites (regularly mowed; disturbance restrictions)	None
MNRR	Park-owned parcels	Undecided	Undecided
MORU	Whole park	None	None
NIOB	Undecided	Undecided	Undecided
SCBL	Whole park	None	None
THRO	North Unit and South Unit as separate sample frames	(Elkhorn Ranch Unit excluded because natural resources not a focus there)	Riparian Lowland vs. Upland in each unit (management importance of riparian lowlands disproportionate to area; North and South Units distinct units that require unequal probability sampling to get desired sample sizes)
WICA	Whole park	Small, isolated parcel owned for water supply purposes	^b 2008 Boundary vs. 2011 Acquisition (2011 acquisition was not included in the sample frame used in 2008) ^c

^aSee text for exclusions that apply to all parks.

^bAt WICA the portion of the park acquired in 2011 will be treated as a separate stratum.

^cAt AGFO and WICA, a riparian sampling method specialized for their narrow riparian corridors will be developed and included in future versions of this protocol; this sampling method will use a different spatial design and the resulting data will be analyzed separately from data of the general plant community composition and structure monitoring.

The NGPN plant community composition and structure methodology is designed to be robust in the range of vegetation types that occur in the Network. Thus, stratification for the first reason – different sampling methods – can be avoided. Generally, stratification at the time of sampling design is not necessary to reap the second and third benefits of stratification described above. Through post-stratification (stratification when analyses are performed), strata can be defined according to the conditions of the population at the time, or according to the specific subpopulations of interest; similarly, domain analysis gives flexibility to analyze any subpopulation of interest. Grassland vs. woodland estimates of native species richness are an example of where post-stratification is useful. Boundaries between these vegetation types vary over the span of decades due to variations in climate, grazing pressure, and fire. Therefore, samples that were in grassland when sampling began may be in woodland when analyses are conducted.

This example illustrates the major disadvantage of stratification, particularly for long-term monitoring: strata delineations are a permanent feature of the sampling design. If conditions change such that the strata boundaries used during sampling design are no longer accurate, the sampling design becomes irrelevant and the resulting data difficult to analyze usefully. Therefore, it is imperative that strata be based on permanent (over the next 100 years) features. Because of this design rigidity, stratification is used sparingly in NGPN plant community composition and structure monitoring. Stratification is used, however, because there is a compelling need for differential allocation of sampling effort in some situations, primarily in parks with large streams or rivers and the lowlands that surround them. These areas have high ecological and management importance compared to their area. Thus, they warrant a much higher sample size than would be achieved through park-wide, equal-probability sampling. Although differential sample allocation could be achieved by using the overdraw capabilities of GRTS sampling, test sample draws using this method showed poor spatial balance and difficulty in achieving the desired sample sizes. Table 3 summarizes the stratification strategy employed, and Appendix B contains detailed explanations for the sampling design, in each park.

2.2.4 Locating Sample Sites

Plot locations are determined using *spsurvey* (Kincaid et al. 2008), a package for the R statistical programming language and environment (R Development Core Team 2008). In this program, a GIS is used to assign attributes that define strata to all grid cells in the sample frame. This produces a list of potential sample locations for each stratum. The *spsurvey* package uses this list to produce an ordered list of spatially balanced, randomly sampled plot locations, which are then assigned to revisit panels (see “Revisit Design” below). The number of plot locations generated is larger than the desired sample size because some locations will be rejected upon visitation in the field; we also wish to maintain the flexibility to use the selected sample for other data-collection efforts that use a larger sample size (e.g., future short-term studies or expansion of long-term monitoring). Appendix C describes the process of generating potential plot locations in detail.

In the field, potential plot locations are visited approximately in the order on the list produced by *spsurvey*. (The visit order can be modified slightly to save travel time by visiting all sites drawn as primary sites in the logistically least expensive order, determining the number of replacement sites needed, visiting those replacement sites in least-cost order, etc.) If the site is suitable based on pre-established suitability criteria (e.g., slope not too great, meets definition of stratum), a

permanent monitoring plot is established. If the site is not suitable, the reason is recorded on the Site Evaluation Checklist and the next site on the list from the same stratum is visited. This process is continued until the desired number of plots is located. Plots are physically marked on the ground and located in the field with a GPS unit. Details relating to evaluating potential sampling plots are described in SOP Site Evaluation in Symstad et al. 2012.

2.3 Temporal Design

2.3.1 Revisit Design

The revisit design specifies the schedule for visiting and measuring sample units across years (McDonald 2003). The membership design specifies how sample units will be selected and assigned to panels in the revisit design (McDonald 2003). A panel is a group of sample units (plots) with the same revisit schedule, so that all members of the panel are visited during the same years.

Many components of plant community composition and structure have high annual variability because of high annual variability in precipitation; water is a limiting resource for plant growth in all but the wettest years in most vegetation of the northern Great Plains (Hooper and Johnson 1999, Adler and Levine 2007). In addition, changes in vegetation in response to specific management actions, such as ungulate herd size control and exotic species treatment, can occur relatively quickly, on the order of a few years. These conditions imply that individual plots should be revisited frequently. On the other hand, spatial variability of most composition and structure components is also high (due to spatial variability in soils, topography, herbivore use, fire, etc.), indicating a need for adequate spatial coverage of the sample frame. Thus, an ideal revisit design would consist of a large number of sites distributed throughout a park being sampled every year. Limited resources, as well as the danger of plot wear-out (trampling and other effects of sampling), preclude this design. A rotating-panel design helps overcome these limitations because only a subset of panels (and therefore plots) are visited each year. This allows more sites than can be visited in one year to be included in the sample design, while including revisitation of sites to address annual variability. A “connected” rotating-panel design overlaps the sampling schedule for different panels so that every panel is linked to every other panel and every year is linked to every other year through a chain of overlapping panel / year combinations. Compared to the always-revisit design, connected panel designs, in which each panel is revisited periodically, sacrifice little power for detecting trend (Urquhart and Kincaid 1999) but provide much greater spatial coverage, and thus improved precision in estimates of status.

NGPN intensive plant community composition and structure monitoring uses a connected [2-x] rotating-panel design: every park is visited every year, but each panel (and the plots therein) is measured for two consecutive years followed by three or more years without sampling. More complicated panel designs also were considered. For example, a [1-0, 1-9] design designates an augmented serially alternating design (Urquhart and Kincaid 1999) with 11 panels, one that is revisited every year plus 10 additional panels, one of which is sampled each year. This allows good estimates of year-to-year variation from the 1-0 panel, and adds many sites to maximize spatial coverage through the 10 additional panels (Urquhart et al. 1993). However, this design is not conducive to domain analyses focusing on plots in areas recently treated with prescribed fires, an analysis important to the NGP FireEP. Meeting this need requires a shorter return interval. Power analyses indicated that a [2-3] design would perform as well as other designs

considered in estimating trend and status for vegetation parameters (Appendix A), so this is the design used by NPGN in most parks (Figure 4). In the two largest parks of the NGPN (THRO and BADL), this revisit design does not provide a large enough sample size to produce good spatial coverage of the parks, to provide good status estimates in these highly heterogeneous areas, or to allow adequate sample sizes for potential domain analyses. Therefore, in these two parks, the revisit interval is increased (to a [2-8] design) so that the total sample size is double that of a [2-3] design. A rollout procedure, in which half of the plots are revisited on the [2-3] schedule in the first 10 years of monitoring, provides repeated measures on the same location for some sites early in the monitoring program (Figure 5). With this rollout design, the longer return interval only slightly increases the time that it requires to detect a trend in important response variables (Appendix A). In addition, because each park is still visited every year in a connected design, park-wide episodic events affecting vegetation (e.g., drought) will be captured. This longer return interval also increases the probability that at least one plot will fall in an area affected by an event smaller than the whole park because of the greater number of plots.

Year↓ / Panel→	P1	P2	P3	P4	P5
2011	X				X
2012	X	X			
2013		X	X		
2014			X	X	
2015				X	X
2016	X				X
2017	X	X			
2018		X	X		
2019			X	X	
2020				X	X
2021	X				X

Figure 4. [2-3] revisit design for intensive plant community composition and structure monitoring at most NGPN parks. Five panels are used in a park or stratum. Data are collected in the plots in a panel two of every five years. Blank cells indicate no plots in the panel are visited that year; “X” = number of plots in a panel. For example, at JECA, X = 3. Thus, 6 plots (2 panels) are sampled each year and the total sample size is 15. See Table 5 for total plot numbers in all parks. Extensive woody sampling uses a $[(1-4)^1]$ revisit design, in which each park has a single panel that is visited once every five years. This revisit design differs from that used for intensive composition and structure monitoring for two reasons. First, tree density and forest structure (distribution of size classes) have much lower annual variability than herb-layer composition and structure, as effects of precipitation fluctuations and browsing are manifested over longer time periods. Thus, frequent sampling is a waste of resources. Although rapid changes occur between years after high-severity fires and insect outbreaks, sampling every 5 years still will allow this sampling to detect such major changes. Second, because of this slow response time, detecting trends in the parameters measured in these plots will take a long time. In the meantime, park managers need good estimates of the status of forest structure to make decisions about mechanical thinning, burning, and other management actions. Fewer revisits to the same plot allows for a greater spatial distribution with the same number of plots, which provides more precision in estimating the

status at any one time. Sampling all extensive woody plots in a park in one year provides a good description of the status of the park's forest structure in that year and uses time efficiently by reducing travel between parks. The revisit schedule for these plots is shown in Figure 6.

Year↓ / Panel→	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
2011	A				A					
2012	A	A								
2013		A	A							
2014			A	A						
2015				A	A					
2016	A/2				A	B/2				
2017	A/2	A/2				B/2	B/2			
2018		A/2	A/2				B/2	B/2		
2019			A/2	A/2				B/2	B/2	
2020				A/2	A/2				B/2	B/2
2021	A				A/2					B/2
2022	A	A								
2023		A	A							
2024			A	A						
2025				A	A					
2026					A	B				
2027						B	B			
2028							B	B		
2029								B	B	
2030									B	B
2031	A									B

Figure 5. [2-8] revisit design with [2-3] rollout for intensive plant community composition and structure monitoring at BADL and THRO. Ten panels are used in a park or stratum, and these panels are split into two groups (A and B). In the first five years of monitoring, data are collected in all plots of the panels in group A. The sixth year of monitoring (2016) begins a transition period, when half the plots in two group A panels are revisited, and half of the plots in two group B panels are visited for the first time (B). The tenth year of monitoring (2021) is the end of the transition period, when supplemental revisits in group A are completed. After this, all plots are visited on a [2-8] schedule. "A" or "B" = number of plots in a panel. For example, at BADL, A = B = 10. Thus, 20 plots are sampled each year and the total sample size is 100.

Park Unit / Year→	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DETO riparian				20					20		
DETO ponderosa				55					55		
FOLA riparian					20					20	
JECA ponderosa		60					60				
KNRI riparian					20					20	
MORU ponderosa	60						60				
SCBL riparian					20					20	
THRO-North riparian						50					50
THRO-South riparian						50					50
WICA ponderosa			80					80			

Figure 6. $[(1-4)^1]$ revisit design for extensive woody plots at appropriate parks. All plots in a park are in a single panel, and all plots are revisited every five years. Parks are grouped to achieve approximately equal sample numbers in each year and to accommodate travel logistics. Blank cells indicate no plots in the panel are visited that year; numbers in cells indicate the number of target plots in each park unit (see Table 5 below). The schedule shown is tentative and includes a “ramp-up” period in the first two years of monitoring.

2.3.2 Visit Schedule within Years

Each plot, whether intensive or extensive, is visited only once in each growing season and is sampled at approximately the same time each year to help differentiate long-term trends in foliar cover and diversity from changes attributable to within-season variability. The season appropriate for sampling herb-layer cover, structure and species richness is constrained in the beginning of the season by the need to allow adequate time for growth of plants after winter (early June) and at the end by senescence due to lack of moisture (early August). Logistical constraints prevent sampling of all parks at their peak biomass or diversity (approximately the same – mid July – for all). Repeated sampling of plots more than once in a growing season would account for this seasonal change, but would be infeasible logistically and would require a large reduction in the number of plots sampled each year, which we consider a poor trade-off. For example, the HTLN vegetation program is switching from two to one visits per plot each year because the benefit of accounting for some seasonal variation was judged to be minor compared to the cost. The best solution to this problem is to sample from south to north within the network, in theory following the progression of the growing season northward. The exception to this rule may be the riparian areas at AGFO or WICA. Peak biomass and ability to differentiate among species occurs later in the growing season here than in most other parks/strata because water is available throughout the growing season. Thus, although these parks are in the southern portion of the NGPN, riparian vegetation may be sampled near the end of the sampling season.

In addition to the biological considerations, the visit schedule within years must meet logistical constraints, including the number of plots the crew can be expected to complete in a day, travel time, and the need to limit trip lengths to 8 days (assuming 10-hour work days). When these constraints are considered, four “tours” are necessary for intensive composition and structure sampling each field season; these and the approximate sampling schedule for intensive plots are shown in Table 4.

Table 4. Within-season sampling plan for intensive plant community composition and structure monitoring in NGPN parks.

Week	Tour	Parks
1 st week of June	Southern	AGFO, SCBL, FOLA
2 nd week of June		
3 rd week of June	Badlands	BADL
4 th week of June		
1 st week of July	Black Hills	DETO, JECA, MORU, WICA
2 nd week of July		
3 rd week of July		
4 th week of July	Northern	FOUS, KNRI, THRO
1 st week of August		
2 nd week of August		

The time frame for extensive woody sampling is not as constrained as it is for herb-layer measurements because woody species typically have their leaves before late May and retain their leaves beyond the August senescence typical of herbaceous vegetation. In Black Hills parks, where the evergreen ponderosa pine is dominant and deciduous tree diversity is low, extensive woody sampling could conceivably be done throughout the year (provided that crew members receive adequate training in recognizing deciduous species without their leaves), although this would compromise their ability to assess tree health/damage. The peak growing season is dedicated to sampling intensive plots. Therefore, extensive woody sampling is generally done in the “shoulder” season (i.e., in April, May, September, and October), but can be done any time in the scheduled year when time allows.

2.4 Allocating Sample Sites

The number of plots allocated to each park and to strata within parks is influenced by a combination of factors, including field work logistics, statistical power estimations (summarized below and detailed in Appendix A), and conformity to the desired revisit design. Plot numbers across parks are allocated roughly proportional to the size of the sample frame for that park, although the minimum number of plots per park was set at 15. Plots are allocated in increments of 5 to facilitate optimal use of the [2-3] or [2-8] revisit design. There were some exceptions to these general rules:

1. Estimates of the spatial variability of species richness within AGFO and SCBL, based on available FireEP and PCP data, were similar to variability for WICA. In addition, extra funding is allocated to AGFO and SCBL through the prototype monitoring program. Together, these lead to a relatively large number of plots with respect to park area at these two parks compared to the large parks.
2. THRO has more sites than BADL even though it has a smaller area because of the need to stratify between upland and riparian zones, as well as between units, at THRO.

Table 5 shows the minimum number of plots allocated to each stratum in the 11 parks in which park-wide plant community composition and structure monitoring occurs. Slightly higher

numbers of plots may occur after the first year of monitoring if previously dormant plots become active.

2.5 Rationale for choosing this design

Although the sampling and response designs for this protocol were designed to be appropriate for the vegetation and address the objectives, stressors, and logistic considerations of the NGPN, some components were specifically chosen to be consistent with the HTLN Vegetation Community Monitoring Protocol. This consistency between networks contributes to one of the five primary goals of the Vital Signs program – to provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments. The breadth of grassland vegetation monitored by the NGPN and HTLN programs will provide an unprecedented, consistent dataset across the central portion of the nation.

Rationale for the spatial and temporal components of this protocol's sampling design is provided in the sections above that describe those components. Therefore, this section focuses on rationale for the response design and the power analyses that support the spatial and temporal design.

2.5.1 Rationale for Response Design

Many sampling methods have been used to describe vegetation community dynamics in grassland and wooded communities. Despite the growing number of institutional monitoring programs (e.g., USDA Forest Service Forest Inventory and Analysis, Canada's Ecological Monitoring and Assessment Network), there is not now, and likely never will be, a standard method of sampling vegetation. This is because the most appropriate method for measuring the number of species and their relative abundance in a plant community depends on the objective of the project for which the measurements are done, as well as on the type of vegetation being measured. The advantages and disadvantages of each method must be weighed carefully when deciding on which method will be used.

NGPN and NGP FireEP considered a wide variety of methods for quantitatively describing vegetation. After narrowing down the possibilities based on logistical constraints, the two programs conducted a study comparing the two most promising methods of measuring herb-layer foliar cover – the point-intercept method used by NGP FireEP, and a modification of the visual estimate method used by PCP and HTLN. The study compared values of variables obtained with each method, as well as the efficiency and repeatability of the two methods. In addition, the power analyses for individual plot estimates of a limited number of variables were performed. The results of this 2005 study were published in a technical report (Symstad et al. 2006); therefore only a brief summary is given here.

Table 5. Plot allocation among strata and parks in the NGPN. Values in area columns are area of grid cells included in the sample frame for each zone.

Park/ Unit	Stratum/Zone	Area (acres)	Area (ha)	Minimum Intensive Plot #	Target Extensive Plot # ^a	Zone-wide Extensive Plot # ^a
AGFO ^b	Park-wide	2,787	1,128	15	0	0
	PCP (trail+control) ^b			5		
	Riparian ^c			"5"		
BADL	North Unit	98,372	39,827	100	0	0
DETO	Riparian lowland	139	56	5	20	30
	Upland	1,029	417	15	55	85
FOLA	Riparian lowland	234	95	5	20	20
	Upland	559	226	10	0	0
FOUS	Bodmer Unit	31	13	5	0	0
	Fort Unit	151	61	10	0	0
JECA	Park-wide	1,145	464	15	60	60
KNRI	Park-wide	1,312	531	20	20	40
MORU	Park-wide	1004	406	15	60	60
SCBL	Upland	2,917	1,181	20 ^d	0	0
	Riparian lowland	63	21		20	25
	PCP (restoration) ^b			4		
THRO- North	Riparian lowland	3,342	1,353	20	50	55
	Upland	19,743	7,993	30	0	0
THRO- South	Riparian lowland	2,122	859	20	50	55
	Upland	42,702	17, 882	70	0	0
WICA	Park-wide ^e	27,365	11,079	35		
	Currently wooded areas	9,212	3,730		80	90
	Riparian ^c			"5"		
<i>Total</i>				419 + "10"	435	

^aValues in the "Target Extensive Plot #" column are the target number for current forested areas, whereas values in the "Zone-wide Extensive Plot #" column is an estimate of the number of extensive plots needed throughout the zone to achieve the desired sample size of active plots, based on current vegetation. Intensive plots with tree and tall shrub species or otherwise meeting the requirements of an extensive woody plot (see Symstad et al. 2012: SOP Site Evaluation) will be counted towards the target extensive plot number and will be sampled for woody species on the extensive schedule. These are referred to as "dual plots." Extensive plots that have no trees or tall shrubs and, in Black Hills parks, no dead & down woody fuels, will be considered dormant (see section 3.2 Conducting Monitoring).

^bAt AGFO and SCBL, a subset of the plots established by the PCP program will continue to be monitored by NGPN using PCP methods. See Appendix D for more details on how these plots are treated.

^cAt AGFO and WICA, a riparian sampling method specialized for their narrow riparian corridors will be developed; this sampling method will use a different spatial design and the resulting data will be analyzed separately from data of the general plant community composition and structure monitoring. At each park, this sampling effort will be the time equivalent of 5 intensive plots.

^dAt SCBL, intensive sampling is not stratified, but extensive plots will be limited to the riparian lowland area.

^eThe estimate for WICA does not include the 2011 addition (5555 acres) or plots that may be established in that area.

Both methods were highly repeatable among observers, although the visual estimate method had slightly higher repeatability for total canopy cover. The greatest difference between the two methods was the amount of time spent collecting data (the point-intercept method approximately half that of the visual estimate method) and the number of species captured by the method (visual estimate method ~50% more than point-intercept method). The greater species capture of the visual estimation method is an advantage of this method. However, those species captured by the visual estimates but missed by the point-intercept method were of low and highly variable abundance, making the precision of the estimates on their abundance very low. These results, coupled with the advantage of having continuity with eight years of data collected previously by NGP FireEP, led to the decision to use the point-intercept method for herb-layer plant community cover monitoring.

The low species capture of the point-intercept method is its greatest disadvantage. To overcome this and increase our ability to detect rare species, we added nested frequency plots to this primary protocol. This addition also provides (1) comparability of species richness data with published literature, which often measures richness on a per-area basis; (2) incorporation of an alternate measure of plant species abundance that is less susceptible to short-term drivers than is cover (i.e., frequency); and (3) consistency with the HTLN vegetation community monitoring protocol. A single size for frequency measures would achieve most of these objectives, but incorporating different quadrat sizes allows a single sampling protocol to provide useful frequency information for a variety of species (Heywood and DeBacker 2007).

Protocols for measuring fuel loads and large shrub and tree composition and structure are essentially streamlined versions of the protocol used by the NGP FireEP. Thus, they are compatible with national-level FireEP data (USDI National Park Service 2003). Circular subplots are an accepted shape for forest mensuration used in the USDA Forest Service Forest Inventory and Analysis and many other I&M networks (e.g., NETN, NCRN). The circular plot size (10 m radius) is within the range used by these various programs.

2.5.2 Statistical Power to Describe Status and Detect Trends

Data from the PCP program at AGFO and SCBL, the NGP FireEP at seven NGPN parks, and NGPN pilot study work (Symstad et al. 2006) were used to assess the statistical power to detect trends and the expected precision of status estimates for a variety of plant community response variables measured with the intensive plant community composition and structure protocol. Four panel designs, three sample sizes, and ten estimates of variance were used for four vegetation attributes relevant to this protocol (total foliar cover, percentage of cover that is exotic, cover of dominant species, and species richness). A subset of the combinations of these factors was done to determine the effect of lengthening the revisit interval for the large parks. The details of these analyses are presented in Appendix A, but the general conclusion of the analysis was that the year-to-year variability in many response variables is so high, that the ability to detect trends is determined much more by the duration of monitoring than by the sample size, panel design, or revisit schedule (Figure 7).

Depending on how the status of a variable is determined, sample size can also have a relatively low impact on the precision of that estimate. Specifically, the status of a variable during a particular time interval can be calculated directly from the values observed during that interval. In this case, the number of plots sampled during that time has a large influence on the precision

of the estimate for that variable. However, that period may be anomalous, and the estimate obtained directly from the observed values reflects that anomaly. On the other hand, the status of a variable during a time period can be estimated from the trend line calculated from longer-term sampling. This estimate reflects the value of that variable as would be expected *on average* at that time, ignoring anomalous situations such as droughts or plagues of locusts. Because the precision of this estimate is determined by the long-term trend, which is affected primarily by the annual variability caused by those anomalous plagues and droughts, sample size at one time is less important for determining the precision of this status estimate.

Given that it will require approximately 20 years of monitoring to accurately describe a relatively small annual trend in most variables, good estimates of status without that trend line are important for providing information useful to park managers in the meantime. Thus, maximizing sample size within logistical constraints while still obtaining the detailed measures of composition that make vegetation monitoring so information-rich was of high priority in choosing the specific method to be used for this monitoring program. Consequently, the amount of time necessary to complete a method was given very high consideration in this decision process. Better estimates of spatial variability will be available after a full round of monitoring has been completed. At this time, we will re-examine our precision for estimating status and the sample sizes needed.

Data from a research project at MORU (Symstad and Bynum 2007) and the NGP FireEP at DETO and WICA were used to estimate the sample sizes needed for monitoring and management objectives in Black Hills ponderosa pine forest, and data from NGPN field work in 2008 from the parks that will have riparian extensive woody plots (DETO, FOLA, KNRI, SCBL, and THRO) were used to estimate sample sizes needed to meet monitoring objectives in riparian forests of these parks. Many analyses focused on sample sizes needed to estimate the status of forest structure (density of certain size classes of trees) across a sampling unit (e.g., FOLA riparian zone or all of MORU) with a variety of confidence interval widths, while other analyses using pre- and post-treatment (fire or mechanical thinning) data from the NGP FireEP focused on estimating sample sizes needed to evaluate specific management objectives in the ponderosa pine forest (e.g., 50% reduction of stems with DBH < 2.54 cm). The resulting sample sizes (Table 5) reflect the results of these analyses but are tempered by the logistical constraints of how many plots the two programs can sample in a given year. Details on the methods and results of these analyses are presented in Appendix A.

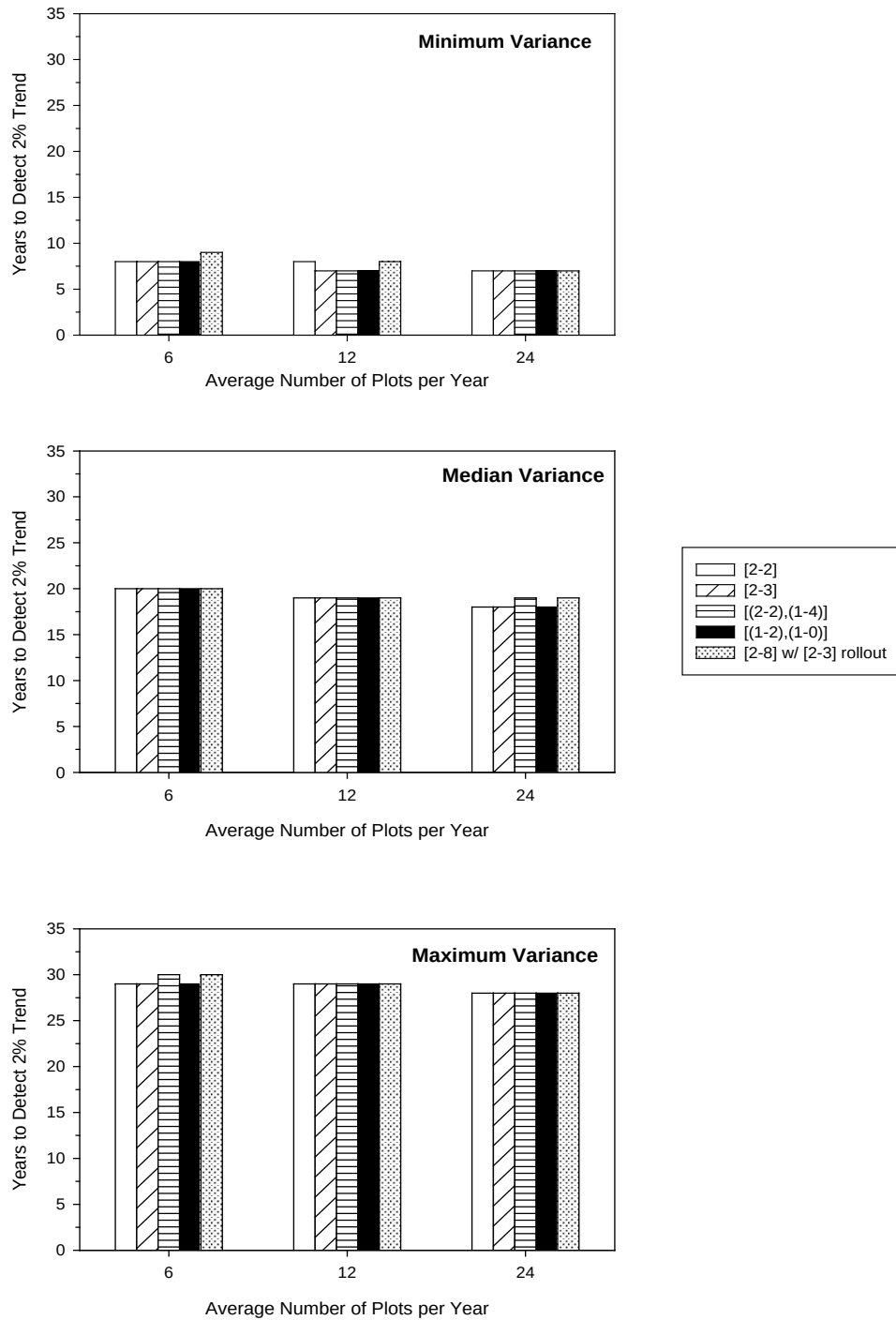


Figure 7. Comparison of revisit designs. Graphs show number of years necessary to detect, with 80% power, a 2% per year trend in $\ln(\text{species richness})$ for five panel/revisit designs, three sample sizes, and three variance estimates. For the panel revisit design, notation follows that of McDonald (2003): first in a pair of numbers indicates number of consecutive visits before rest; second in a pair of numbers indicates number of years rest; different revisit schemes for different sets of panels are separated by a comma.

3. Field Methods

This section summarizes the essential components of the field methodology. Detailed descriptions of procedures can be found in the companion publication of SOPs (Symstad et al. 2012). Below we cite only the SOP name used in Symstad et al. 2012.

3.1 Field Season Preparations and Training

The Plant Ecologist is responsible for ensuring that preparations are made for the coming field season (SOP Field Preparation) but preparation duties are shared between the Plant Ecologist and the Plant Lead Biological Technician (Plant Lead Biotech). They determine which plots will be established or revisited that season from the Vegetation Monitoring directory maintained by NGPN Data Management. They schedule sampling dates and organize logistics, including scheduling park housing or camping, hotel reservations, and vehicle use. They contact park staff to confirm logistical arrangements. They prepare park folders containing park species lists and maps of plot locations and upload files onto GPS units. They prepare plot folders containing data forms, maps and directions to plots, plot species lists, and photographs for locating plot corners. They organize, order, and repair equipment and field supplies as necessary prior to the beginning of the sampling season.

The Plant Ecologist is responsible for training crew members and ensuring their understanding of all procedures prior to any data collection. This training includes review of this entire protocol, including all relevant SOPs, and review of plant identification using live and dead plant material, field guides, and NGPN-specific “cheat sheets” (identification guides for difficult-to-distinguish species). This identification training is particularly important because plant misidentifications are difficult to trace once the field season begins and the learning curve in the field is greatly reduced with pre-field study. The training process is described in detail in SOP Training.

3.2 Conducting Monitoring

When evaluating plots, plots must be visited in the specific order described in SOP Site Evaluation. Revisits to established plots may occur in whatever order is appropriate within a park, so long as the sampling time remains within the designated window for that location (Table 4). If there is concern that not all plots will be visited, the priority should be to complete the plots in each panel that were lower in the GRTS draw. The Plant Ecologist and Lead Plant Biotech decide the sequence in which plots are sampled and assign plots to each crew.

Figure 8 outlines the procedures followed at a potential monitoring site on the first visit to that site. After navigating to the plot location (SOP Using the GPS), the site is compared against established rejection criteria to determine whether it will be rejected completely, considered dormant, or established as an active, permanent plot (SOP Site Evaluation). A site is rejected if it meets any permanent rejection criteria (e.g., on or largely comprised of an inaccessible rock outcrop). A site is considered dormant if it passes all permanent rejection criteria but meets one or more temporary rejection criteria (e.g., not currently owned by the park). A site is established as active if it passes all rejection criteria.

Figure 9 outlines the procedures followed at a site designated as dormant or active. Because sites may be evaluated years before their establishment and first data collection visit, all sites are reevaluated at each visit, following SOP Site Evaluation. Plot establishment (if not already

done) and data collection then proceed according to whether the plot is dormant or active; intensive, extensive, or dual; and, if dual, whether intensive or extensive only measurements are scheduled for that plot for that year. Data collection at dormant sites is limited to photography (where possible), whereas data collection at active sites includes plant community composition and structure measurements and repeat photography. For intensive plots, it is anticipated that the number of dormant plots will be small and that, once established, an active plot will remain active in the vast majority of circumstances. The most likely situation that would cause an active, intensive plot to become dormant is its being engulfed by a meandering stream. In contrast, the proportion of extensive woody plots that are dormant will be relatively large in many parks because an extensive woody plot is designated as active under more limiting circumstances (tree, tall shrub species, and/or downed woody fuels present in or near the designated site; see SOP Site Evaluation). In addition, the transitions from active to dormant and vice versa could be more frequent with extensive woody plots because of the dynamic nature of the prairie-forest border and floodplain forests in NGPN parks. To increase consistency of sample sizes and continuity in data, and to minimize complications and confusion due to these dynamics, site characterization criteria for woody extensive plots incorporate the history of the plot: once established as active, a plot remains in that state for at least three visits (see SOP Site Evaluation).

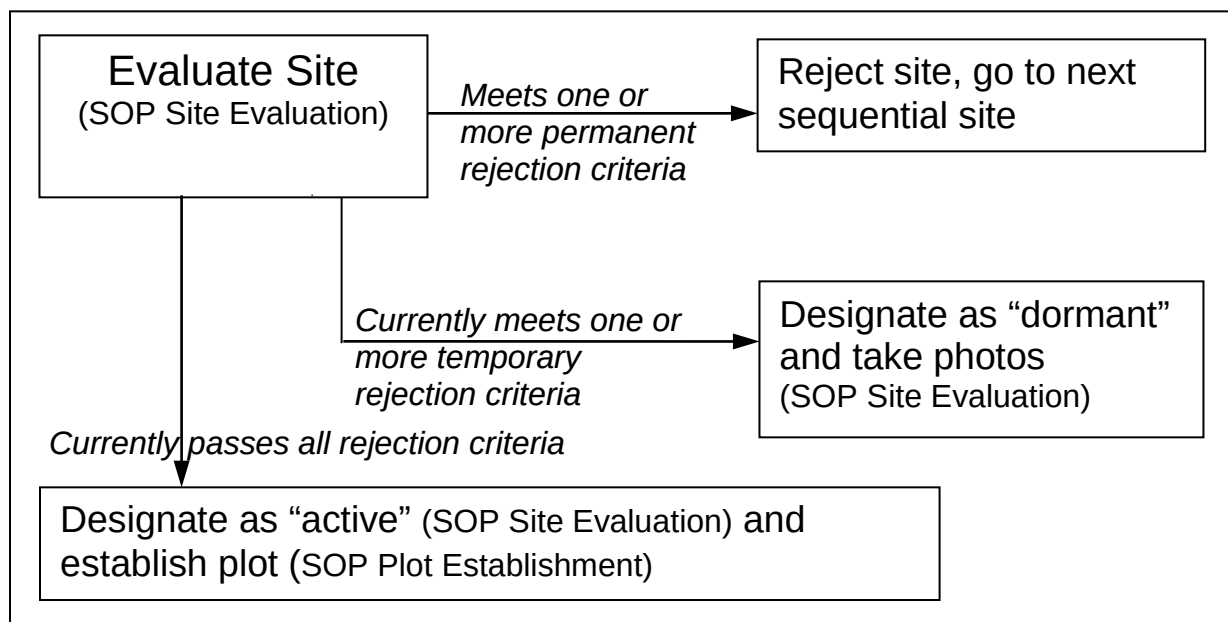


Figure 8. Outline of initial field procedures on the first visit to a potential monitoring plot. If a plot is designated as dormant or active, procedures outlined in Figure 9 are followed.

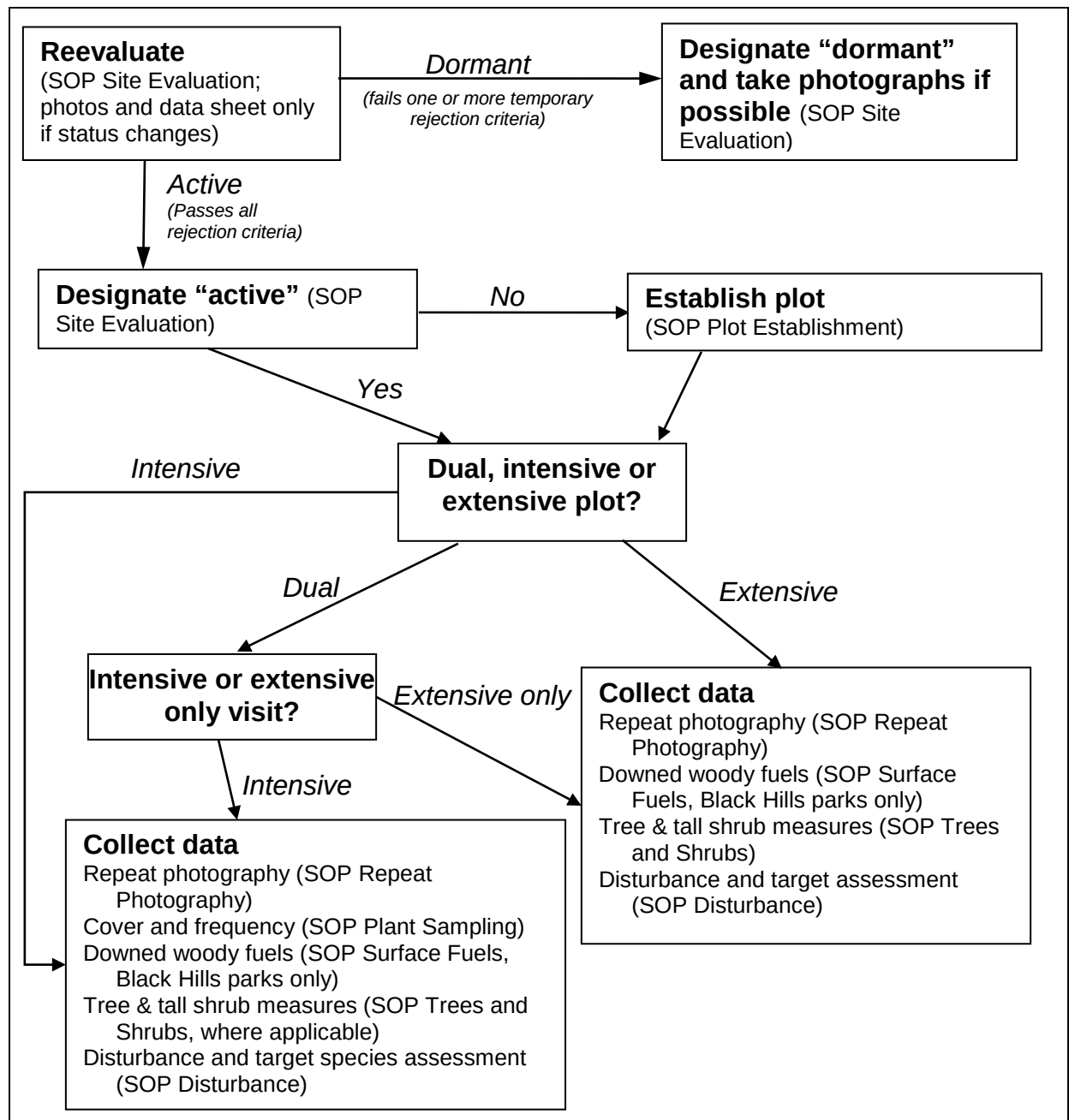


Figure 9. Outline of procedures followed at a site after initial evaluation. Because initial evaluation of a site may occur many years before data collection begins at that site, and because conditions can change, reevaluating the suitability of the site is necessary at all visits. Order of data collection procedures should follow that shown in the figure to avoid trampling impacts on each data type. Dual sites are possible anywhere in the park at DETO, JECA, and MORU; only in the riparian lowland stratum at FOLA, SCBL, and THRO; and in the areas designated for extensive sampling at KNRI and WICA detailed in Appendix B.

3.2.1 Intensive Plots

Locations of all intensive plots will be determined before monitoring begins in the site evaluation process (SOP Site Evaluation). At this time, a single plot marker, marked with a metal tag identifying the plot and the marker as the center (C), is driven into the ground at the center of the plot. At plot establishment (which may be done prior to the first visit for data collection), two permanent transects are marked by driving markers into the ground at the end points of each transect (SOP Plot Establishment). A metal tag imprinted with the park code, plot ID, corner name (A0, A50, B0, or B50), and establishment date is attached to each marker. Each transect is also marked with large nails and washers sunk flush with the ground at 10.92 m, 23.42 m, 35.92 m, and 46.84 m from the 0 end of each transect. At each transect end, a photograph is taken down the length of the transect. Additional photographs may be taken to capture the entire plot. When trees and/or tall shrub species are present in or near the plot, the ends of two additional perpendicular, 100-ft^a (30.49 m) transects centered at the C plot marker are marked with large nails and washers (Figure 2a). One of these transects is parallel to the herb-layer transects and the second is perpendicular to that transect.

Herb-layer and ground cover data are collected by two pairs of observers, each working on a single transect. Starting at the 0 end of each transect, a 50-m tape is stretched over the length of the transect, ensuring that it follows the path marked by the nails and washers. Foliar cover, ground cover, and plant height data (point-intercept method) are collected first (SOP Plant Sampling) because these measurements are most sensitive to trampling. The observer and recorder stand and walk on the side of the transect opposite of where the nested frequency quadrats are located to prevent trampling effects on the vegetation that is monitored. Nested frequency data are collected only after point-intercept data collection is complete. Nested quadrats are located so that they go into the 20 m x 50 m plot and towards the 50 end of the transect (Figures 2a, 3). Beginning with the 0.01 m² quadrat, all species rooted in the quadrat are identified and recorded. Once all species in this quadrat are recorded, the observer moves onto the 0.1 m² quadrat, listing only species not observed in the 0.01 m² quadrat for the scribe to record. This is repeated in the 1.0 m² and 10 m² quadrats. Only species rooted in each quadrat are included in the species list for that quadrat. A reference list for each 10 m² quadrat lists the names of species previously collected in that quadrat for comparison to those being recorded after the quadrat has been searched thoroughly. If any species from previous years were missed, the quadrat is searched again for the species. Comparison with the previous year's species list maintains consistency in species identification and creates a check for missing species, but this species list is used cautiously (i.e., only after the observers feel they have found everything) to avoid bias. Unknown or unidentifiable species are given a unique code and catalogued following SOP Unknown Plants.

Measurements of woody fuel loads are also sensitive to trampling, but these measurements are done in locations different than the herb-layer measurements. Therefore, where ponderosa pine is present in or near the 0.1 ha plot, woody fuel loads are measured immediately after herb-layer sampling is completed. These measurements are done on the two perpendicular transects centered at the center of the 0.1 ha plot using the Brown's Line method (Brown 1974, Brown et al. 1982), following SOP Surface Fuels. On each transect, duff and litter depths are measured at

^a Because the dead and down fuel sampling method (SOP Surface Fuels) uses English units, we use English units when describing distances used in this method.

ten locations along the transect. Dead and detached woody fuel are also measured on these transects by tallying the number of items in a given size class for a pre-determined length (Table 6) along the 100-ft transect.

Table 6. Summary of sampling scheme for fire fuels. Fuel hours refers to the approximate number of hours necessary for the moisture of the fuel to equilibrate with the moisture of the environment.

Fire Fuel Class	Diameter (inches)	Condition	Fuel hours	Sampling length (ft) along 100-ft transect
1	0 – 0.25	not applicable	1	0 – 6
2	0.25 – 1	not applicable	10	0 – 12
3	1 – 3	not applicable	100	0 – 12
4	> 3	sound	1000	0 – 100
5	> 3	rotten	1000	0 – 100

After completing Brown's transects, tree and tall shrub data are collected following SOP Trees and Shrubs. In the first (standardized by relationship to slope of plot) quarter of the 10 m-radius circle at the center of the plot, stems of all tree species and selected tall shrub species more than one year old (i.e., no cotyledons present and stem woody) but with DBH < 2.54 cm are tallied by species and height class (≤ 137 cm vs. > 137 cm). Seedling counts are continued in the remaining quarters of the circle, with values being recorded separately for each quarter. Counts for an individual species may cease after the sum of seedlings of that species for one or more quarters is greater than 100; however, the count for this species must be complete for the entire quarter in which this sum is reached. The area (number of quarters) counted for each species is recorded. This flexibility in the number of quarters in which seedlings are counted is necessary to prevent extraordinary amounts of time spent counting seedlings in very dense stands. In addition, DBH, status (live or dead) and species are recorded, by quarter, for all pole-size ($2.54 \text{ cm} \leq \text{DBH} \leq 15 \text{ cm}$) trees and tall shrubs in the 10 m-radius circle. All trees with DBH > 15 cm in the 20 m x 50 m plot, which is bordered by the herb-layer transects, are mapped and marked with metal tags, and their species, DBH to the immediate lower 0.1 cm, and condition code (Table 7) are recorded.

3.2.2 Extensive Woody Plots

Monitoring procedures in extensive woody plots are essentially a subset of those used in intensive plots. Once the site of an extensive woody plot is designated as active, it is established by driving one piece of rebar into the ground at the center of the 10 m-radius plot. The rebar is marked with a metal tag imprinted with the park code, plot ID, and establishment date. The ends of two perpendicular, 100-ft transects centered at this rebar and oriented with respect to the dominant aspect of the plot (see SOP Site Evaluation) are marked with large nails and washers (Figure 2b). Photographs are taken from the beginning and end of each transect towards the center of the plot.

Table 7. Condition categories and codes for standing trees.

Category	Description	Code
Standing Dead		
Recent snag	Recently dead tree with bark intact; branches and needles/leaves may also be intact.	RS
Loose bark snag	Tree dead several years; bark partially deteriorated and fallen off; tops often broken.	LS
Clean snag	Tree dead several years; bark completely gone and most branches usually gone; tops often broken.	CS
Standing Live		
Sound	Nothing wrong with tree – i.e., none of the other condition codes apply.	SND
Dieback	Recent mortality of branches with fine twigs that begins at the terminal portion of a branch and proceeds toward the trunk. Considered dieback only when it occurs in the upper and outer portions of the tree, not in lower portion where self-thinning is expected. Designate only if dieback comprises >10% of crown.	DBK
Foliage discoloration	At least 30% of the foliage is more than 50% affected, where affected means foliage is more of some color other than green.	DIS
Decay	Signs of advanced decay present. These include conks and fruiting bodies on the main bole and at the point of branch attachment; bird cavities; and “punky” (soft, moist, degraded) wood.	DEC
Insect signs	Visible insect use of tree, including piles of frass, pitch tubes, or bark beetle galleries.	INS

Where ponderosa pine is present in Black Hills parks (DETO, JECA, MORU, WICA), woody fuel loads are measured first, using the methods described above and in SOP Surface Fuels. Tree and tall shrub data are collected according to SOP Trees and Shrubs. The methodology is the same as in intensive plots except that trees (DBH >15 cm) and poles ($2.54 \text{ cm} \leq \text{DBH} \leq 15 \text{ cm}$) are not mapped or tagged, and trees are recorded only within circular plot. For areas with sparse tree/pole cover (<5 trees or poles within the 10 m radius), the radius is extended to 20 m.

3.2.3 All Plots

Before leaving any sampling site, all equipment, collected specimens, and data sheets are reviewed for completeness and accuracy, accounted for, and stored in their proper locations. When leaving the field each day, the Plant Ecologist or his/her designee checks data sheets and labels on unknown specimens for completeness and readability, and missing information is added and errors are corrected as much as possible. At the end of a tour, scans of data sheets are made and checked for legibility and completeness (e.g., nothing in margins is lost). These digital files are stored on a server with an offsite back-up.

3.3 End of Season Procedures

At the end of the field season but while all field crew members are still available, a final, thorough check of all data sheets is completed to clarify any ambiguities, and the Plant Ecologist and crew members review the protocols for their clarity and efficiency. When substantial issues of the protocol are identified, the Plant Ecologist or his/her designee completes a Protocol Review form and stores it with the protocol to aid in future revisions. The Plant Ecologist or his/her designee also completes a Field Season Review form, which describes logistical problems, departures from protocol, species identification problems, and other issues that affect

the quality and/or quantity of data collected. This form is stored in hard-copy form with the data from that field season.

Unidentified specimens are permanently mounted according to procedures in SOP Unknown Plants, and they are identified as specifically as possible using taxonomic keys and in consultation with experts. Identification information is annotated on relevant data sheets and in the species list of the NGPN-FFI Database. The equipment list is updated with the number of equipment items that are functional and available for the next field season. This list is compared to perceived needs of the next season, and supplies are replenished and equipment repaired as necessary.

Data are entered into the NGPN-FFI Database by field crew members following the procedures described in the next section.

4. Data Management, Analysis and Reporting

This protocol will result in the annual collection of thousands of observations about plant community composition and structure. The purposes of data management are to ensure accurate recording of these observations when they are collected in the field, to assure correct transfer of these records into an electronic database, to thoroughly document the data for future utility, and to maintain these records for access in perpetuity. Regular data analysis and subsequent reporting translate the raw data into meaningful information that park managers can use to guide and evaluate natural resource management practices.

Effective long-term monitoring requires procedures for good data management, analysis and reporting. The NGPN's Data Management Plan (Appendix E in Gitzen et al. 2010) describes these procedures in general terms. The following sections outline the application of those procedures to plant community composition and structure monitoring, and two SOPs (Symstad et al. 2012: SOP Data Management and SOP Data Analysis) describe these procedures in detail.

4.1 Data Management

4.1.1 Overview of Database Design

FFI (FEAT/FIREMON Integrated; <http://frames.gov/ffi/>) is the primary software environment for managing plant community data. NGPN uses its components for data entry, data storage, and basic summary reports. Although developed from products originally used by the fire effects monitoring community, it is useful for a wide range of ecological information, including the plant community data collected through this protocol. A "Protocol Manager" tool enables the user to create data entry and summary tools tailored to a specific monitoring protocol. FFI is used by a variety of agencies (e.g., NPS, USDA Forest Service, U.S. Fish and Wildlife Service), has a national-level support system, and generally conforms to the Natural Resource Database Template standards established by the Inventory and Monitoring Program. Staff members of the NGP FireEP were involved in its testing and development and therefore they have a unique understanding of the software and good working relationships with its developers.

FFI is based on a hierarchy of geography, time, and sampling method. The geographic hierarchy is represented by the administrative unit (e.g., park), project unit (e.g., riparian area), plot, and sample (e.g., point on a point-intercept transect). The temporal component is represented by scheduled sample events. Plot information and data are entered using forms and protocols that are part of the FFI software. Species nomenclature and attribute (life form, origin, etc.) information are stored within the species management area of FFI; a species list is tied to data entry protocols for validation and to summary protocols for reporting values by species attributes. Details about FFI as used by NGPN are given in Symstad et al. 2012: SOP Data Management.

4.1.2 Data Entry, Verification, and Validation

Data entry is the initial set of operations in which raw data from paper field forms or data loggers (i.e., GPS units) are entered into a database. Data entry is best performed by a person who is familiar with the data and data collection processes. Data entry takes place as soon as possible after collection by field crew members. GPS data are downloaded into the project's GIS database no later than at the end of a field tour. Plant community composition and structure data are entered whenever possible during a field season (e.g., in spare time at the end of a day or at

the end of a tour before the next tour is scheduled to begin), but should be completely entered and verified before the seasonal crew leaves. The Plant Ecologist is responsible for training crew members on the use of the database software and proper data entry and checking procedures.

The goal of data entry is to transcribe data from paper records into the computer with 100% accuracy. The FFI data entry forms include quality assurance and quality control (QA/QC) features to minimize transcription errors. These include park-specific species lists that ensure correct nomenclature and prohibit entry of species not known to occur in a park (this can be overridden for new discoveries or unknown species).

Data verification occurs immediately after data entry; a printout of the entered data is compared against the original field forms and errors are corrected immediately. To minimize transcription errors, 100% of records are verified to their original source. A further 10% of records are reviewed a second time by the Plant Ecologist and the results of that comparison are reported as part of the metadata. If errors are found in the Plant Ecologist's review, the entire data set is verified again.

Data validation ensures that collected and entered data are accurate and logical. It occurs at three times: before the field crew leaves a plot, during data entry, and after data verification is complete. For example, a DBH of 327 cm might be recorded for a green ash tree, but it is illogical and almost certainly incorrect (32.7 cm is more likely). The crew lead should find and correct this mistake when checking data sheets at the end of data collection before leaving the site. This mistake might be missed, however, and caught during data entry. FFI data entry forms are designed to minimize errors such as skipping subplots or points, but other validation procedures are necessary. Some validation of plot data takes place during data entry, but after verification is complete, the Plant Ecologist does a complete validation process described in SOP Data Management. Validation of spatial database information (e.g., coordinates of plot locations) is accomplished using ArcGIS. Locations are mapped on appropriate backgrounds (aerial or satellite imagery, topographical maps, park boundaries, etc.) for visual inspection. Two crew members that visited that location are responsible for validating the location.

During the entry, verification and validation phases, the Plant Ecologist is responsible for the data. The Plant Ecologist must assure consistency between field forms and the FFI database by noting how and why any changes were made to the data on the original field forms. In general, changes made to the field forms should not be made via erasure, but rather through marginal notes or attached explanations. Once validation is complete, the paper data forms and the electronic files are turned over to the Data Manager for archiving and storage.

4.1.3 Metadata, Data Archiving, and Editing Procedures

Once a database has passed the QA/QC procedures specified in the protocol, the Data Manager creates a new metadata record for the database based on the Metadata Interview Form completed by the Plant Ecologist (SOP Data Management.). The Data Manager then places a read-only electronic version of the database on the NGPN server as the archive. Backup copies of the data are maintained at the NGPN office and an additional digital copy is forwarded to the NPS Inventory and Monitoring Program Archive. Tape backups of all NGPN server files are made daily. On a weekly basis, one tape is transferred for storage offsite at Mount Rushmore National Memorial (MORU). Both sites store tapes in a secure, access-restricted lockbox.

The Database Manager maintains a data management log for each project. This log includes a data edit log, which records changes made to data sets after they have been archived. Such changes are inevitable and necessary, but they are done only under the following conditions: 1) data integrity must be maintained; 2) once archived, all changes to the data set must be documented; and 3) mistakes made during editing must be recoverable. Any editing of archived data is accomplished jointly by the Plant Ecologist and Data Manager. Every change must be documented in the data edit log and accompanied by an explanation that includes pre- and post-edit data descriptions. Once the data are archived, original field forms are not altered. Field forms can be reconciled to the FFI database through the use of the data edit log.

Prior to any changes in an archived data set, a copy is stored with the appropriate date in the file name, which allows for the tracking of changes over time. Versioning of archived data sets is handled by changing the date included in the file name. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Frequent users of the data are notified of the updates and provided with a copy of the most recent archived version.

Data for which all QA/QC has been completed will be available for research and management applications by requesting them from the NGPN Data Manager. Eventually, plant community composition and structure monitoring data will be available for download directly from the NPS Natural Resource Information Portal maintained by the national I&M office. Data requests should be directed to:

NGPN Data Manager
National Park Service
231 East Saint Joseph Street
Rapid City, SD 57701
605-341-2804

4.2 Data Analysis and Reporting

Plant community composition and structure monitoring is information-rich, with a nearly infinite number of components or combinations of components that can be analyzed and reported. A major challenge, then, is to distill the large amounts of information available into meaningful reports that managers can comprehend and use. The analyses and reports described in this section are only a subset of those that could be performed. The parameters that will be reported automatically and regularly were chosen because they incorporate information useful to all park natural resource managers, they provide an evaluation of indicators of ecosystem health or stressors, and because they are useful for comparing widely varying vegetation types and park units. Additional analyses could be performed when park managers require information about a specific subset of species, location in a park, size class of tree, etc.

Four general types of data analyses are performed:

1. Annual calculation of descriptive and summary statistics for the most recent monitoring observations
2. Determination of status and trends of selected parameters

3. Synthesis of status and trend information from this protocol in concert with information from other protocols (e.g., Landscape Pattern and Dynamics, Weather and Climate, Land Birds) to examine larger scale aspects of ecosystem structure and function.
4. Re-assessment of the magnitude of sources of variability in the overall sampling design

4.2.1 Annual Summaries and Reports

Annual summaries are intended to provide an accounting of the number of monitoring plots visited in a year and a summary of the field measures on those plots. Data for an annual summary are plot-level measures derived from subsamples (points, subplots) collected on a plot. Table 8 lists the summary variables and indices reported from a single year's data. For each of these attributes, the mean, median, minimum, and maximum plot-level value is reported for the whole park and individual strata (where applicable), and the number of plots contributing to each of these values is noted. The standard deviation or standard error of each attribute is reported as a measure of variability. Although annual summaries are not intended to provide status and trend information, certain attributes (such as frequency and abundance of target exotic species) may be of immediate interest to park management.

In addition to providing these data summaries, annual reports contain an overview of any necessary changes to protocol procedures and proposed future monitoring efforts. An annual report is generated separately for each park. For parks with extensive woody plots, a one-year summary of these data is included in the annual report for the year in which the sampling was completed (i.e., only once every five years).

4.2.2 Status and Trends and Comprehensive Synthesis Reports

Status and trends reports document analyses that determine the status and trends in selected parameters, as well as the confidence in those estimates. The first step in these assessments generally is to generate a graph of a parameter's mean and some measure of its variability versus time. These graphs enable the analyst to determine which analysis techniques beyond the standard method may be appropriate. The standard analysis technique is a mixed-effects model that examines whether a trend in a specific parameter is significantly different from zero. The status estimation for this parameter is determined by its trend line: if the trend is zero, the status is simply the average of all observations over some meaningful window of time; if the trend line is not zero, the status is the value estimated from the trend line for a particular point (or range of points) in time. When appropriate, these analyses will incorporate other information (e.g., climate data) to account for factors that are known to drive certain plant community parameters in the northern Great Plains.

The first status and trends report, covering all parks in the Network, will be completed in the sixth year after data collection commences, after a complete rotation of the panel design is completed in all but BADL and THRO. Status and trends reports will then be completed at least every five years after that, but they may be done more frequently if trends are occurring, if new management practices are implemented, or if a resource attribute is believed to be changing rapidly. When a trend is detected, the report will highlight this trend so that park managers are fully aware of its occurrence.

Table 8. Attributes to be summarized and reported in annual reports.

Measure	Attribute or Context	Spatial Scale(s) of Observation
Absolute Percent Cover	Herb-layer total cover	Point-transects
	Herb-layer graminoid cover	
	Herb-layer forb cover	
	Herb-layer shrub cover	
	Herb-layer cover of target species ^b	
	Ground-layer bare soil cover	
Relative Cover	Percentage of herb-layer cover that is exotic (=exotic cover/total cover)	Point-transects
	Percentage of graminoid cover that is warm-season (=warm-season graminoid cover/graminoid cover)	
Percent Frequency ^a	Targeted individual species ^b	0.01, 0.1, 1.0, 10 m ² ; plot
Species Richness (number of species)	Native species richness	Point-transect; 1.0, 10 m ²
	Exotic species richness	
	Graminoid species richness	
	Forb species richness	
Species Diversity (H') and Evenness (J')	All herb-layer species	Point-transect
	Native herb-layer species	
Density	Individual tree species by size class (seedling<1.37 m tall, seedling>1.37 m tall, pole, tree)	314.2 m ² or 0.1 ha
	All tree species combined by size class (seedling<1.37 m tall, seedling>1.37 m tall, pole, tree)	314.2 m ² or 0.1 ha
	All tall shrub species combined by size class (seedling<1.37 m tall, seedling>1.37 m tall, pole)	314.2 m ²
	Snag density by size class (≤15 cm DBH, >15 cm DBH)	314.2 m ² or 0.1 ha
Dead and down woody fuel load	Fine (1, 10, and 100-hr)	Two 100-ft transects
	Coarse (1000-hr)	
	Litter	
	Duff	
	Total	

^aPercent frequency at the plot level is the percentage of plots in which that species occurs.

^bDetermined for each park or park unit. Examples: a dominant grass species, an invasive species targeted for control.

When appropriate, status and trend analyses will be supplemented with more in-depth evaluation of all collected plant community composition and structure data in concert with information from other Network protocols and other sources (parks, partners, etc.). These comprehensive synthesis reports will seek to understand the status and trends of plant community attributes. They will report results of statistical techniques incorporating data from other vital signs monitoring to discern relationships among the monitored parameters. When such combined analyses are not possible, trends or patterns discerned from analyzing data from other vital signs or from other sources will be used to generate hypotheses regarding the reasons for observed changes in plant community composition and structure. For example, fluctuations in prairie dog colony size cannot be incorporated into a statistical model evaluating vegetation trends, but

parallel patterns between colony size and a vegetation pattern would suggest a connection between them.

Comprehensive synthesis reports supplement status and trends reports by examining the potential reasons behind the patterns of status and trend. One or more of these reports will be completed on a regular schedule, beginning when relevant supplementary information is available. A comprehensive synthesis report will usually cover a single park or a group of similar parks (e.g., small parks in the Black Hills). A potential schedule for comprehensive synthesis reports is in Symstad et al. 2012: SOP Data Analysis.

4.2.3 Variance Assessment and Report

Regular reevaluation of the sampling design ensures that the design is achieving the sampling objectives and may illuminate the need to adjust the design. After five years of data have been collected, and at regular intervals after that (5-10 years), a variance assessment similar to that described in Appendix A will be performed. This assessment will determine if reallocation of plant community sampling efforts between sampling types, within and among parks, and to other vital signs is needed and will guide any necessary reallocation. Results of this assessment will be reported as a separate, network-wide report, or, if appropriate, as part of a park's annual summary report.

4.2.4 Report Dissemination

The primary outlet of reports will be the NPS Natural Resource Publications system (<http://www.nature.nps.gov/publications/NRPM/>). Annual reports and some status and trends reports will be produced as Natural Resource Data Series or Technical Reports. More comprehensive status and trends reports, as well as comprehensive synthesis reports and variance assessment reports will be produced as Natural Resource Technical Reports. All of these are available to the general public through the NPS Natural Resource Publications website. Some results will also be submitted as articles to *Park Science*, an NPS journal, or to peer-reviewed, scientific journals. These outlets usually receive broader attention than NPS data series and technical reports, but they usually do not allow the extent of information that can be included in the report series publications. All output will adhere to NPS peer-review and publication approval requirements. All published documents will be catalogued in the NPS Integrated Resource Management Applications Portal (<https://irma.nps.gov/App/Portal/Home>) and provided in hard copy and electronic format to the NGPN technical committee representative of the park(s) to which the document applies. Oral presentations may be made at annual NGPN Technical Committee meetings and at regional and national conferences/meetings.

5. Personnel Requirements and Training

5.1 Roles and Responsibilities

The Plant Ecologist is the project lead for this protocol; implementation of plant community composition and structure monitoring is his/her primary responsibility. This person is supervised by the NGPN Network Coordinator, who assures that the project is supplied with resources adequate to accomplish its objectives. Because of the need for a high level of consistency in implementing the protocol, the Plant Ecologist will be responsible for training the seasonal and permanent personnel assisting with the monitoring efforts. The data management aspect of the monitoring effort is the shared responsibility of the Plant Ecologist and the Data Manager. Typically, the Plant Ecologist is responsible for data collection, entry, verification, validation, summary, analysis, and reporting. The Data Manager is responsible for database design, data security, data archiving, and data dissemination. The Data Manager, in collaboration with the Plant Ecologist, also develops data entry forms, database features for quality assurance, and automated report generation procedures. The Data Manager is ultimately responsible for ensuring that adequate QA/QC procedures are built into the database management system and that appropriate data handling procedures are followed.

Additional roles and responsibilities of specific project staff are as follows:

Plant Ecologist – hires seasonal staff, applies for park research permits, conducts or arranges training of new staff on field and data entry protocols, leads field crew, collects data, reviews procedures in the field, resolves questions about methods and procedures, revises protocols as necessary, works with Quantitative Ecologist to analyze data and prepare reports, and presents results to park staff.

Plant Lead Biological Technician – assists Plant Ecologist in hiring and training seasonal staff, ensures that required equipment is available and in good condition prior to the field season, contacts parks regarding logistics of site visits, makes travel arrangements, prepares site packets (data forms, maps, etc.), schedules field activities, leads a field team, and collects and enters data.

Seasonal field technicians – perform all field procedures, collect and enter data, and provide feedback on methods during and after season.

Quantitative Ecologist – works with Plant Ecologist to analyze data and prepare reports. [This person will not be Network staff because these skills are not needed every year. The Network will dedicate funds every 5-10 years to obtain this expertise through another I&M network, the national I&M office, or outside partners (e.g., USGS, university).]

Data Manager – reviews data quality assurance and quality control procedures, performs data archiving, modifies database if necessary, and prepares metadata.

GIS Specialist – programs GPS units, provides GIS and GPS support, maintains spatial database.

All involved staff participate in end-of-season project review procedures.

5.2 Qualifications

This section describes the necessary qualifications of the staff whose primary responsibility is plant community composition and structure monitoring. Necessary qualifications for others involved in this protocol (Data Manager, Network Coordinator) are described in other NGPN documents.

The Plant Ecologist must be a highly organized, detail-oriented person with strong botanical skills and ecological knowledge, and have a good understanding of statistical theory and sampling design. Although this person's botanical and ecological knowledge may not be specific to the Black Hills and northern Great Plains initially, s/he must possess the skills to learn new plants quickly, learn about ecological processes that drive vegetation dynamics in this region, and apply that knowledge in field work, data analysis, and reporting.

The Plant Lead Biotech must also be a highly organized, detail-oriented person with strong botanical skills. As with the Plant Ecologist, this person's botanical knowledge may not be specific to the region initially, but s/he must be able to build this knowledge quickly. S/he must have the people skills necessary to lead a portion of the crew and interact with park staff for organizing logistics.

Field technicians do not have the luxury of having a lot of time to learn new plants. Thus, at least two of the six technicians hired each year must have a high level of knowledge of plants in the Black Hills and northern Great Plains and botanical skills developed enough to know when they do not know a plant. These more highly skilled technicians, along with the Plant Ecologist and Plant Lead Biotech, will generally be responsible for making the observations that require plant identification in the field (i.e., point-intercept and nested frequency measurements). The other field crew members will be responsible for recording these observations. They will also be involved in collecting data for all other measurements (e.g., tree and tall shrub, fuel measurements). Thus, all field technicians must be detail-oriented to ensure the high quality of data collected and recorded in the field and entered into the database in the office. Additional necessary qualifications for all involved in field work include the ability to work methodically and consistently under difficult conditions and the ability to hike long distances over sometimes rough terrain. Experience with vegetation measurement methods and familiarity with local environmental conditions and hazards are also desired qualifications.

5.3 Training Procedures

Training procedures and content are detailed in Symstad et al. 2012: SOP Training. All participants in plant community and structure monitoring are required to participate in training prior to the beginning of each field season. All crew members must review this protocol narrative and SOPs for procedures in which they will be involved. Permanent NGPN staff will provide training on navigation and recording using a GPS receiver and field procedures for collecting monitoring data. Of special concern is the ability of crew members to correctly identify plant species and to objectively record point-intercept data. Herbarium specimens and comparative notes on difficult or uncommon species are provided as part of the training. These notes will be one of the source materials used for plant identification in the field. Field technicians involved in measurements requiring plant identification will be tested frequently on their ability to identify the relevant species, with the testing tailored for problematic species. Time should also be invested in training personnel on objective and consistent point-intercept

measurements, rules for inclusion of plants in nested frequency observations, and layout of sampling transects. All of these strongly affect monitoring results. Participants will also receive training in safety, administrative processes and policies, information technology policies, and wilderness/backcountry procedures.

6. Operational Requirements

Field teams for intensive plots consist of four people – either the Plant Ecologist or the Plant Lead Biotech, one field technician with strong Black Hills/northern Great Plains botanical knowledge, and two other field technicians. In general, two field teams conduct intensive plot monitoring; during the North Dakota tour an additional field team (from the FireEP) joins these two teams. For the last week of the intensive season only one team visits the AGFO riparian area. Each intensive plot field team needs a vehicle and equipment dedicated to their work during the intensive plot monitoring season. Field crews for extensive woody plots consist of two people. A minimum of two of these teams conducts extensive woody monitoring at a limited number of parks each year. Two extensive teams can share a vehicle, but each team must have their own equipment during the time that they are sampling.

6.1 Annual Workload and Field Schedule

This protocol is designed to produce a nearly uniform workload each year, with 40% of the total number of intensive plots being sampled in one year (Table 5) on the same field schedule (Table 4). However, variations in the number of extensive woody plots sampled each year occur because the number of extensive woody plots varies among parks and different parks are monitored each year. The field schedule is based on the assumptions that one four-person field team can sample two intensive plots per day, one two-person field crew can sample two extensive woody plots per day, and work weeks consist of four 10-hour days. Depending on the distance of travel, work weeks are sometimes combined into tours of eight consecutive days. Travel time is accounted for in the field schedule.

Hiring processes begin in late October of the year prior to field work, field work preparation occurs in March-early May, training occurs in the second half of May, intensive plot field work occurs from the first week in June through the second week in August, and extensive woody plot field work occurs any time when conditions are amenable, but preferably before the end of October each year. Data entry, verification, and validation are done in August-October. Data summary, analysis, and reporting occur in November-February.

6.2 Facility and Equipment Needs

The nature of vegetation monitoring does not require much in the way of facilities beyond office space and herbarium and equipment storage. Field equipment needs are detailed in Symstad et al. 2012: SOP Field Preparation. Office equipment needs are primarily computers for data entry by field technicians and normal office equipment for the permanent staff.

6.3 Startup Costs and Budget Considerations

Personnel expenses are for two weeks of training; two crews of four people for intensive plot sampling for eleven weeks^a; one crew of four people for intensive plot sampling for one week (AGFO riparian); two crews of two people for extensive woody plot sampling for four weeks; 592 hours of data entry, verification, and validation by seasonal technicians; and the remainder of the Plant Ecologist's and Plant Lead Biotech's annual time. The Plant Ecologist, Plant Lead Biotech, and six seasonal biological science technicians comprise the field crews. Not included are data management, network coordination, analysis, reporting, and administrative costs that are

^a Table 4 shows 9 weeks of sampling except for AGFO riparian; the extra week is for overtime.

shared among multiple monitoring projects. The NGP FireEP contributes, from their own budget, personnel and travel funds for one crew of four people for two weeks in late July/early August (North Dakota intensive plot sampling), and two crews of two people each for extensive woody plot sampling for four weeks. The annual budget for the protocol is shown in Table 9. Purchases of major equipment listed in SOP Field Preparations have been completed and therefore are not included in this budget.

Table 9. Estimated annual budget for NGPN plant community composition and structure monitoring.

Item	Time (months)	Salary and Benefits	Total
Plant Ecologist, GS-11/4	12	\$ 7,085	\$ 85,020
Lead Biological Technican (Plants), GS 7/4	11	\$ 4,840	\$ 53,240
Biologican Technicans, GS 5/1 (6 positions)	24.5	\$ 2,900	\$ 71,100
Supplies			\$ 4,000
Travel			\$ 32,000
Vehicles			\$ 15,000
Total			\$ 260,360

6.4 Procedures for Revising the Protocol

Over time, revisions to the protocol narrative and SOPs are to be expected. Careful documentation of changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis. To this end, the metadata for each FFI database identifies which version of the protocol was being used when the data were collected. In addition, a record of protocol changes and the reasoning behind those changes prevents revisions to methods that yielded unsatisfactory results in the past and were discontinued.

The steps for changing the protocol narrative and SOPs are outlined in Symstad et al. 2012: SOP Revisions. Each SOP contains a revision history log that is filled out each time a SOP is revised. This log explains reasons for changes and assigns a new version number to the revised SOP. The new version of the SOP and protocol narrative is archived in the NGPN protocol library under the appropriate folder.

7. Literature Cited

- Adler, P. B., and J. M. Levine. 2007. Contrasting relationships between precipitation and species richness in space and time. *Oikos* **116**:221-232.
- Anderson, B. G., I. D. Rutherford, and A. W. Western. 2006. An analysis of the influence of riparian vegetation on the propagation of flood waves. *Environmental Modelling & Software* **21**:1290-1296.
- Biondini, M. E., B. D. Patton, and P. E. Nyren. 1998. Grazing intensity and ecosystem processes in a northern mixed-grass prairie, USA. *Ecological Applications* **8**:469-479.
- Brown, J. K. 1974. Handbook for inventorying downed material. General Technical Report INT-16, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Brown, J. K., R. D. Oberhue, and C. M. Johnston. 1982. Inventorying surface fuels and biomass in the Interior West. General Technical Report INT-129, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Brown, P., and B. Cook. 2006. Early settlement forest structure in Black Hills ponderosa pine forests. *Forest Ecology and Management* **223**:284-290.
- Butler, J. L., and D. R. Cogan. 2004. Leafy spurge effects on patterns of plant species richness. *Journal of Range Management* **57**:305-311.
- Clark, C. M., E. E. Cleland, S. L. Collins, J. E. Fargione, L. Gough, K. L. Gross, S. C. Pennings, K. N. Suding, and J. B. Grace. 2007. Environmental and plant community determinants of species loss following nitrogen enrichment. *Ecology Letters* **10**:596-607.
- Cochran, W. G. 1977. Sampling techniques. 3rd edition. John Wiley and Sons, New York.
- Cogan, D., H. Marriot, J. Von Loh, and M. Pucherelli. 1999. USGS-NPS Vegetation Mapping Program, Wind Cave National Park, South Dakota. USDI Bureau of Reclamation, Denver, CO.
- D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass-fire cycle, and global change. *Annual Review of Ecology and Systematics* **23**:63-87.
- DeBacker, M. D., A. N. Sasseen, C. Becker, G. A. Rowell, L. P. Thomas, J. R. Boetsch, and G. D. Willson. 2004. Vegetation community monitoring protocol for the Heartland I&M Network and Prairie Cluster Prototype Monitoring Program. National Park Service, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program, Republic, Missouri.
- Dixon, M. D., W. C. Johnson, M. L. Scott, and D. Bowen. 2009. 2008 Annual Report -- Missouri River Cottonwood Study. University of South Dakota, Vermillion, SD.
- Floyd, D. A., and J. E. Anderson. 1987. A comparison of three methods for estimating plant cover. *Journal of Ecology* **75**:221-228.
- Fuhlendorf, S. D. and F.E. Smeins. 1997. Long-term vegetation dynamics mediated by herbivores, weather and fire in a *Juniperus-Quercus* savanna. *Journal of Vegetation Science* **8**:819-822.
- Geissler, P. H., and T. L. McDonald. 2003. Sampling designs for national park monitoring. Draft Presentation to the George Wright Society, USGS and West Inc.
- Gitzen, R. A., M. Wilson, J. Brumm, M. Bynum, J. Wrede, J. J. Millspaugh, and K. J. Paintner. 2010. Northern Great Plains Network Vital Signs Monitoring Plan. Natural Resource Report NPS/NGPN/NRR--2010/186, National Park Service, Fort Collins, CO.

- Helm, D. J., and B. R. Mead. 2004. Reproducibility of vegetation cover estimates in south-central Alaskan forests. *Journal of Vegetation Science* **15**:33-40.
- Heywood, J. S., and M. D. DeBacker. 2007. Optimal sampling designs for monitoring plant frequency. *Rangeland Ecology and Management* **60**:426-434.
- Hooper, D. U., F. S. Chapin, III, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, D. M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setälä, A. J. Symstad, J. Vandermeer, and D. A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecological Monographs* **75**:3-35.
- Hooper, D. U., and L. Johnson. 1999. Nitrogen limitation in dryland ecosystems: Responses to geographical and temporal variation in precipitation. *Biogeochemistry* **46**:247-293.
- Jones, G. P. 2007. A program to monitor composition and structure of selected vegetation types on Fort Laramie National Historic Site. Objective 2: Tree recruitment in the riparian woodlands. University of Wyoming, Wyoming Natural Diversity Database, Laramie, WY.
- Kincaid, T. M., T. Olsen, D. Stevens, C. Platt, D. White, and R. Remington. 2008. spsurvey: Spatial Survey Design and Analysis. R package version 2.0. Available from <http://www.epa.gov/nheerl/arm/analysispages/software.htm>.
- Licht, D. S. 1997. Ecology and economics of the Great Plains. University of Nebraska, Lincoln.
- McDonald, T. L. 2003. Review of environmental monitoring methods: Survey designs. *Environmental Monitoring and Assessment* **85**:277-292.
- Mitchell, S. W., and F. Csillag. 2001. Assessing the stability and uncertainty of predicted vegetation growth under climatic variability: Northern mixed grass prairie. *Ecological Modelling* **139**:101-121.
- Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. Wiley and Sons, New York.
- Neave, M., and S. Rayburg. 2007. Nonlinear biofluvial responses to vegetation change in a semiarid environment. *Geomorphology* **89**:217-239.
- Omernik, J. M. 2007. Level III Ecoregions of the Continental United States. U.S. EPA National Health and Environmental Effects Laboratory, Corvallis, Oregon.
- Owensby, C. E., J. M. Ham, A. K. Knapp, and L. M. Auen. 1999. Biomass production and species composition change in a tallgrass prairie ecosystem after long-term exposure to elevated atmospheric CO₂. *Global Change Biology* **5**:497-506.
- R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Reed, H. E., T. R. Seastedt, and J. M. Blair. 2005. Ecological consequences of C-4 grass invasion of a C-4 grassland: A dilemma for management. *Ecological Applications* **15**:1560-1569.
- Ripple, W. J., and R. L. Beschta. 2007. Hardwood tree decline following large carnivore loss on the Great Plains, USA. *Frontiers in Ecology and the Environment* **5**:241-246.
- Samson, F. B., and F. L. Knopf. 1994. Prairie conservation in North America. *BioScience* **44**:418-421.
- Särndal, C.-E., B. Swensson, and J. Wretman. 1992. Model assisted survey sampling. Springer, New York, NY.
- Scott, M. L., G. T. Auble, and J. M. Friedman. 1997. Flood dependency of cottonwood establishment along the Missouri River, Montana, USA. *Ecological Applications* **7**:677-690.

- Sedivec, K. K., and W. T. Barker. 1998. Selected North Dakota and Minnesota range plants. North Dakota State University Extension Service.
- Singer, F. J., and J. E. Norland. 1994. Niche relationships within a guild of ungulate species in Yellowstone National Park, Wyoming, following release from artificial controls. *Canadian Journal of Zoology* **72**:1383-1394.
- Sjodin, N. E. 2007. Pollinator behavioural responses to grazing intensity. *Biodiversity and Conservation* **16**:2103-2121.
- Smith, C. C. 1940. The effect of overgrazing and erosion upon the biota of the mixed-grass prairie of Oklahoma. *Ecology* **21**:381-397.
- Smith, T. M., H. H. Shugart, and F. I. Woodward, editors. 1997. Plant functional types: their relevance to ecosystem properties and global change. Cambridge University Press, Cambridge, UK.
- Stevens, D. L., Jr. 1997. Variable density grid-based sampling of natural resources. *Environmetrics* **8**:167-195.
- Stevens, D. L., Jr., and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. *Environmetrics* **14**:593-610.
- Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* **99**:262-278.
- Stevens, D. L., Jr., and N. S. Urquhart. 2000. Response designs and support regions in sampling continuous domains. *Environmetrics* **11**:13-41.
- Sundermann, C. R. 2004. Wetland delineation, Niobrara River, Agate Fossil Beds National Monument, Harrison, Nebraska. U.S. Department of the Interior National Park Service, Harrison, NE.
- Symstad, A. J. 2004. 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. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Keystone, SD.
- Symstad, A. J., R. A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner-Green. 2012. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network - Standard Operating Procedures: Version 1.01. Natural Resource Report NPS/NRPC/NRR—2012/489.1. National Park Service, Fort Collins, Colorado.
- Symstad, A. J., and M. Bynum. 2007. Conservation value of Mount Rushmore National Memorial's forest. *Natural Areas Journal* **27**:293-301.
- Symstad, A. J., C. L. Wienk, and A. Thorstenson. 2006. Field-based evaluation of two herbaceous plant community sampling methods for long-term monitoring in northern Great Plains national parks. Open-File Report 2006-1282, U.S. Geological Survey, Helena, MT.
- Temple, P. J., and P. R. Miller. 1994. Foliar ozone injury and radial growth of ponderosa pine. *Canadian Journal of Forest Research* **24**:1877-1882.
- Thompson, S. K. 2002. Sampling. 2nd edition. Wiley, New York, NY.
- Uresk, D. W. 1990. Using multivariate techniques to quantitatively estimate ecological stages in a mixed grass prairie. *Journal of Range Management* **43**:282-285.
- Urquhart, N. S., and T. M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. *Journal of Agricultural, Biological, and Environmental Statistics* **4**:404-414.

- Urquhart, N. S., W. S. Overton, and D. S. Birkes. 1993. Comparing sampling designs for the monitoring of ecological status and trends: impact of temporal patterns. Pages 71-85 *in* V. Barnett and K. F. Turkman, editors. Statistics for the environment. Wiley, London, UK.
- USDA-NRCS. 1997. National Range and Pasture Handbook. United States Department of Agriculture, Natural Resources Conservation Service, Grazing Lands Institute, Washington, DC.
- USDI National Park Service. 2003. Fire Monitoring Handbook. Fire Management Program Center. National Interagency Fire Center, Boise, ID.
- Vaness, B. M., and S. D. Wilson. 2008. Impact and management of crested wheatgrass (*Agropyron cristatum*) in the northern Great Plains. Canadian Journal of Plant Science **87**:1023-1028.
- Willson, G. D., L. P. Thomas, M. D. DeBacker, W. M. Rizzo, and C. Buck. 2002. Plant community monitoring protocol for six prairie parks. USGS, Northern Prairie Wildlife Research Center, MO Field Station, U. of Missouri, Columbia, MO.

Appendix A: Power Analyses for Sampling Design

We used the following approaches to determine various aspects of the sampling design for plant community composition and structure monitoring in the Northern Great Plains I&M Network:

1. For selected characteristics of herb-layer vegetation, we used estimates of spatial, temporal, and residual variance estimated from data collected by other monitoring programs in NGPN parks to compare several revisit designs based on their power to detect trend and precision for estimating status.
2. For Black Hills ponderosa pine forest, we used the following two approaches:
 - a. First, we used data collected from a one-time survey of stand characteristics in MORU to estimate spatial variability in density of trees in various size categories, and we calculated sample sizes necessary to estimate status of (with various levels of precision) or detect change in tree density for selected size categories.
 - b. Second, we estimated sample sizes needed to detect significant differences in vegetation relevant to prescribed fire objectives, using the data collected by the Northern Great Plains Fire Ecology/Fire Effects (NGP FireEP) specifically for evaluating those objectives.
3. For riparian lowlands, we estimated sample sizes needed to estimate status of density of trees in various size categories with various levels of precision using variance estimates from data collected by NGPN specifically for this purpose.

This appendix documents these approaches and their results.

Comparison of revisit designs and sample sizes for the herb-layer component of plant community monitoring

Overview

The utility of a revisit design for a monitoring program is determined by a variety of factors. Two key elements are the power of the design to detect trends and the precision of the status estimates resulting from the design. The power for detecting trend and the effect of sample size on power and precision depends on the relative magnitude of several sources of variability, or variance components. Thus, to determine the relative merits of various revisit designs and sample sizes, we estimated the year-to-year, spatial, and residual variance components expected in plant community composition and structure monitoring in NGPN parks. We then used these estimates to estimate power and precision of a set of revisit designs.

We used four attributes of plant community composition and structure for this process: species richness, total cover, cover of a single, dominant species (“dominant species cover”), and proportion of total cover comprised of exotic species (“proportion exotic cover”). Previously collected data for these attributes were available from three programs/studies: the Northern Great Plains Fire Ecology/Fire Effects Monitoring Program (NGP FireEP), the Prairie Cluster Prototype Monitoring Program (“PCP”), and a pilot study comparing data collection methods done by NGPN in 2005 (“Pilot Study”). The data available from these programs/studies for each park are presented in Table A1. Using these data, we estimated variance components for each attribute. We used linear mixed-effects models to estimate variance components separately for each park from which appropriate data were available. For each variance component, we then pooled estimates from all parks to produce a plausible range of values that would apply to all NGPN parks. We examined power and precision for alternative revisit designs under different combinations of the minimum, maximum, and median values for each variance component. Our definition of variance components and the use of these variance components for estimating power and precision follow the framework and examples developed by Urquhart, Kincaid, and Larsen (Urquhart et al. 1993, Urquhart et al. 1998, Urquhart and Kincaid 1999, Larsen et al. 2001, Kincaid et al. 2004, Larsen et al. 2004).

Table A1. Data used for estimating variance components in NGPN herb-layer vegetation.

Park	Data sets
AGFO	PCP Monitoring: 11 sites, 5 years, 53 site x year visits FireEP Monitoring and Pilot Study: 14 sites, 3 years, 20 site x year visits
BADL	FireEP Monitoring: 34 sites, 9 years, 91 site x year visits
DETO	FireEP Monitoring and Pilot Study: 21 sites, 10 years, 64 site x year visits
FOLA	Pilot Study: 6 sites in 1 year; only grassland sites used
KNRI	FireEP Monitoring: 6 sites, 9 years, 31 site x year visits
SCBL	PCP Monitoring: 14 sites, 7 years, 66 site x year visits FireEP Monitoring: 17 sites, 9 years, 63 site x year visits
THRO	FireEP Monitoring and Pilot Study: 32 sites, 8 years, 78 site x year visits
WICA	FireEP Monitoring and Pilot Study: 42 sites, 8 years, 92 site x year visits

Methods

Overview of Variance Components: For estimating power and precision of status estimates, we needed estimates of three variance components:

- σ^2_{Site} is systematic variation among sites that is consistent across years (e.g., variation in vegetation productivity due to soil type).
- σ^2_{Year} is synchronous, among-year variation, apart from effects of any long-term trend; these are year effects that affect all sites in the population of an individual park (e.g., park-wide climatic variation).
- $\sigma^2_{\text{Residual}} = \sigma^2_{\text{Site*Year}} + \sigma^2_{\text{Measurement}}$, where
 - $\sigma^2_{\text{Site*Year}}$ is non-synchronous, among-year variation among sites (e.g., sites show different short-term reactions to region-wide fire) and/or ephemeral variation (e.g., a pathogen outbreak in a single site); and
 - $\sigma^2_{\text{Measurement}}$ is non-systematic measurement error: observer variability, within-site (local) spatial variability due to small inconsistencies in measurement relocation, or within-year temporal variability.

Pooling both $\sigma^2_{\text{Site*Year}}$ and $\sigma^2_{\text{Measurement}}$ into a single variance term (Residual) is appropriate unless multiple visits per year and/or different measurement techniques are being considered. Multiple visits per site per year are not an option for NGPN monitoring, so our analyses assumed one visit per year per site. By the time of this analysis, the measurement technique to be used at each plot had been selected. Therefore, measurement variability was independent of the factors we were examining (sample sizes and revisit designs). For power calculations based on one visit per year to each site, the contribution of both of these components to the variability in the estimate of long-term trend depends on $1/n$, where n is the number of sites visited (Urquhart and Kincaid 1999). Consequently, we did not need to separate these components.

Estimating Variance Components: For each park with data from NGP FireEP monitoring, we summarized point-intercept data for each upland monitoring plot by year (data were too limited for estimating variability in lowland areas.) For data collected in 2005 as part of the Pilot Study (Symstad et al. 2008), we summarized these attributes from point-intercept data⁵. The similarity in methods used to collect data in these two studies allowed us to combine their data within each park, which expanded the spatial coverage of the data. The species used for the dominant species cover attribute was simply the species with the highest total cover over all plots in a park used in the analyses. Thus, the dominant species varied among parks as follows: BADL and THRO, *Pascopyrum smithii*; DETO and WICA, *Poa pratensis*; KNRI and SCBL, *Hesperostipa comata*.

We estimated variance components for data collected as part of PCP monitoring at Scotts Bluff and Agate Fossil Beds NMs separately from the NGP FireEP/Pilot study dataset. In PCP

⁵ Visual cover estimate data were also collected, but we did not use these because we did not expect variability in these data to be comparable to what we will encounter with point-intercept sampling to be used in the NGPN field protocol.

monitoring at these two parks, cover data were estimated visually. Thus, we expected variability to be different between this method and the point-intercept sampling to be used in the future. However, the species richness data collected from 10 m² frequency plots are comparable to the data that will be collected in 10 m² frequency plots in the NGPN protocol. Thus, for this dataset we focused on species richness, analyzing average species richness per 10 m² plot.

We used linear mixed effects models (as implemented in package lme4 in Program R) to estimate variance components for each attribute with the following approach:

- Variance components were estimated either on the raw or transformed scales for each attribute. Residual plots were screened initially to determine the need for transformations to improve normality for each parameter. Based on this examination, we used the natural-log transformation for modeling total cover and species richness, but used no transformation for proportion exotic cover or dominant species cover⁶.
- We incorporated a fixed effect of year as a numeric covariate to account for any multi-year trend in the data, as we were seeking to estimate year-to-year variation apart from a systematic effect of trend.
- Because NGP FireEP plots were collected at various time points before and after prescribed fire, we used a fixed effect to account for any year-to-year changes caused by fire and to remove this factor from our estimates of yearly variation. For each park and attribute, we modeled the effect of fire either as a linear change with time since fire, as a polynomial change, or by including an indicator variable denoting whether the time since fire was either 1 year or > 1 year; this would allow a threshold change in which fire had a detectable impact in the first year, followed by no detectable impact at any greater time since fire. For each park and data set, we examined the statistical significance of each potential parameterization of the fire effect, as well as a model which omitted any fire effect. For each park and variable, we selected one of these alternate parameterizations based on data plots, screening of standard errors of estimated coefficients, and AIC values for alternative models. In general, choice of parameterizations had minor effects on our estimates of variance components. No effect of fire was modeled for the PCP monitoring data, as few of these plots were in burned areas.
- Mixed-effects models included crossed random effects for “Year” as a categorical variable [to estimate synchronous year-to-year variation within a park (σ^2_{Year}) after removing any trend] and “Site” [to model spatial variation (σ^2_{Site})].
- In some cases, we could not get meaningful estimates of all variance components. We used only components that appeared sensible. For example, we removed estimates that were very close to 0 when there were too few years monitored to have confidence in this estimate.

⁶ Arcsin-square-root and other transformations for the latter variables were not necessary to improve normality; we also estimated variance coefficients using these transformations and examined the effects on power and status, but effects on ultimate power calculations were minor.

Limitations of the Data Sets: For most parks, revisit schedules for individual plots were highly variable and inconsistent across habitat types within a park. For example, pilot study data were collected in a single year and often covered plots in habitat types not monitored by the NGP FireEP plots. Sites were not a random sample of each park, but generally were concentrated in purposely selected habitats. In addition, sites often were concentrated in a limited portion of the park, probably causing us to underestimate spatial variability. For the combined NGP FireEP/Pilot Study data, the matrix of “Sites” by “Years” was not connected, in a design sense, across the years for which data were available for a park. That is, each site was not linked to every other site in the matrix by an overlapping series of sites and years, and there were years with no data from a given park.

We attempted to examine these limitations when feasible. For example, when a park had highly distinct habitats (e.g., badlands or sparse areas) that were monitored in only one year without any design connection to other monitored sites, we estimated variance components with and without these sites to see if our estimates changed much when we focused on “connected” subsets of the data for a park. Our estimates generally changed little when we examined such factors. Thus, although the messiness of the data must be considered when evaluating the robustness of our partitioning of variance components, we are comfortable with the results for our purposes.

Examining Power and Precision: Because of the limited spatial coverage of our sites in most parks and the irregular frequency of monitoring across years, we assumed that variance estimates for any individual park were of limited value. Rather, for each attribute and variance component, we pooled variance component estimates for all years and data sources, and determined the minimum, median, and maximum value for each variance component. We used these to define generic plausible bounds on the expected magnitude of each variance component in upland areas of NGPN parks. In power analyses, we created plausible scenarios for the expected variance structure, cross-combining the three values of each variance component (minimum, median, maximum) with each possible combination of the values for the other variance component to produce nine combinations. This approach was not valid for the dominant species cover attribute, however, for which we used the single, park-specific estimate of each variance component in the power analyses.

We followed the approach of Urquhart et al. (1993, 1998), Urquhart and Kincaid (1999) and Larsen et al. (2001) to examine power and the precision of model-based estimates of status. With this approach, we focused on the power of a linear mixed-effects model to detect a linear trend of a specified magnitude, where trend is characterized by the regression coefficient of the fixed effect of “year”, a numeric covariate. We examined the precision (standard error) of the expected estimate of status in year i , where status corresponds to the linear-model estimate of initial status plus the change in status due to the long-term trend ($\text{Status}_{\text{year } i} = B_o + B_{\text{trend}} * i$). We calculated power to detect a specified trend and precision of the resulting status estimate using an unpublished function written by Tom Kincaid, US EPA, Corvallis, Oregon, for Program R (see Attachment for the code of this function). This function takes as input the variance components, desired probability of Type 1 error (alpha), and a matrix designating the planned panel design, where each row is a panel, each column is a year, and the value in each cell is the number of sites to be visited in each panel each year. In all analyses, we set alpha = 0.10, and we examined power over a 50-year time frame. The power analysis also requires two additional correlation values; based on Urquhart et al. (1993), we set these to their default values in the R function

(site.rho = 1; year.rho = 0). For log-transformed attributes (total cover and species richness), we could directly calculate power and precision of status for specified yearly proportional changes of 1, 2, or 4%. For proportion exotic cover and dominant species cover, we did not use a log-linear response and therefore had to specify absolute rather than proportional trends. To do this for proportion exotic cover, we estimated the mean value of the attribute across all years and sites and used this value (0.25) as the starting value. We then evaluated absolute increases of 0.01 and 0.02 per year. For dominant species cover, we estimated the mean value of the cover of the dominant species for each park individually. We used that mean as the baseline for the park, then evaluated power to detect an increase of 1% cover per year. Baseline values are shown in Table A2. To provide an alternative picture of precision in estimating status (particularly when standard error estimates related to ln-transformed variables), we computed approximate 95% confidence intervals for the expected estimate of status in year 11 (estimated status or ln-transformed in year 11 $\pm$ 1.96* estimated SE; confidence interval values were then back-transformed for ln-transformed variables).

Table A2. Baseline values of dominant species cover used in power and precision analyses.

Park	Species	Baseline Value
BADL	<i>Pascopyrum smithii</i>	57.83
DETO	<i>Poa pratensis</i>	27.04
KNRI	<i>Hesperostipa comata</i>	36.74
SCBL	<i>Hesperostipa comata</i>	25.51
THRO	<i>Pascopyrum smithii</i>	22.89
WICA	<i>Poa pratensis</i>	26.71

We focused on four revisit designs for each attribute (Figures A1 and A2). We also briefly examined a 5th revisit design with a longer return interval between all sites (Figure A3) to determine if this design had any meaningful costs in our power to detect trend in species richness. For each revisit design, we looked at sample sizes that would produce an average of 6, 12, or 24 sites visited per year. For example, with the rotating [2-2] and [2-3] designs, two panels would be visited each year, so we examined sample sizes of 3, 6, or 12 sites per panel.

Panel\Year→	1	2	3	4	5	6	7	8	9	10
1	x	x	0	0	x	x	0	0	x	x
2	0	x	x	0	0	x	x	0	0	x
3	0	0	x	x	0	0	x	x	0	0
4	x	0	0	x	x	0	0	x	x	0

Panel\Year→	1	2	3	4	5	6	7	8	9	10
1	x	x	0	0	0	x	x	0	0	0
2	0	x	x	0	0	0	x	x	0	0
3	0	0	x	x	0	0	0	x	x	0
4	0	0	0	x	x	0	0	0	x	x
5	x	0	0	0	x	x	0	0	0	x

Figure A1. Rotating panel designs evaluated in power analysis. Top: [2-2] revisit design. Bottom: [2-3] revisit design. For both, sample sizes evaluated were $x = 3, 6$, and 12 .

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	x	0	0	x	0	0	x	0	0	x
2	0	x	0	0	x	0	0	x	0	0
3	0	0	x	0	0	x	0	0	x	0
4	y	y	y	y	y	y	y	y	y	y

Panel↓/Year→	1	2	3	4	5	6	7	8	9	10
1	x	x	0	0	x	x	0	0	x	x
2	0	x	x	0	0	x	x	0	0	x
3	0	0	x	x	0	0	x	x	0	0
4	x	0	0	x	x	0	0	x	x	0
5	y	0	0	0	0	y	0	0	0	0

Figure A2. Split panel designs evaluated in power analysis. Top: [(1-2), (1-0)1] revisit design. Sample sizes evaluated: $x = 4, 10$, or 21 ; $y = 2, 2$, or 3 . Bottom: [(2-2), (1-4)1] revisit design. Sample sizes evaluated: $x = 2, 4$, or 8 ; $y = 10, 20$, or 40 .

Year→/ Panel↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	6	6	0	0	0	3	3	0	0	0	6	6	0	0	0	0	0	0	0	0	6
2	0	6	6	0	0	0	3	3	0	0	0	6	6	0	0	0	0	0	0	0	0
3	0	0	6	6	0	0	0	3	3	0	0	0	6	6	0	0	0	0	0	0	0
4	0	0	0	6	6	0	0	0	3	3	0	0	0	6	6	0	0	0	0	0	0
5	6	0	0	0	6	6	0	0	0	3	3	0	0	0	6	6	0	0	0	0	0
6	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	6	6	0	0	0	0
7	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	6	6	0	0	0
8	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	6	6	0	0
9	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	6	6	0
10	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	6	6

Figure A3. [2-8] design that starts as a [2-3] design for a subset of sites during years 1-10. Sample size shown is 6 sites per panel once the roll-out period is finished.

Results

Variance components: The relative (Figure A4) and absolute (Table A3) magnitude of spatial, yearly, and residual variation varied by park and attribute. Spatial variability was the greatest source of variation for six of the eight cases for species richness, five of the eight cases for proportion exotic cover, and all six of the cases for dominant species cover. In contrast, for total cover, yearly and spatial variation were each the greatest source of variation in three of the six cases.

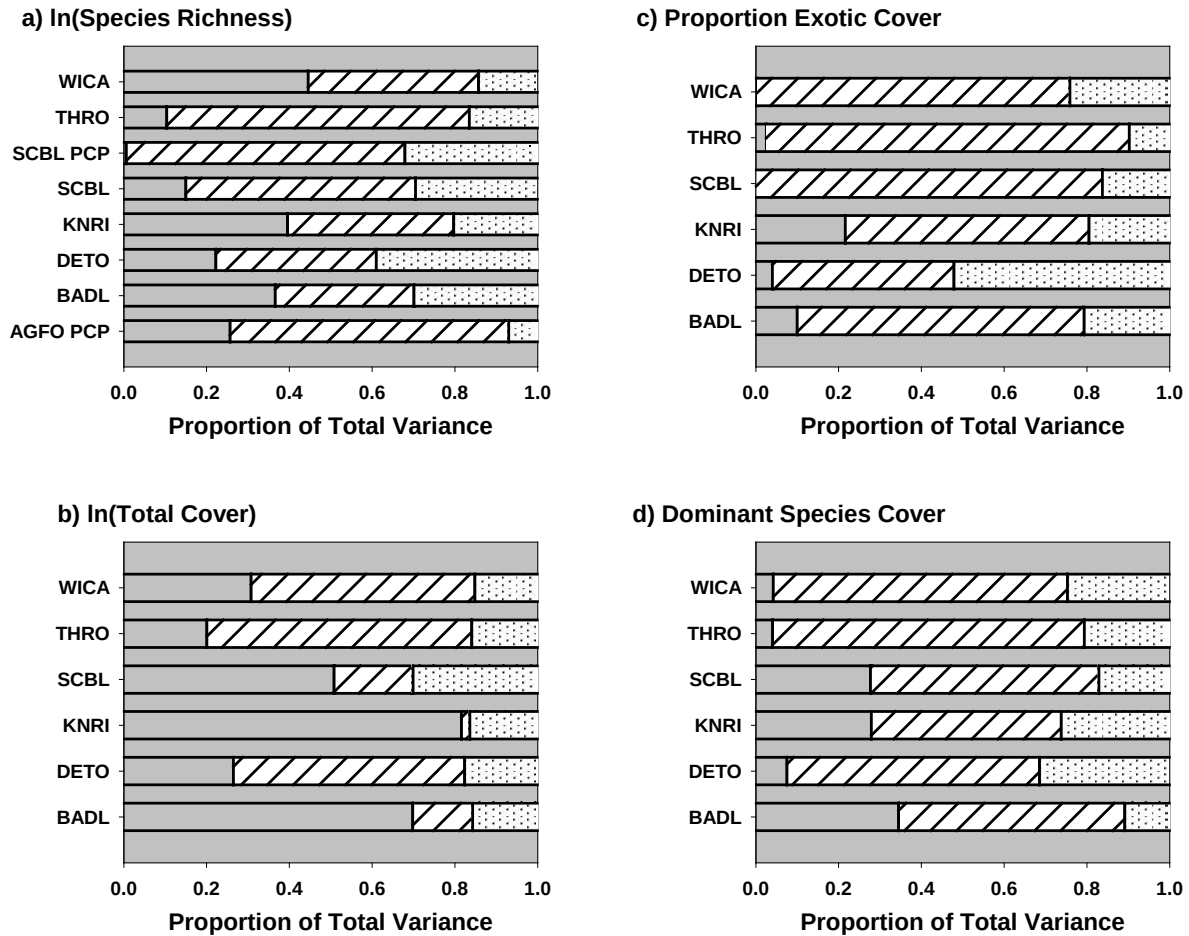


Figure A4. Contribution of yearly (solid black bar), spatial (hatched bar), and residual (dotted bar) variance components to total variation for each attribute, by park. When the park's code is followed by "PCP", data are from the Prairie Cluster Prototype monitoring program. Otherwise, data are from the NGP FireEP and Pilot Study.

Table A3. Summary of variance values used in NGPN power analysis.

Variance Source		ln(Richness)	ln(Cover)	Proportion Exotic Cover
Year	Minimum	0.001	0.032	0.000
	Median	0.029	0.069	0.002
	Maximum	0.108	0.186	0.004
Space	Minimum	0.021	0.001	0.008
	Median	0.090	0.034	0.027
	Maximum	0.132	0.155	0.065
Residual	Minimum	0.009	0.009	0.003
	Median	0.048	0.040	0.008
	Maximum	0.133	0.046	0.017

Table A3, continued. Summary of variance values used for dominant grass species cover in NGPN power analysis.

Park	Species	Year Variance	Spatial Variance	Residual Variance
BADL	<i>Pascopyrum smithii</i>	422.7	669.5	132.6
DETO	<i>Poa pratensis</i>	56.2	455.8	235.0
KNRI	<i>Hesperostipa comata</i>	143.7	236.2	134.9
SCBL	<i>Hesperostipa comata</i>	190.4	379.0	117.4
THRO	<i>Pascopyrum smithii</i>	24.7	458.7	125.4
WICA	<i>Poa pratensis</i>	37.8	638.0	221.6

Power and Precision Estimates for Sampling Designs: Although the magnitude of the specified trend had a large effect on our power to detect the trend, comparisons among designs and effects of the different combinations of variance components were similar for different trends (1%, 2% or 4% for total cover and species richness; 0.01 or 0.02 for exotic proportion of cover). Thus, we present only the results for the 2% trend. We limit our presentation of results for precision of status estimates to the standard error of the status estimate [$SE(status)$] in the 11th year of monitoring.

Design and number of sites visited per year had relatively small effects on the number of years expected to detect the trend with 80% power for all attributes (Figures A5, A6, A7). The largest effect of sample size was on proportion exotic cover and cover of dominant species, for which quadrupling the sample size only reduced the time to detect the trend by 2-3 years at most. Year-to-year variation had the greatest effect on time to detect the trend. For the [2-3] design, 12 sites visited per year, and median residual variance, changing the spatial variance from its minimum to its maximum had no effect on time to detect the trend when temporal variance was held constant, whereas changing the temporal variance from one third its median to its maximum while holding spatial variance constant more than doubled the time necessary to detect the trend (Figure A8).

The precision of status estimates was more sensitive to design and number of sites visited per year than was power to detect trend. Relative values of $SE(status)$ among designs were generally consistent among variance scenarios within a given sample size, but they varied somewhat more among sample sizes when other factors were held constant (Figures A9, A10, A11). For example, for proportion exotic cover, SE was lowest for the [(2-2),(1-4)] and [2-3] designs and highest for the [(1-2),(1-0)] and (2-2) designs for 6 or 12 sites visited per year, but the [(1-2),(1-0)] design had the lowest SE for 24 sites visited per year. Relative precision of designs varied somewhat among attributes, but differences among designs were small compared to differences in precision caused by varying sample sizes. The greatest difference in $SE(status)$ was a reduction of 19% (for proportion exotic cover, minimum variance, and 24 sites per year). A slightly larger reduction in SE was achieved by doubling the samples size within the [2-3] design, and $SE(status)$ was reduced by 40% by quadrupling the sample size (Figure A12).

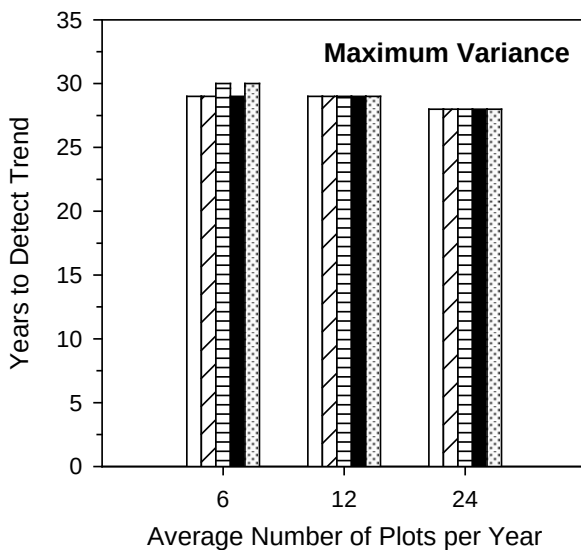
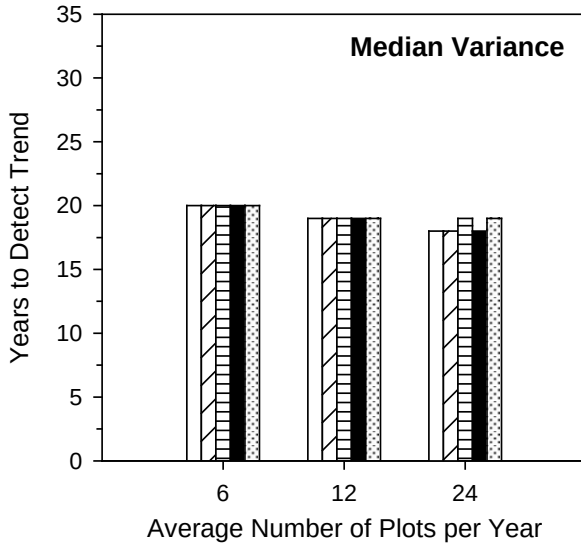
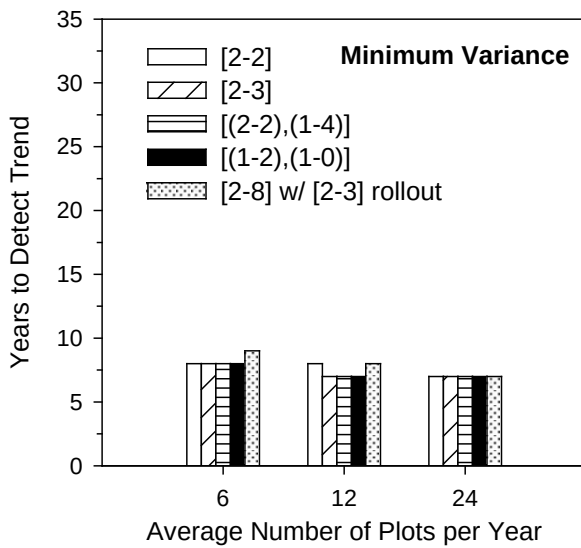


Figure A5. Number of years necessary to detect, with 80% power, a 2% per year trend in $\ln(\text{species richness})$ for five panel/revisit designs, three sample sizes, and three variance estimates (minimum, median, or maximum spatial, temporal, and residual variance). For the panel revisit design, notation follows that of McDonald (2003): first in a pair of numbers indicates number of consecutive visits before rest; second in a pair of numbers indicates number of years rest; for split-panel designs, the different revisit schemes for different sets of panels are separated by a comma.

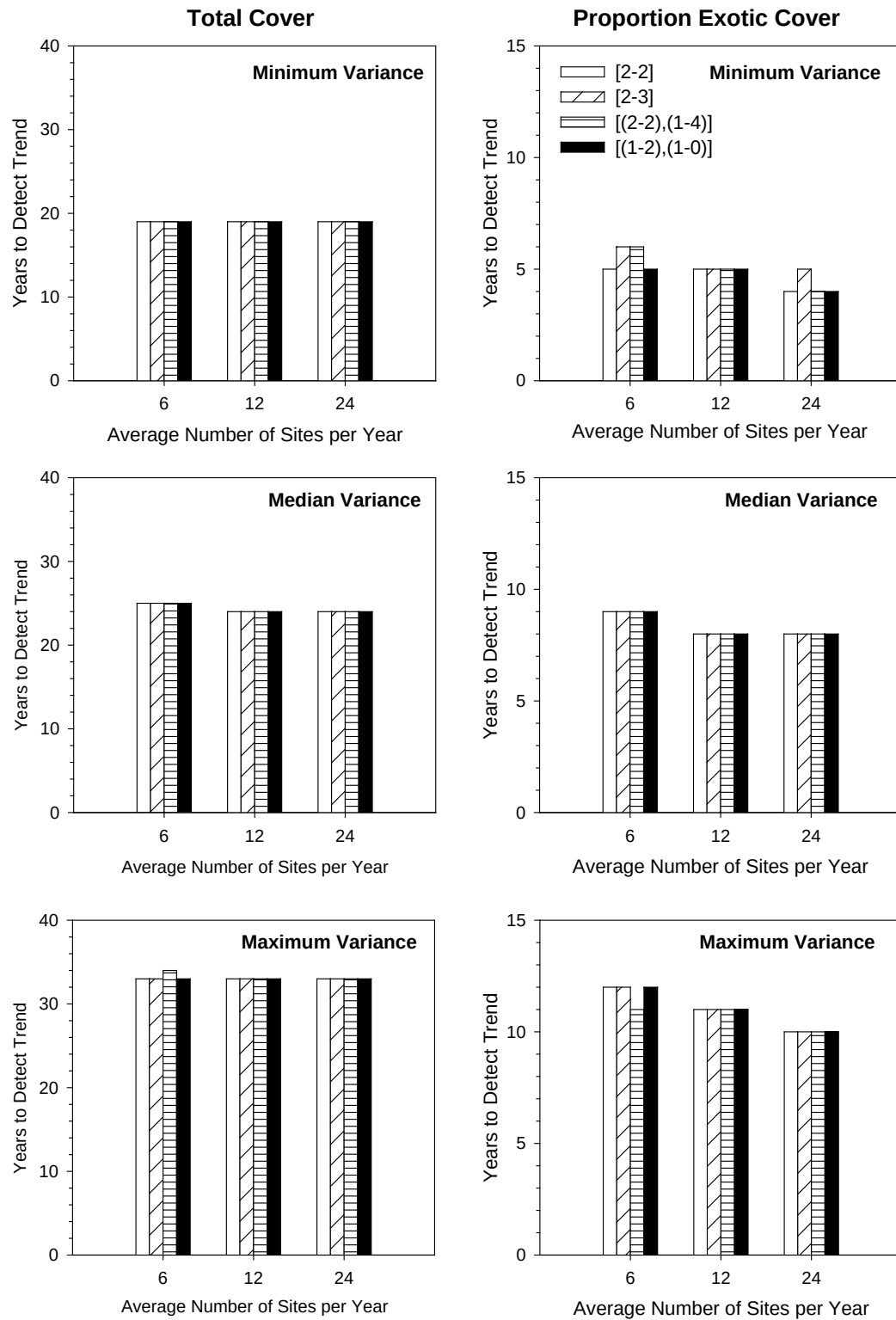


Figure A6. Number of years necessary to detect, with 80% power, a 2% per year trend in $\ln(\text{total cover})$ [left] or an annual increase of 0.02 in proportion exotic cover (right) for four panel/revisit designs, three sample sizes, and three variance estimates. Notation for panel revisit designs follows that in Figure A5.

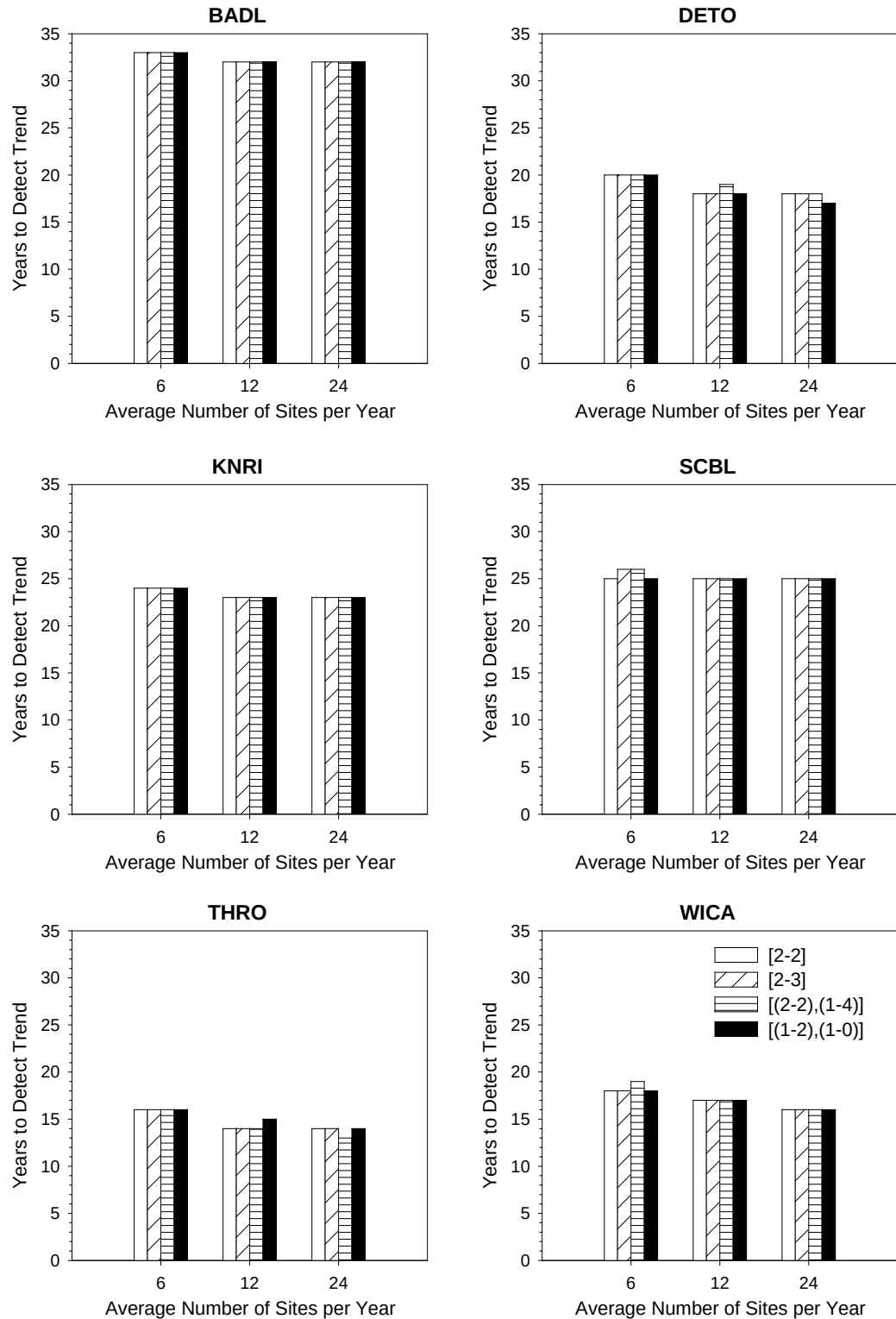


Figure A7. Number of years necessary to detect, with 80% power, an increase of 1% cover per year trend in cover of the dominant grass species in six NGPN parks for four panel/revisit designs and three sample sizes. Notation for panel revisit designs follows that in Figure A5.

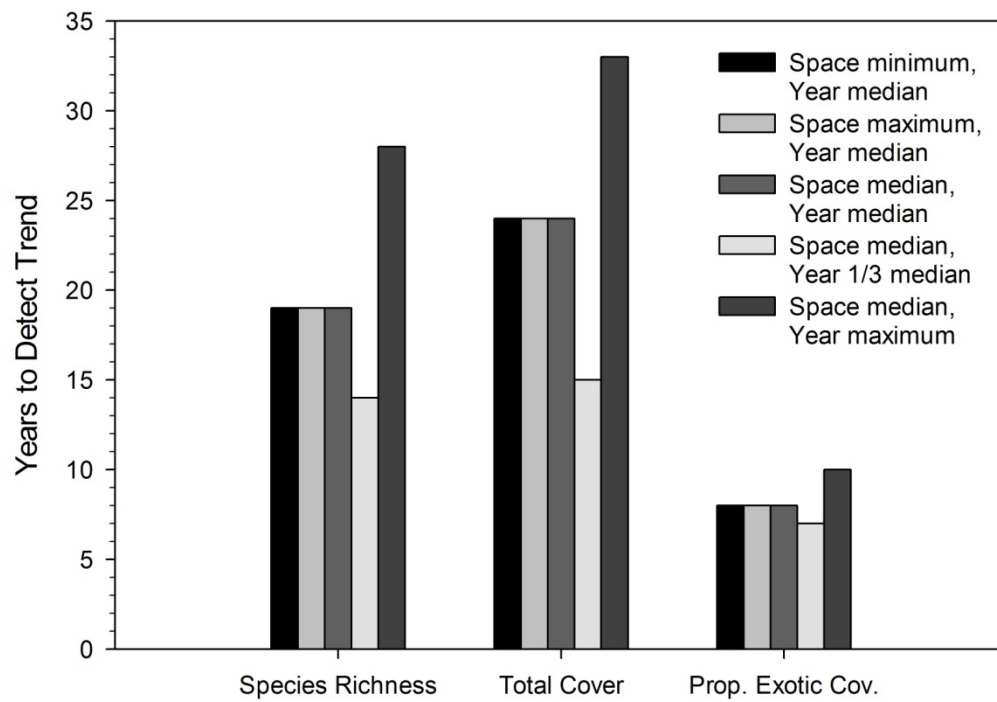


Figure A8. Number of years necessary to detect, with 80% power, a 2% per year trend in $\ln(\text{species richness})$, $\ln(\text{total cover})$, or an annual increase of 0.02 in proportion exotic cover for five variance scenarios using a [2-3] panel/revisit design and average of 12 sample sites per year.

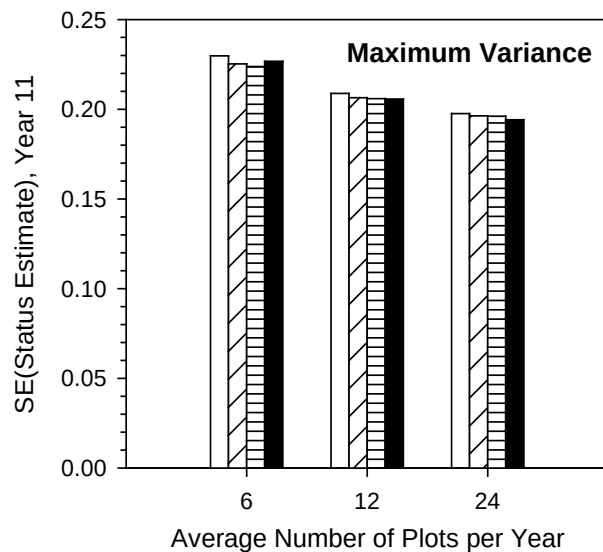
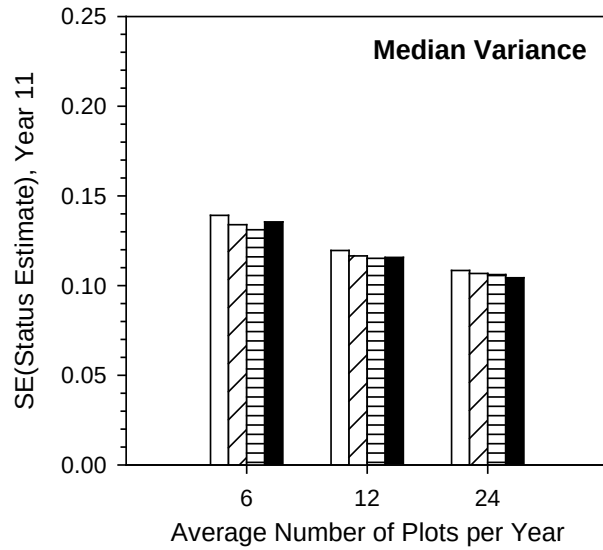
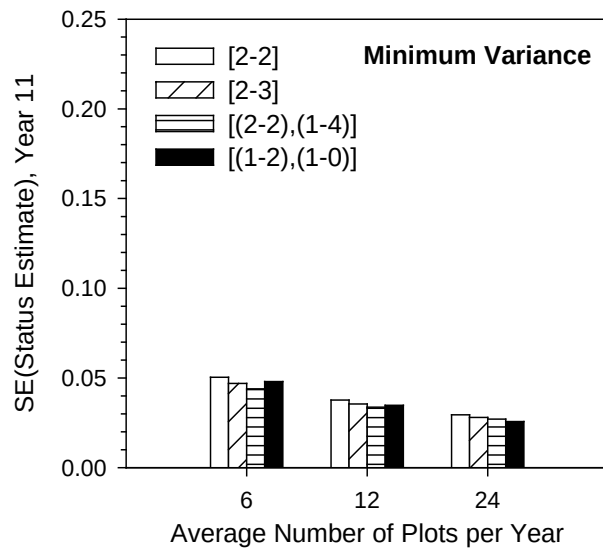


Figure A9. Standard error of the status estimate of $\ln(\text{species richness})$ in the 11th year of monitoring for four panel/revisit designs, three sample sizes, and three variance scenarios (same as in trend power analyses). Panel/revisit design notation follows that in Figure A5. These values translate to approximate 95% confidence intervals for mean richness in the 11th year, assuming species richness was 14 species in year 1 and decreased 2% per year, as follows:

SE = 0.15: (8.5, 15.4)
 SE = 0.10: (9.4, 14.0)
 SE = 0.05: (10.4, 12.6)

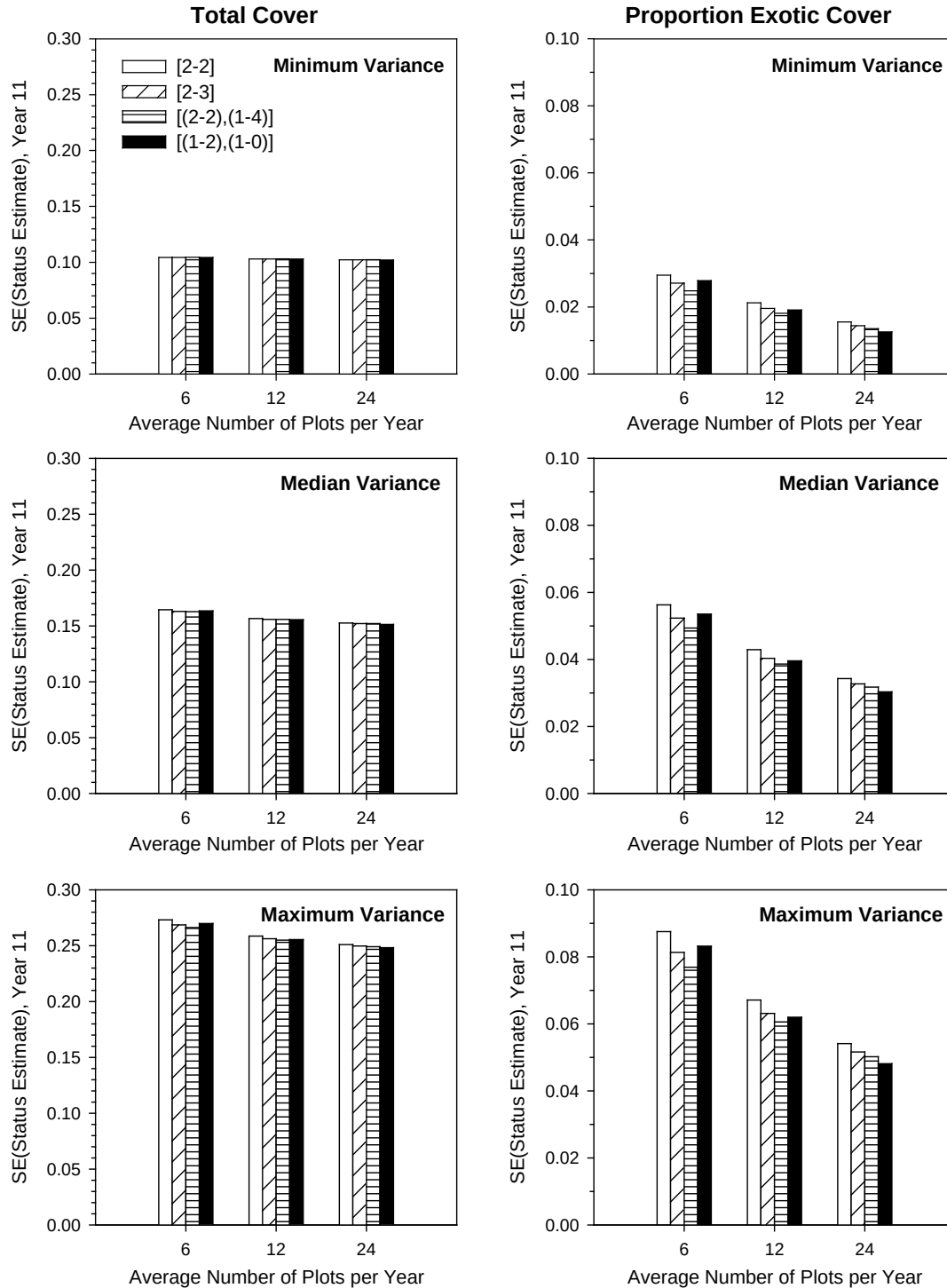


Figure A10. Standard error of the status estimate of $\ln(\text{total cover})$ [left] and proportion exotic cover (right) in the 11th year of monitoring for four panel/revisit designs, three sample sizes, and three variance scenarios. Panel/revisit design notation follows that in Figure A5. These values translate to ~95% confidence intervals for mean total cover in the 11th year, assuming 140% cover in year 1 and a 2%/year decline, in the following manner: SE = 0.20: (116, 258); SE = 0.15: (128, 234); SE = 0.10: (142, 211). They translate to ~95% confidence intervals for mean proportion exotic cover, assuming a 1%/yr increase and starting point of ~25% exotic as follows: SE = 0.08: (19, 51); SE = 0.04: (27, 43); SE = 0.022: (31, 39).

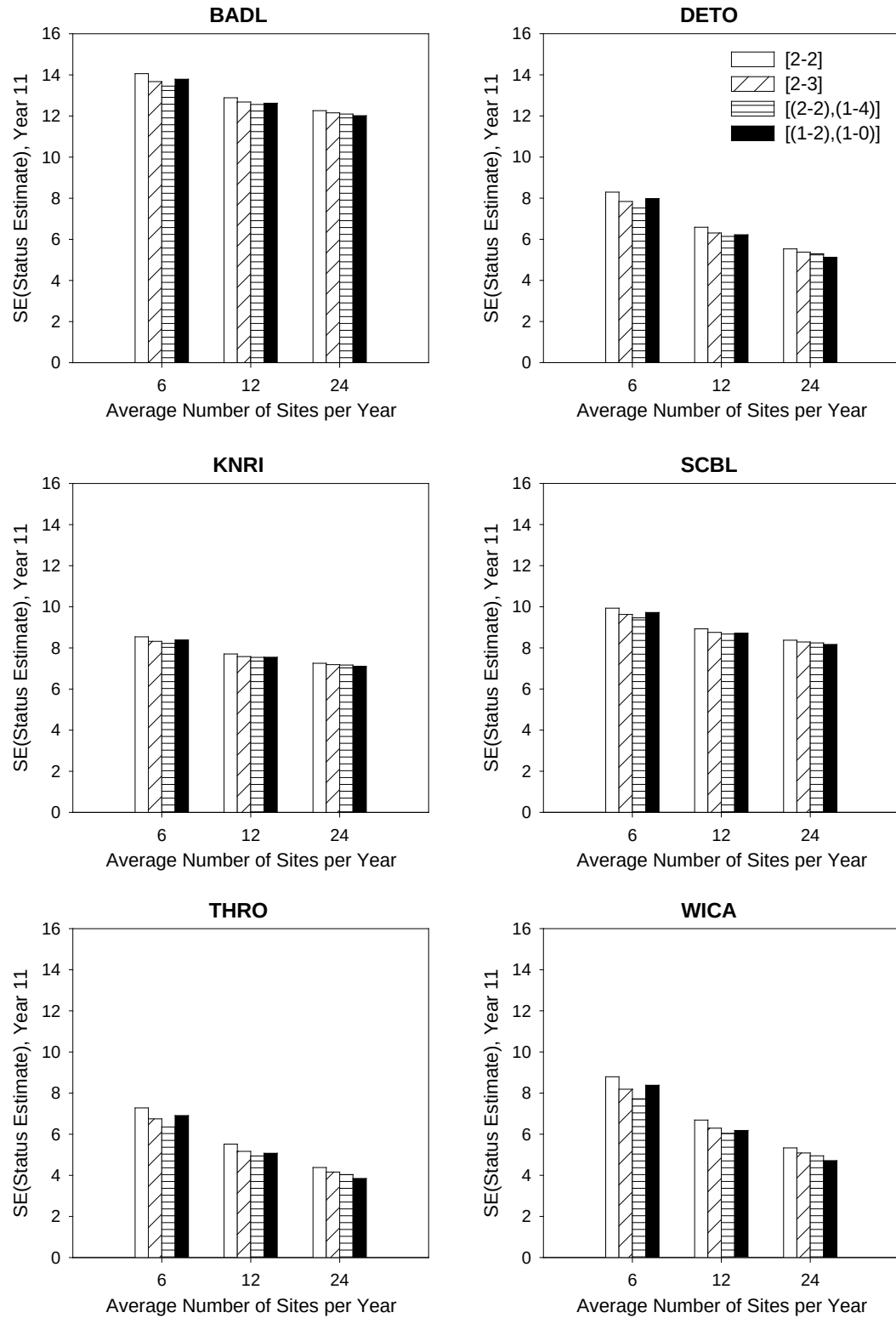


Figure A11. Standard error of the status estimate of dominant species cover in the 11th year of monitoring for four panel/revisit designs and three sample sizes in six parks. Panel/revisit design notation follows that in Figure A5.

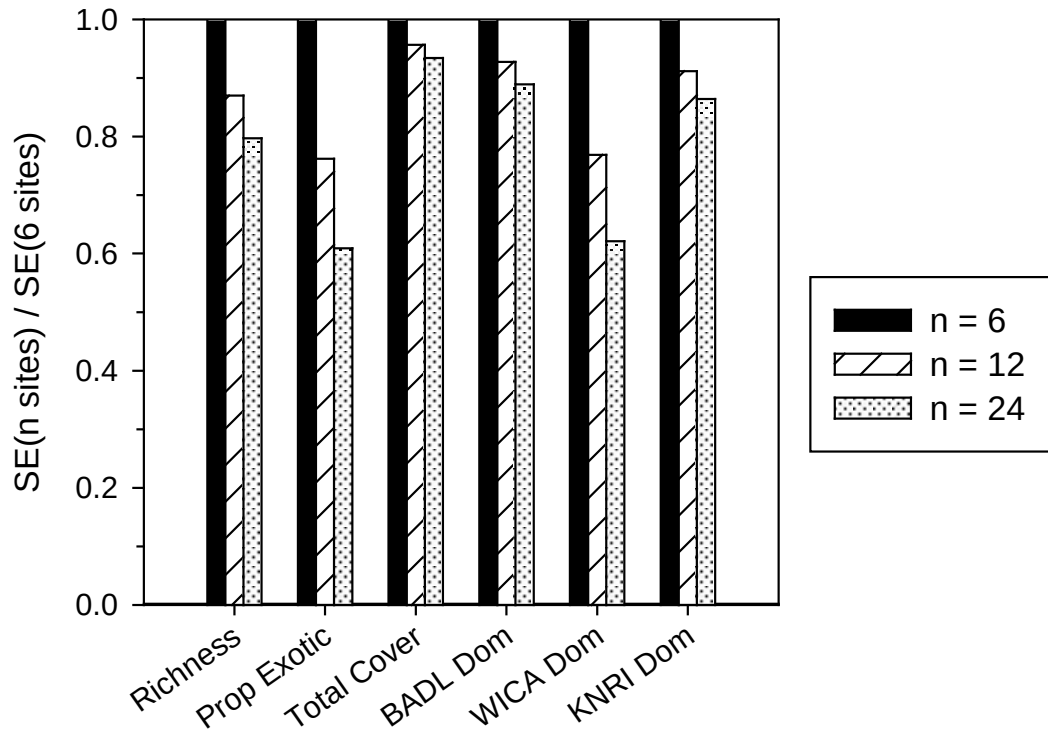


Figure A12. Relative standard error of the status estimate ($SE_{n=i} / SE_{n=6}$) of four attributes (dominant species cover separated into three parks) depending on sample size (number of sites visited per year). Values shown are for the 11th year of monitoring, the [2-3] panel/revisit design, and median variance for species richness, proportion exotic cover, and total cover.

Discussion and Conclusions

The minor differences among panel/revisit designs in their effects on the time to detect a trend in the attributes analyzed may be due in part to their similarity. However, increasing the rest time from three to eight years resulted in only a minor (1 year) increase in the time to detect the trend. More important is the high coherent yearly variation in the attributes used in these analyses and expected in most herb-layer vegetation attributes in the northern Great Plains. This variation has an overriding effect on power to detect long-term trends (Urquhart and Kincaid 1999). Insensitivity to sample size was not due to the relatively small range of sample sizes we examined; exploratory analyses indicated that power changed little when sample sizes were much larger (50-100 sites per panel) than those presented here. Inclusion of covariates, particularly precipitation, may help explain this variation and increase power somewhat. As revealed by the small decreases in time to detect trend even when the sample size was quadrupled, sampling more intensively will do nothing to address this variation; time is the only cure.

In contrast, our analyses suggest that increasing sample size will increase the precision of status estimates for some attributes, and that sample size is more important than revisit design for this precision. Greater sample sizes are particularly important for attributes with high spatial variation, such as proportion exotic cover and cover of a dominant species. Exploration of the general effects of another source of variability, differences in trends among sites (Site*Trend variance), is in progress (S. Urquhart, in prep). Intuitively, the higher this source of variation, the greater the need will be for a high number of monitoring sites to estimate an area-wide average trend. In addition, higher total sample sizes facilitate analyses of subpopulations of interest. Thus, maximizing sample sizes within logistical constraints should yield benefits for detecting trends and estimating the status of these attributes.

Given our results, we chose the [2-3] panel/revisit design for most parks for monitoring the herb-layer vegetation. This design generally had the second lowest SE(status) of the four designs investigated in detail, and it produces the largest total number of sites in a park of the four designs (Figures A1, A2). For the largest parks (BADL and THRO), we increased the revisit interval to eight years to double the sample size in these highly heterogeneous parks, but included a [2-3] rollout design to provide some trend information early in the monitoring program.

Calculation of sample sizes necessary to estimate status or detect change in various components of forest structure in Black Hills ponderosa pine (*Pinus ponderosa*) forest

Overview

Connectivity in the revisit design was deemed unnecessary for pine forest structure sampling in Black Hills parks (DETO, JECA, MORU, WICA) because tree density and forest structure (distribution of size classes) have much lower annual variability than herb-layer composition and structure. Effects of precipitation fluctuations, fire, and browsing are manifested over longer time periods, and changes due to severe events (e.g., high-intensity fire, insect outbreak) can be detected with infrequent sampling. Thus, collecting data in every park every year is a waste of resources. In addition, because of the slow response time of these parameters to many drivers, detecting trends in the parameters measured in these plots will take a long time. In the meantime, park managers need good estimates of the status of forest structure to make decisions about mechanical thinning, burning, and other management actions. Sampling all sites within a park every few years, rather than a subset of sites every year, allows for simpler, periodic estimates of status. In addition, fewer revisits to the same plot allows for a greater spatial distribution with the same number of plots, which provides more precision in estimating the status at any one time, and sampling all plots in a park in one year uses time efficiently by reducing travel between parks.

Consequently, we determined that the revisit design for forest structure measurements would be a $[(1-x)^1]$ design, in which all sites with tree and targeted tall shrub species in a park are visited in a single year, then rested for x years before being revisited. Because of our emphasis on status for these measurements, we suspected that the number of samples provided by the intensive plots used for herb-layer vegetation sampling may be inadequate for the precision desired in estimates of forest structure and snag density status⁷ or for detecting changes relevant to management actions. Thus, we conducted the following analyses to estimate the number of plots needed to obtain a given precision level or detect a given change and, conversely, the precision obtainable or change detectable with a given number of plots.

Methods

MORU stand exam data

Data Sources and Variance Estimation: We estimated spatial variance of tree and snag density among 0.10-ha plots, the plot size originally proposed for tree and target tall shrub species monitoring, in Black Hills ponderosa pine forest from data collected in a stand exam conducted by the USDA Forest Service for an old-growth forest inventory at Mount Rushmore National Memorial (MORU) in 2004 (Symstad and Bynum 2007). This inventory had 149 sample points. At each point, trees were sampled using a variable radius plot (Basal Area Factor 4.6, such that all trees that would yield a basal area of 4.6 m²/ha are included in the plot) for all live trees greater than 12.7 cm diameter at breast height (dbh), a small fixed plot (radius 2.07 m) for all

⁷ Snag density was of interest because of the importance of snags as nesting habitat for certain bird species.

live trees less than 12.7 cm dbh, and a large fixed plot (radius 17.95 m) for all standing dead trees (snags). Height and dbh of each tree in the plot were measured, and a count of seedlings (dbh < 2.54 cm) was made in the small fixed plot.

The stand exam used a more-or-less stratified sampling design, with delineated stands as strata and multiple plots within each stand. To estimate park-wide spatial variance from this stratified design, we calculated weighted means and variances with library ‘Hmisc’ (Harrell 2001) in program R. We calculated sample weights for each plot as the amount of area “represented” by each plot = area of the stand / number of plots in the stand (i.e., the sample-expansion factor). As a result, weights were the same for all plots in a stand but varied among stands; weights were rescaled so that the average stand weight was 1.0. In addition to this weighted point estimate of the spatial variance, we used a weighted bootstrap to estimate upper and lower bounds of a 95% confidence interval (95% CI) for this spatial variance.

The variable plot radius used for measuring density of larger trees complicates the estimation of variance for a given area. We assumed that variance estimates corresponded approximately to variance expected based on the fixed-radius plot used for snags and downed trees, which had an area of 0.10 ha. Thus, variance estimates of snags/ha were adjusted as:

$$\text{var}(\text{trees or snags/ha}) = 10^2 * \text{var}(\text{trees or snags}/(0.10 \text{ ha})).$$

Snag Density: We focused on density (snags/ha) of snags ≥ 15 cm dbh. We estimated sample sizes for two situations. First, we treated snag measurements as a series of infrequent status estimates and calculated the number of plots needed for a one-time survey to estimate snag density across a range of absolute and relative precisions (Zar 1996). We calculated sample sizes for the point estimate of spatial variance, as well as with the 95% CI bounds. Second, we calculated (with program R) the number of plots needed to detect various changes in snag density between two times based on a paired t-test. This calculation required estimates of the within-plot correlation (r) in snag densities and the variance of the differences in snag density between the two times. We calculated sample sizes across a range of plausible positive correlations. We used the upper and lower 95% CI bounds as the among-site variance estimates for snag density at each time (i.e., upper bound as the variance at time 1, lower bound for time 2). For each correlation, we calculated the variance of the difference in snag densities between the two times as:

$$\text{var}(\text{time1} - \text{time2}) = \text{var}(\text{time1}) + \text{var}(\text{time2}) - 2*r*\text{sqrt}[\text{var}(\text{time1})*\text{var}(\text{time2})].$$

We performed these “one-time inventory” or “two-time difference” calculations rather than estimating power to detect long-term trends across many measurements for several reasons. First, snags will be measured infrequently, and several decades will pass before sufficient monitoring has been done to detect a long-term trend. Second, for periodically assessing the habitat condition of parks for cavity-nesting birds, the absolute snag density would be of interest rather than relative trends. Third, snag density is likely to change in a pulse or stair-step pattern (e.g., after a large fire), and long-term continuous/monotonic changes are unlikely. Comparisons of current to a past status estimate or management target will be of more immediate relevance to park management.

Tree Density: We examined sample size effects on precision for estimates of tree density in several size categories: $\text{dbh} < 10 \text{ cm}$, $2.54 \text{ cm} \leq \text{dbh} < 20 \text{ cm}$, $20 \text{ cm} \leq \text{dbh} \leq 40 \text{ cm}$, and $\text{dbh} > 40 \text{ cm}$. We used the same approach described above for snags to estimate sample size needed for a variety of absolute and relative precision levels. In addition, we explored the number of samples needed to estimate the number of plots with $>x$ trees/ha in some diameter class. This is a value relevant to management, in that x could be a management threshold (e.g., if managers wanted to maintain 90% of the forest with <100 trees/ha in the $<10 \text{ cm}$ dbh class to encourage ground, rather than canopy, fire). Although this type of question probably is best answered by estimating the cumulative distribution function and examining changes in this distribution over time, for simplicity, we summarized the relationship between precision and sample size for estimating a proportion in a one-time survey. This precision – sample-size relationship depends only on true proportion, and applies to any situation where a point-estimate of a proportion is useful.

We do not consider these data to be entirely representative of the forest conditions at the other three NGPN parks in the Black Hills, Devils Tower National Monument (DETO), Jewel Cave National Monument (JECA), and Wind Cave National Park (WICA). For example, as of 2009, mechanical thinning and prescribed fire activities have been used to a much greater extent at DETO than at MORU. Thus, dense stands of small pine trees are likely to be more abundant at MORU than at DETO. An intense wildfire burned most of the forest at JECA in 2000, killing most of the pine trees in the park. Regeneration after this fire has been slow because of the large extent of the severely burned area due to this fire, resulting in very different forest structure (more snags and downed wood than live trees) in this park than in the other three. Thus, we supplemented the detailed analyses possible with the data from the MORU stand exam with data collected by the Northern Great Plains Fire Ecology Program to evaluate specific prescribed fire objectives at DETO and WICA.

Northern Great Plains Fire Ecology Program prescribed fire objective data: Densities of overstory ($\text{dbh} > 15 \text{ cm}$) trees were measured in $20 \times 50 \text{ m}$ plots in ponderosa pine forest or woodland in prescribed fire areas at WICA ($N = 9$) and DETO ($N = 7$). In each plot, seedling ($\text{dbh} < 2.5 \text{ cm}$) and pole ($2.5 \text{ cm} \leq \text{dbh} \leq 15 \text{ cm}$) densities were measured in a single $5 \times 10 \text{ m}$ or $10 \times 25 \text{ m}$ subplot, respectively. Total dead and down fuel load was measured on four 100-foot (30.5 m) transects at each plot location using the Brown's line method (Brown 1974, Brown et al. 1982). Measurements were done one or two years prior to the prescribed fire, then repeated one or two years after the prescribed fire in the same plot, subplot, and transect locations. Plot locations were chosen randomly within the ponderosa pine vegetation type within the prescribed fire area at each park.

Mean and standard deviation values from these measurements were used in a sample-size calculator created for the NPS Fire Ecology Program by Ken Gerow (U. of Wyoming; gerow@uwyo.edu) to estimate the minimum sample size necessary to detect a given change with $\alpha = 0.1$ and $\beta = 0.1$. The minimum detectable change for each size class was determined by the objectives of the prescribed fires: 70%, 50%, and 30% mortality of ponderosa pine seedlings, poles, and overstory trees, respectively. The minimum detectable change for total fuel load was set at 30%.

Results

MORU stand exam data: Mean density and estimated standard deviation of the categories (snags, live tree size classes) varied 20- and 40-fold, respectively (Table A4). Snags and large (dbh > 40 cm) trees had relatively low densities with standard deviations similar to the means, whereas small tree categories had very high mean densities and standard deviations at least twice that of their mean.

Table A4. Parameters used in sample size estimates for snag and tree density sampling in NGPN Black Hills ponderosa pine forest from data collected at MORU. Low and high standard deviation (sd) are the lower and upper limits of the 95% confidence interval.

Parameter	Snags	Trees (dbh in cm)			
		dbh < 10	2.54 ≤ dbh < 20	20 ≤ dbh < 40	dbh > 40
mean (ha ⁻¹)	31.4	386	650	228	40.3
observed sd (ha ⁻¹)	30.6	1083	1274	167	36.3
low sd (ha ⁻¹)	26.2	681	875	151	33.3
high sd (ha ⁻¹)	37.7	1376	1588	193	40.9

Consequently, the precision of an estimate obtainable with a given number of plots varied widely among categories. For example, our estimates suggest that 19-23 plots would be necessary to obtain 50% precision (assuming the observed standard deviation) for snags and the two largest live tree size classes. This level of precision would require 46 and 65 plots for the 1-20 and < 10 cm dbh categories, respectively. Conversely, 50% precision could be obtained with only 6-11 plots for snags and the two largest live tree categories, but would require 41 and 85 plots for the 1-20 and <10 cm dbh categories, respectively. High variability in the smaller size categories also broadened the confidence intervals, producing much wider ranges in the estimates of precision for a given sample size, or sample size needed for a given precision level, than for snags or large trees (Figure A13). The detectable difference between two samples followed a similar pattern. For snags and the larger size categories, a difference of 10-20 snags or trees/ha (10-50% of the mean) could be detected with 50 plots, whereas for the smaller size categories, 50 plots would only detect much larger differences (350-410 trees/ha, or 60-90% of the mean; Figure A14).

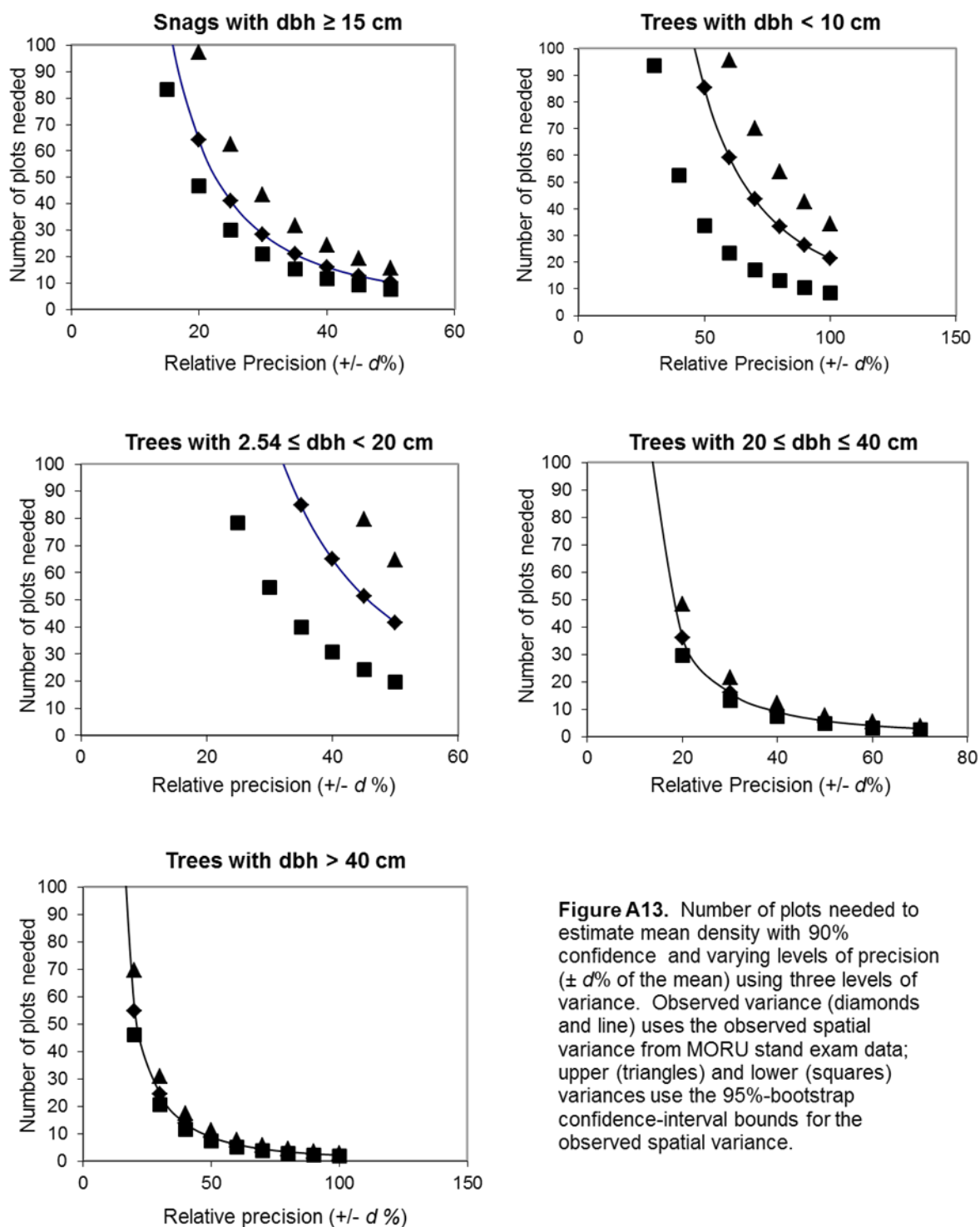


Figure A13. Number of plots needed to estimate mean density with 90% confidence and varying levels of precision ($\pm d\%$ of the mean) using three levels of variance. Observed variance (diamonds and line) uses the observed spatial variance from MORU stand exam data; upper (triangles) and lower (squares) variances use the 95%-bootstrap confidence-interval bounds for the observed spatial variance.

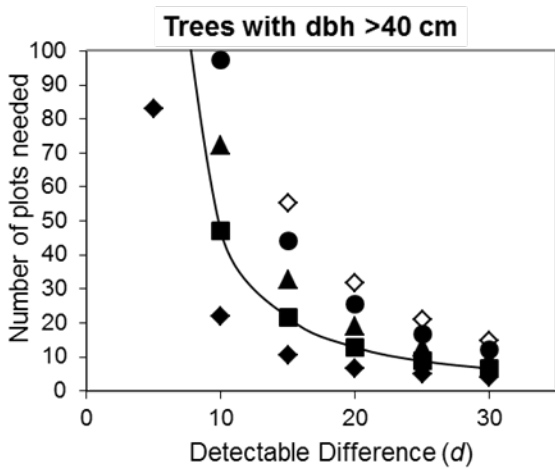
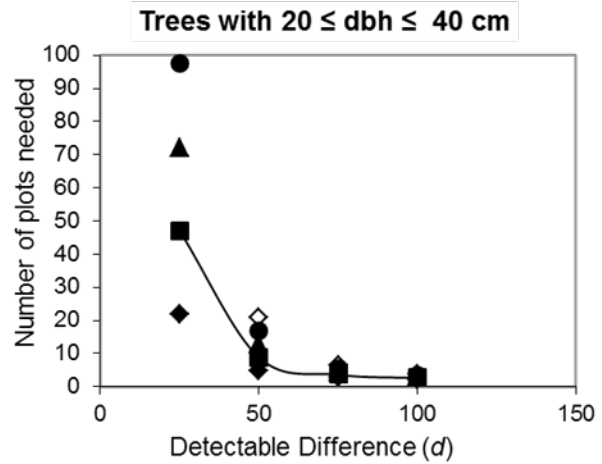
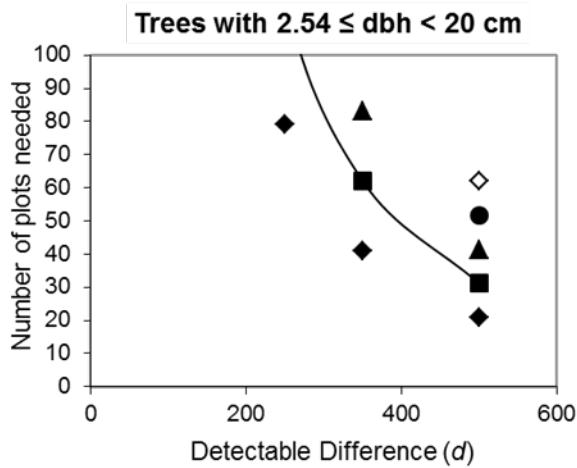
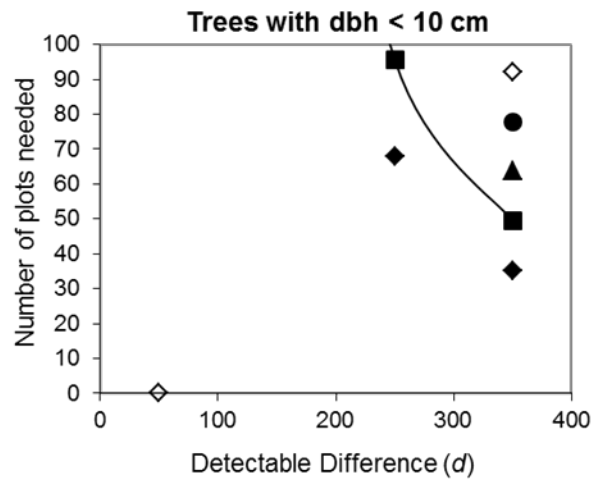
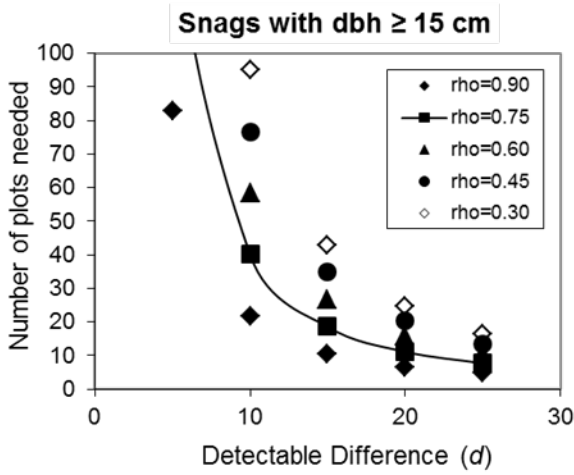


Figure A14. Number of plots needed to detect (with a paired t-test) the change ' d ' in density (ha^{-1}) between two measurement periods on the same plots with power = 0.80, $\alpha = 0.1$. ' ρ ' is the within-plot correlation between measurements at time 1 and 2. Variance of this difference was calculated with the upper and lower bounds of the bootstrap confidence intervals for current spatial variance at MORU. Relatively high correlations (0.75, smoothed line) probably are realistic for short-term changes (5-10 yrs) in the absence of major disturbances.

Finally, when high precision (e.g., 0.05) for estimating the proportion of plots with a given density is desired, the number of plots needed is quite high (>50 , and depending on the true value of that proportion). However, if more moderate precision (e.g., 0.10) is acceptable, approximately 60 plots should be sufficient to adequately estimate the proportion of plots with a given density, regardless of the true value of that proportion. Ten plots would provide low precision of this estimate (0.25; Figure A15).

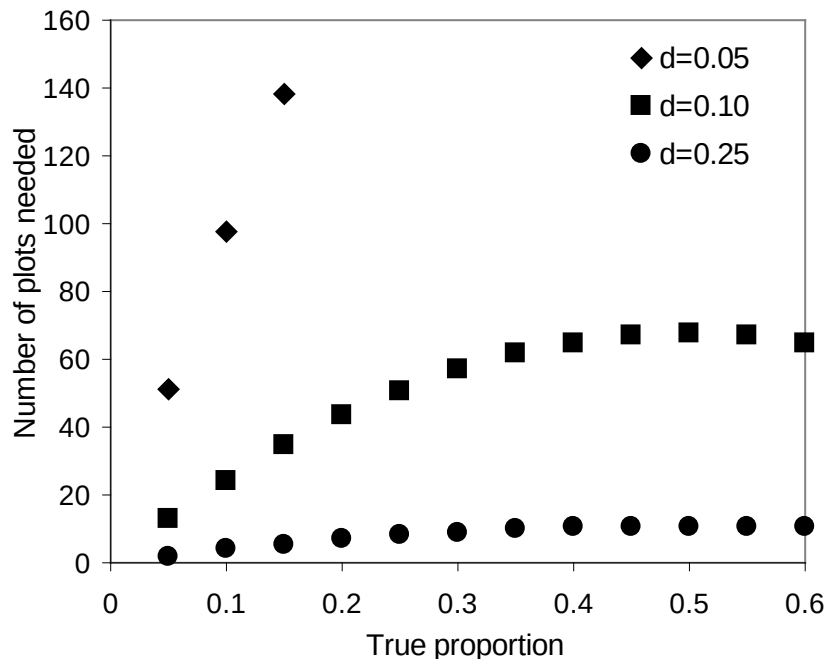


Figure A15. Number of plots needed to estimate a proportion (e.g., proportion of plots with $> x$ trees < 10 cm DBH / ha) with precision $\pm d$ and 90% confidence for a one-time survey.

Northern Great Plains Fire Ecology Program prescribed fire objective data: Parameter values used in calculations and the estimated sample size needed to evaluate each prescribed fire objective are shown in Table A5. High standard deviations relative to mean for pole density at WICA and seedling density at DETO resulted in large minimum sample sizes needed to detect the desired changes. In contrast, low variability among plots and high correlation between measurements for overstory trees yielded quite low sample sizes needed to detect the desired change for this size class. Low correlations between pre- and post-fire means for seedling densities, as well as increased seedling densities in post-fire measurements in some plots, at both parks suggest there were measurement errors in this size class.

Table A5. Parameters used in sample-size calculator and minimum sample size ($\alpha = \beta = 0.1$) needed to detect a decrease of 30% (overstory trees and fuel load), 50% (pole-sized trees), or 70% (seedlings) at two parks.

Variable	Pre-fire Mean	Pre-fire SD	Post-fire SD	Pre-post fire mean correlation	Minimum Sample Size Needed
WICA					
overstory trees (ha ⁻¹)	113	58	61	0.95	4
poles (ha ⁻¹)	150	222	178	0.24	71
seedlings (ha ⁻¹)	6007	5796	1072	0.11	13
fuel load (tons/acre)	23.0	14.6	6.7	0.90	12
DETO					
overstory trees (ha ⁻¹)	109	59	73.9	0.96	5
poles (ha ⁻¹)	111	118	43	0.34	28
seedlings (ha ⁻¹)	347	749	214	-0.01	67
fuel load (tons/acre)	22.6	11.6	5.9	0.66	12

Discussion and Conclusions

Given that our proposed number of intensive plots in most Black Hills parks is 15, our assumption that these plots would not provide acceptable precision on estimates of precision was validated by these analyses. The data from the MORU stand exam suggest that plot numbers in the 50-60 range would provide moderate precision of status estimates, as well as the ability to detect reasonable changes in density, for all but the smallest size class. Calculations based on the data from the NGP FireEP are more difficult to translate into whole-park sample sizes, since the area burned, and therefore the area in which samples would be needed, varies among prescribed fires. Assuming that a single prescribed fire covers ~20% of a park, 50-60 plots in a park should be adequate to detect changes in overstory tree and fuel load changes stated in prescribed fire objectives; additional sampling would probably be necessary to detect changes in pole or seedling densities like those in the objectives for the fires for which the data were collected.

Based on these calculations and logistical considerations, we chose a [(1-4)¹] design for forest structure measurements in Black Hills ponderosa pine forest. In this design, all sites with tree and targeted tall shrub species in a park are visited in a single year, then rested for four years before being revisited. The return interval was chosen to correspond with the five-year revisit design of the herb-layer sampling because some plots sampled for herb-layer vegetation will also have woody vegetation sampled. Doing both in one visit, when possible, increases efficiency. With this revisit design, sample sizes in the 50-60 range for each of the smaller Black Hills parks (DETO, JECA, MORU) and 80 plots in the forested area of WICA are near the maximum of what is logistically feasible when other plant community composition and structure sampling obligations are considered.

Calculation of sample sizes necessary to estimate status of forest structure in riparian lowlands

Overview

Regeneration – or lack thereof – of riparian forest trees is one measure of ecosystem health in northern Great Plains parks with significant riparian lowland areas. Because of the high spatial variability in forest structure within riparian lowlands, we expected that the precision of forest structure estimates that would be obtainable from measurements done in the intensive plant community composition and structure plots would not be acceptable. Therefore, in summer 2008, we collected forest structure data in all NGPN parks with significant areas of riparian forest within the area that the I&M program will be monitoring (DETO, FOLA, KNRI, SCBL, THRO).

Methods

Riparian Area Delineation, Sample Locations, and Sampling Dates: Different methods were used to determine sample locations at each park because of differences in topography, management, and information available for each park.

At THRO, the riparian area was those areas along the Little Missouri River corridor with alluvial soils (see Appendix B for more details). Areas outside of the Little Missouri River corridor with these soil types (e.g., along Jones Creek) were excluded. Using a GIS, 31 points were randomly located within the designated riparian area for each unit of the park (North Unit and South Unit). GPS coordinates of these points and a map with the points on an aerial photograph background were used to locate points in the field. Twelve points were sampled in each unit July 10-14, 2008. Accessibility, travel time, variability in apparent vegetation structure (based on aerial photographs), and geographic distribution were considered when choosing points that were actually sampled from the list of those generated by the GIS. Additional points were occasionally generated in the field by choosing a random distance and direction of travel from an established point – this was done to reduce travel time between points and therefore achieve the desired sample size within time limits.

At KNRI, previous and current park management has a much larger effect on the location of forest than do topography and soil types. Therefore, the riparian forest area at this park was delimited by a trail system that generally follows the edges of forested areas. Points were chosen randomly in the field by choosing random distances and directions from each successive plot, with the condition that they stay within the limits of the riparian forest. Ten plots were sampled July 15-16, 2008.

At DETO, the riparian forest area was delimited using a polygon designated as the 500-year floodplain from a document and GIS files in park records. The polygon was extended to include the area north of the bridge (which was not considered in the floodplain study), but reduced to exclude areas outside of a fence near the Belle Fourche River⁸. Twenty points within the designated area were randomly chosen using a GIS, and the same criteria used at THRO were

⁸ This area is slightly different from the final designated riparian area in Appendix B.

used to determine the 10 points actually sampled in the field. Sampling at this park was done July 21-22, 2008.

Soil maps did not exist for SCBL. Therefore, at this park the 3890 foot contour line was used as the boundary for the riparian zone⁹. Twenty-one points were randomly located within this zone using a GIS, and ten of these were sampled following criteria used at THRO. Three sites were rejected because of dense poison ivy within the site. Sampling at this park was done August 4-7, 2008.

At FOLA (Fort Laramie National Historic Site), sample sites were chosen in a manner similar to that used at KNRI. However, at FOLA, the riparian zone was delineated by topography, rather than by mowed paths. River terraces, usually quite obvious in the field at this park, are not captured well in Digital Elevation Models or on topographic maps. Thus, delineation had to be done in the field by walking the border with a GPS. Twelve points were sampled within the delineated area August 7-8, 2008.

Sampling Methods: The protocol used for collecting data at the sites differed slightly between THRO and KNRI (the first two parks sampled) and in the remaining three parks. At all parks, species and dbh were recorded for all live trees with dbh ≥ 2.5 cm within a 10 m radius of the point designated by the random sampling process. In addition, all live seedlings (dbh < 2.5 cm or height < 1.37 m) except those with cotyledons (first-year seedlings) were counted by species in the entire circle and numbers recorded by quarter of the circle (i.e., NE, SE, NW, or SW quarter). First-year seedlings were counted by species in four 1 m x 1 m subplots, one per quarter, at KNRI and the parks sampled later in the season. (No first-year seedlings were encountered at THRO.) At DETO, SCBL, and FOLA, this process was clarified and slightly modified in two ways: (1) seedlings were tallied by species, height class (< 1.37 m or ≥ 1.37 m), and whether it was a root sprout or not; and (2) selected large shrub species (*Prunus virginiana*, *Rhamnus cathartica*, and all *Salix* species) were included in counts in addition to all tree species. In all parks, the dbh of only the largest-diameter stem was recorded for multiple-stemmed individuals.

Data Analysis: The number of stems in a variety of size categories was calculated for each plot. The mean and standard deviation of stem density in each of these categories was calculated for each park, and these values were plugged into the one-sample, two-sided confidence interval option in SAS Analyst's sample size calculator (SAS Institute Inc. 2002-2003) to estimate the sample size needed to obtain 20%, 50%, or 100% precision for the estimate of stem density in each size category for each park. For all calculations, data were pooled over all species.

To evaluate the effect on precision of counting seedlings in a smaller area, we also calculated the mean, standard deviation, and coefficient of variation of seedling stem density when data from only one quarter in each plot were used; this was calculated for each quarter. Seedlings were defined as tree or tall shrub species with dbh < 2.5 cm and no cotyledons present. Seedlings with cotyledons were not included in these calculations because of their ephemeral nature.

⁹ This area differs slightly from that designated as the final riparian zone in Appendix B.

Results

Forest structure varied substantially among parks, with DETO having few trees in the small (dbh < 2.5 cm or dbh 2.5-10 cm) and largest (dbh > 40 cm) size classes compared to most other parks. No trees of the largest size class were encountered in plots at the south unit of THRO (THRO-S). High variability in density among plots was common in all size classes at all parks (coefficients of variation > 1.5), and patterns of variability among size classes were not consistent among parks (Table A6). Consequently, sample sizes needed to achieve high precision of density estimates (20% of mean) are large (Table A7). Sample sizes of 20-30 would provide 50% precision for many size classes in three of the smaller parks (FOLA, KNRI, and SCBL), but not at DETO (a smaller park) or in the two units of THRO. In these three units, sample sizes would have to be approximately three times as large to achieve the same precision.

The coefficient of variation of seedling density tended to be lower when seedlings were counted in the whole plot than when counted in one quarter of the plot. On average, counting seedlings in a quarter increased the sample size necessary to estimate the mean density by 90%, 34 %, and 25% for DETO, FOLA, and SCBL, respectively.

Table A6. Stem density ("with cotyledons", m⁻²; all others ha⁻¹) statistics used for calculating sample sizes for riparian forest structure.

Park	Stem Density						
	with cotyledons	dbh < 2.5 cm (no cotys)	dbh 2.5-10 cm	dbh 10.1-20 cm	dbh 20.1-40 cm	dbh > 40 cm	
THRO-N	0.0	10531	146	16	21	34	Mean
THRO-S	0.0	2954	197	64	17	0	
DETO	2.1	344	6	25	54	3	
FOLA	0.0	1759	40	72	66	48	
KNRI	18.0	3524	153	111	127	38	
SCBL	0.4	2238	197	191	35	16	
THRO-N	0.00	17333	347	40	44	58	Standard Deviation
THRO-S	0.00	5683	521	111	48	0	
DETO	4.13	649	20	52	86	10	
FOLA	0.00	2413	64	107	63	48	
KNRI	36.16	5897	285	174	123	29	
SCBL	1.11	2380	318	217	38	23	
THRO-N	.	1.646	2.378	2.486	2.056	1.691	Coefficient of Variation
THRO-S	.	1.924	2.649	1.746	2.764	.	
DETO	0.485	1.888	3.162	2.024	1.594	3.162	
FOLA	.	1.372	1.605	1.494	0.948	1.005	
KNRI	0.503	1.673	1.865	1.561	0.965	0.766	
SCBL	0.791	1.063	1.609	1.139	1.088	1.414	

Table A7. Estimated sample sizes needed to achieve various levels of precision for different size classes of tree and tall shrub species in riparian forests at six park units. For all, $\alpha = \beta = 0.1$.

Park	Stem Density						
	with cotyledons	dbh < 2.5 cm (no cotys)	dbh 2.5-10 cm	dbh 10.1-20 cm	dbh 20.1-40 cm	dbh > 40 cm	
THRO-N	.	202	405	442	323	205	N for 20% precision
THRO-S	.	27	499	225	539	.	
DETO	276	292	704	299	189	726	
FOLA	.	144	192	167	71	80	
KNRI	295	210	255	182	74	49	
SCBL	710	90	193	101	93	152	
THRO-N	.	38	72	78	57	40	N for 50% precision
THRO-S	.	50	88	42	97	.	
DETO	50	53	122	54	36	125	
FOLA	.	27	36	32	15	17	
KNRI	53	39	47	17	16	11	
SCBL	121	18	36	20	19	29	
THRO-N	.	12	22	23	17	13	N for 100% precision
THRO-S	.	16	26	14	28	.	
DETO	16	14	35	17	12	36	
FOLA	.	10	12	11	6	7	
KNRI	17	13	15	12	6	5	
SCBL	35	7	12	8	7	10	

Table A8. Comparison of mean, standard deviation, coefficient of variation and sample size needed to estimate the mean seedling (dbh < 2.5 cm) density (ha^{-1}) with 50% precision, 90% confidence, and 90% power when sampled in a wedge-shaped quarter (NE, SE, SW, NW) vs. in the whole plot (PLOT).

Park	Quarter	Mean	SD	CV	N
DETO	NE	25	81	3.16	130
DETO	SE	407	720	1.77	46
DETO	SW	140	443	3.16	128
DETO	NW	802	2003	2.50	84
DETO	PLOT	344	649	1.89	51
FOLA	NE	2090	3952	1.89	52
FOLA	SE	1804	2806	1.56	37
FOLA	SW	1475	2448	1.66	41
FOLA	NW	1666	2336	1.40	31
FOLA	PLOT	1759	2413	1.37	30
SCBL	NE	2406	3069	1.28	27
SCBL	SE	2024	2140	1.06	20
SCBL	SW	1553	1860	1.20	24
SCBL	NW	2967	3933	1.33	29
SCBL	PLOT	2238	2380	1.06	20

Discussion and Conclusions

As with the ponderosa pine forest, these analyses confirm that the number of samples obtained by intensive plant sampling would not provide reasonable precision for status estimates of forest structure in the riparian lowlands of NGPN park units. However, the amount that the sample size can be increased to improve this precision must be tempered by logistical constraints.

Consistency with the revisit design of the intensive plant community plots is also desirable.

Taking these things into consideration, as well as the sample size estimates provided by these calculations, we chose a [(1-4)¹] revisit design for extensive woody plots in riparian lowlands and determined sample sizes for each park. These sample sizes are shown in the main text. In general, smaller parks will have a sample size of 25-40 in riparian lowlands, whereas the riparian lowlands of the two units at THRO will have a sample size of 70.¹⁰ These values should provide approximately 50% precision in status estimates of many size classes, although precision of estimates at DETO will be worse because of very high spatial variability at this park. This admittedly is not as precise as many managers might desire (20% seems to be a common threshold). Future work, based on data collected in the first round of extensive plot sampling, will better determine actual precision levels obtained and provide information for determining whether precision can be improved.

Our comparison of precision obtainable with whole-plot vs. single-quarter seedling counts showed that smaller sample areas would lead to lower precision of estimates when number of samples is held constant. However, the three-fold increase in time required to count the whole plot vs. a single quarter must be considered. When seedling density is high, this increase can be as much as two hours for a team of two people searching and one recording. To balance the trade-off in time vs. precision, we determined that when seedling density of a given species is very high, seedling counts would be done in fewer than four quarters of the plot. SOP Trees and Shrubs describes the details of this procedure.

¹⁰ These sample sizes include the intensive plots, since forest structure will be measured in them as well.

Literature Cited

- Brown, J. K. 1974. Handbook for inventorying downed material. General Technical Report INT-16, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Brown, J. K., R. D. Oberhue, and C. M. Johnston. 1982. Inventorying surface fuels and biomass in the Interior West. General Technical Report INT-129, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Harrell, F. E., Jr. 2001. Regression modeling strategies: with applications to linear models, logistic regression, and survival analysis. Springer, New York, NY.
- Kincaid, T. M., D. P. Larsen, and N. S. Urquhart. 2004. The structure of variation and its influence on the estimation of status: indicators of condition of lakes in the Northeast, U.S.A. *Environmental Monitoring and Assessment* **98**:1-21.
- Larsen, D. P., P. R. Kaufmann, T. M. Kincaid, and N. S. Urquhart. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. *Canadian Journal of Fisheries and Aquatic Sciences* **61**:283-291.
- Larsen, D. P., T. M. Kincaid, S. E. Jacobs, and N. S. Urquhart. 2001. Designs for evaluating local and regional scale trends. *BioScience* **51**:1069-1078.
- McDonald, T. L. 2003. Review of environmental monitoring methods: Survey designs. *Environmental Monitoring and Assessment* **85**:277-292.
- SAS Institute Inc. 2002-2003. The SAS system for Windows. Cary, NC.
- Symstad, A. J., and M. Bynum. 2007. Conservation value of Mount Rushmore National Memorial's forest. *Natural Areas Journal* **27**:293-301.
- Symstad, A. J., C. L. Wienk, and A. D. Thorstenson. 2008. Precision, repeatability, and efficiency of two canopy-cover estimate methods in northern Great Plains vegetation. *Rangeland Ecology & Management* **61**:419-429.
- Urquhart, N. S., and T. M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. *Journal of Agricultural, Biological, and Environmental Statistics* **4**:404-414.
- Urquhart, N. S., W. S. Overton, and D. S. Birkes. 1993. Comparing sampling designs for the monitoring of ecological status and trends: impact of temporal patterns. Pages 71-85 in V. Barnett and K. F. Turkman, editors. *Statistics for the environment*. Wiley, London, UK.
- Urquhart, N. S., S. G. Paulsen, and D. P. Larsen. 1998. Monitoring for policy-relevant regional trends over time. *Ecological Applications* **8**:246-257.
- Zar, J. H. 1996. Biostatistical analysis. 3rd edition. Prentice-Hall, Upper Saddle River, NJ.

Attachment. Program R function used to calculate power to detect linear trend and precision of status estimates for NGPN Vegetation monitoring. Function was written by Tom Kincaid, EPA, Corvallis, OR, and modified slightly by R. Gitzen after discussion with T. Kincaid so that the standard error of the estimate of status would be produced.

```
# Define function that takes these input values
power.status.fcn <- function(indicator="Test Indicator", ind.mean=1, trend=2, nsites=matrix(rep(50, 20), nrow=1, ncol=20),
nrepeats=1, site.var=1, year.var=0.001, siteyear.var=0.1, index.var=0.5, site.rho=1, year.rho=0, alfa=0.05, plot.ind=TRUE) {

#Text in following box describes the function and each of these input values
#####
# Function: power.status.fcn
# Programmer: Tom Kincaid
# Date: January 19, 2005; modified 3 Aug 2006 R. Gitzen to output SE of status
# Description:
# This function calculates power for trend detection for a set of indicators,
# where the model includes variance component for sites, years, and the
# interaction of sites and years. Default values for the function calculate
# power to detect a trend of 2% per year for an indicator named "Test
# Indicator" that has a mean value equal to 1, site variance equal to 1, year
# variance equal to 0.001, site-by-year variance equal to 0.1, and residual
# (index) variance equal to 0.5. The default design uses a single panel of 50
# sites that are visited once each year for 20 years. By default, a plot of
# power for trend detection is produced.
# Input:
# indicator = a vector of indicator names, where the maximum number of
# indicators is six. The default is "Test Indicator".
# ind.mean = a vector of indicator means, where a value of one is used for
# log transformed indicators. The default is 1.
# trend = the trend expressed as percent per year. The default is 2%.
# nsites = a matrix (dimensions: number of panels (rows) by number of years
# (columns)) containing the number of sites visited for each combination
# of panel and year. The default is a single panel containing 50 sites
# that are visited for 20 years.
# nrepeats = either a single number or a matrix the same dimension as
# nsites specifying the number of revisits to the sites in a panel for a
# year, where a single number indicates a fixed number of revisits for
# all years. The default is 1.
# site.var = a vector of variance component estimates for site. The
# default is 1.
# year.var = a vector of variance component estimates for year. The
# default is 0.001.
# site.year.var = a vector of variance component estimates for site by year
# interaction. The default is 0.01.
# index.var = a vector of variance component estimates for index (residual)
# error. The default is 0.5.
# site.rho = site correlation across years. The default is 1.
# year.rho = year autocorrelation. The default is 0.
# alfa = the alpha, Type I error, level. The default is 0.05.
# plot.ind = option to produce a plot of power values, where TRUE = produce
# the plot and FALSE = do not produce the plot. The default is TRUE.
# Output:
# The function returns a data frame of power values for trend detection.
# Optionally, a plot of power values can be produced.
#####

# Calculate additional required values

nind <- length(indicator)
trend <- trend/100
trend.mean <- trend*ind.mean

# Ensure that nsites is a matrix
```

```

if(length(nsites) == 1)
  stop("\n\nThe input value for nsites must be a matrix.")
if(!is.matrix(nsites))
  nsites <- as.matrix(nsites)

# Calculate the number of panels and the number of years for nsites

npanels <- nrow(nsites)
nyears <- ncol(nsites)

# Ensure for a design with a single panel that nsites has one row

if(nyears == 1) {
  nsites <- t(nsites)
  nyears <- npanels
  npanels <- 1
}

# As necessary, create nrepeats

if(length(nrepeats) == 1) {
  temp <- nrepeats
  nrepeats <- matrix(0, nrow=npanels, ncol=nyears)
  nrepeats[nsites > 0] <- temp
}

# Ensure that nrepeats is a matrix

if(!is.matrix(nrepeats))
  nrepeats <- as.matrix(nrepeats)

# Calculate the number of panels and the number of years for nrepeats

npanels.nr <- nrow(nrepeats)
nyears.nr <- ncol(nrepeats)

# Ensure for a design with a single panel that nrepeats has one row

if(nyears.nr == 1) {
  nrepeats <- t(nrepeats)
  nyears.nr <- npanels.nr
  npanels.nr <- 1
}

# Ensure that nsites and nrepeats have the same dimensions

if(npanels != npanels.nr)
  stop("\n\nThe input values for nsites and nrepeats must have the same number of rows")
if(nyears != nyyears.nr)
  stop("\n\nThe input values for nsites and nrepeats must have the same number of columns")

# Create the array for output power values
#modified pout <- array(0, c(nyears-1,nind))
pout <- array(0, c(nyears-1,nind*2)) #modified to allow nind additional columns of status SEs

# modified Calculate power values
# Calculate power and status values
for(j in 1:nind) {
  for(i in 2:nyears) {
    #modified indexse <- trend.se.fcn(nsites=nsites[,1:i], nrepeats=nrepeats[,1:i],
    # site.var=site.var[j], year.var=year.var[j],

```

```

    # siteyear.var=siteyear.var[j], index.var=index.var[j],
    # site.rho=site.rho, year.rho=year.rho)
  #Now calculate betahat.cov here
  betahat.cov <- statustrend.bcov.fcn(nsites=nsites[,1:i], nrepeats=nrepeats[,1:i],
  site.var=site.var[j], year.var=year.var[j],
  siteyear.var=siteyear.var[j], index.var=index.var[j],
  site.rho=site.rho, year.rho=year.rho)
  #Power
  indexse<-sqrt(betahat.cov[2,2])
  pout[i-1,j] <- (pnorm(qnorm(alfa/2) - (trend.mean[j]/indexse))) +
  (1 - pnorm(qnorm(1-(alfa/2)) - (trend.mean[j]/indexse)) )

  #Status
  Co<-matrix(c(1,i,0,1),nrow=2,byrow=T)
  pout[i-1,j+nind] <- sqrt((Co%*%betahat.cov%*%t(Co))[1,1])
}
}

# Begin the section to produce the power plot

if(plot.ind) {

# Set up the plot of power curves

par(mar=c(3.1,4.1,0.1,0.1), oma=c(0,0.1,2.1,0.1), xpd=T)
ltype <- c(1, 3:6, 8)

plot(seq(0,nyears,length=11), seq(0,1,length=11), ylim=c(0,1),
  xlim=c(0,nyears), ylab="", xlab="", type="n", axes=F)

axis(side=1, line=-0.75, at=seq(0, nyears, by=5), labels=seq(0, nyears,
  by=5), adj=0.5, font=3, cex=1)
axis(side=2, line=-0.5, at=seq(0, 1, by=0.2), labels=c("0%", "20%", "40%",
  "60%", "80%", "100%"), adj=0.85, font=3, cex=1)
mtext(outer=F, side=1, line=1.8, text="Number of Years", cex=1.5, font=3)
mtext(outer=F, side=2, line=2.5, text="Power for Trend Detection",
  cex=1.5, font=3)

# Plot the power values

for(j in 1:nind) {
  lines(2:nyears, pout[,j], lty=ltype[j], lwd=3)
}
# Create the legend for the plot

#legend(0, 1, as.character(indicator), lty=ltype[1:nind], lwd=3)

# Create the title for the plot

# End the section for the power plot

}

# Output the data frame of power values

pout <- data.frame(Year=2:nyears, pout)
names(pout)[-1] <- indicator
pout
}

```

#Program R function called by power.status.fcn to calculate covariance matrices for estimates #of status and trend. Written by Tom Kincaid, EPA, Corvallis, OR; modified slightly by #R.Gitzen

```
statustrend.bcov.fcn <- function(nsites, nrepeats=1, site.var=0, year.var=0, siteyear.var=0, index.var=0, site.rho=1, year.rho=0) {
```

```
#####
# Function:  statustrend.bcov.fcn = slight Gitzen modification of  trend.se.fcn
# Programmer: Tom Kincaid
# Date:      April 11, 2003; Modified 3 Aug 2006 to output betahat.cov
# Description:
# This function calculates the standard error for trend for a design.
# Input:
# nsites = a matrix (dimensions: number of panels (rows) by number of years
# (columns)) containing the number of sites visited for each combination
# of panel and year
# nrepeats = either a single number or a matrix the same dimension as
# nsites specifying the number of revisits to the sites in a panel for a
# year, where a single number indicates a fixed number of revisits for
# all years. The default is 1.
# site.var = the variance component estimate for site. The default is 0.
# year.var = the variance component estimate for year. The default is 0.
# site.year.var = the variance component estimate for site by year
# interaction. The default is 0.
# index.var = the variance component estimate for index error. The default
# is 0.
# site.rho = site correlation across years. The default is 1.
# year.rho = year autocorrelation. The default is 0.
# Output:
# The standard error for trend for a design. Modified 3 Aug 2006 by B. Gitzen to output betahat.cov.
#####
```

```
# Ensure that nsites is a matrix
```

```
if(length(nsites) == 1)
  stop("\n\nThe input value for nsites must be a matrix.")
if(!is.matrix(nsites))
  nsites <- as.matrix(nsites)
```

```
# Calculate the number of panels and the number of years for nsites
```

```
npanels <- nrow(nsites)
nyears <- ncol(nsites)
```

```
# Ensure for a design with a single panel that nsites has one row
```

```
if(nyears == 1) {
  nsites <- t(nsites)
  nyears <- npanels
  npanels <- 1
}
```

```
# Calculate the number of sites in each panel
```

```
panel.nsites <- apply(nsites, 1, max)
```

```
# Create a diagonal matrix containing the inverse of the number of sites in each panel
```

```
if(npanels > 1)
  dinv <- diag(1/panel.nsites)
else
  dinv <- 1/panel.nsites
```

```

# As necessary, create nrepeats

if(length(nrepeats) == 1) {
  temp <- nrepeats
  nrepeats <- matrix(0, nrow=npanels, ncol=nyears)
  nrepeats[nsites > 0] <- temp
}

# Ensure that nrepeats is a matrix

if(!is.matrix(nrepeats))
  nrepeats <- as.matrix(nrepeats)

# Calculate the number of panels and the number of years for nrepeats

npanels.nr <- nrow(nrepeats)
nyears.nr <- ncol(nrepeats)

# Ensure for a design with a single panel that nrepeats has one row

if(nyears.nr == 1) {
  nrepeats <- t(nrepeats)
  nyyears.nr <- npanels.nr
  npanels.nr <- 1
}

# Ensure that nsites and nrepeats have the same dimensions

if(npanels != npanels.nr)
  stop("\n\nThe input values for nsites and nrepeats must have the same number of rows")
if(nyears != nyyears.nr)
  stop("\n\nThe input values for nsites and nrepeats must have the same number of columns")

# Create a diagonal matrix containing the inverse of the number of sites in each panel times the number of visits

dinv.index <- diag(as.vector(ifelse((nsites*nrepeats) > 0, 1/(nsites*nrepeats), 0)))

# Create the matrix for year-to-year correlation of a panel mean

rhomat <- matrix(0, nrow=nyears, ncol=nyears)
rhomat[1,] <- 0:(nyears-1)
for(i in 2:nyears) {
  rhomat[i,] <- c(rev(1:(i-1)), 0:(nyears-i))
}

# Create the matrix for year-to-year covariance of the response due to site variation

site.cov <- site.var*(site.rho ^ rhomat)

# Create the matrix for year-to-year covariance of the response due to year variation

year.cov <- year.var*(year.rho ^ rhomat)

# Create the matrix for year-to-year covariance of the response due to site-by-year variation

siteyear.cov <- siteyear.var*diag(nyears)

# Create the matrix for year-to-year covariance of the response due to index variation

index.cov <- index.var*diag(nyears)

# Create the design matrix for trend

```

```

xmat <- cbind(rep(1, npanels*nyears), rep(1:nyears, rep(npanels, nyears)))

# Create the covariance matrix for panel means across years

phi <- kronecker(site.cov,dinv) + kronecker(year.cov,matrix(1, nrow=npanels, ncol=npanels)) + kronecker(siteyear.cov,dinv) +
kronecker(index.cov,diag(npanels))*dinv.index

# Reduce the dimensionality of xmat and phi to retain only those years in which a panel is visited

indx <- as.vector(nsites) > 0
xmat <- xmat[indx,]
phi <- phi[indx, indx]

# Calculate the variance/covariance matrix for the intercept and trend estimates

temp.qr <- qr(phi)
if(temp.qr$rank < sum(indx))
  stop("\n\nThe covariance matrix is less than full rank.")
phi.inv <- solve(temp.qr)
betahat.cov <- solve(t(xmat) %*% phi.inv %*% xmat)
#return betahat.cov
betahat.cov

#old
# Return the standard error of the trend estimate
#sqrt(betahat.cov[2,2])
}

```

Appendix B: Sample Frame and Differential Allocation of Sampling Efforts by Park

The main text of the Protocol describes the general rules applied across all parks for excluding areas from each park's sample frame. This appendix describes exceptions and additions to these rules and explains the reasons for, and specific boundaries of, stratification or differential allocation of sampling effort in each park.

Agate Fossil Beds National Monument (AGFO)

The sample frame for this park follows the general rules described in the main text of the Protocol, with one exception. Several trails/access routes are not paved but are regularly mowed during the growing season. These trails, with a minimal buffer, are excluded for the same reason as areas within 10 m of a park boundary (i.e., the management activities are not representative of the whole park). Figure B1 shows these trails.

Approximately 25% of the area within the park's administrative boundary is not owned in fee-title by the park. Although there are no immediate plans for the park to acquire these areas, most were included in the sampling frame in case they do become part of the park. No single parcel is large enough to encompass a whole new panel of samples, and it is unlikely that all parcels would be obtained at the same time. One parcel currently in the boundary of the park but not owned was not included in the sample frame: the access route to the *Stenomylus* quarry (east side of park), was not included because its linear shape would not accommodate samples.

The riparian zone will be sampled using the small stream riparian sampling protocol under development. This protocol will accommodate the unique circumstances of the Niobrara River at AGFO within the NGPN (areas of true wetland vegetation, active meandering of the stream) and result in a greater sampling effort in this zone than is warranted by its area. The exact boundaries of the riparian zone will be determined as part of this protocol.

This park has no extensive woody sampling.

Figure B1 shows the administrative boundary, sampling frame points by ownership, roads, trails, and Prairie Cluster Prototype plot locations for AGFO. Prairie Cluster Prototype plot symbols are coded as to whether the plot will continue to be monitored by NGPN as "Legacy Plots" or will become dormant (see Appendix D for more information on these plots).

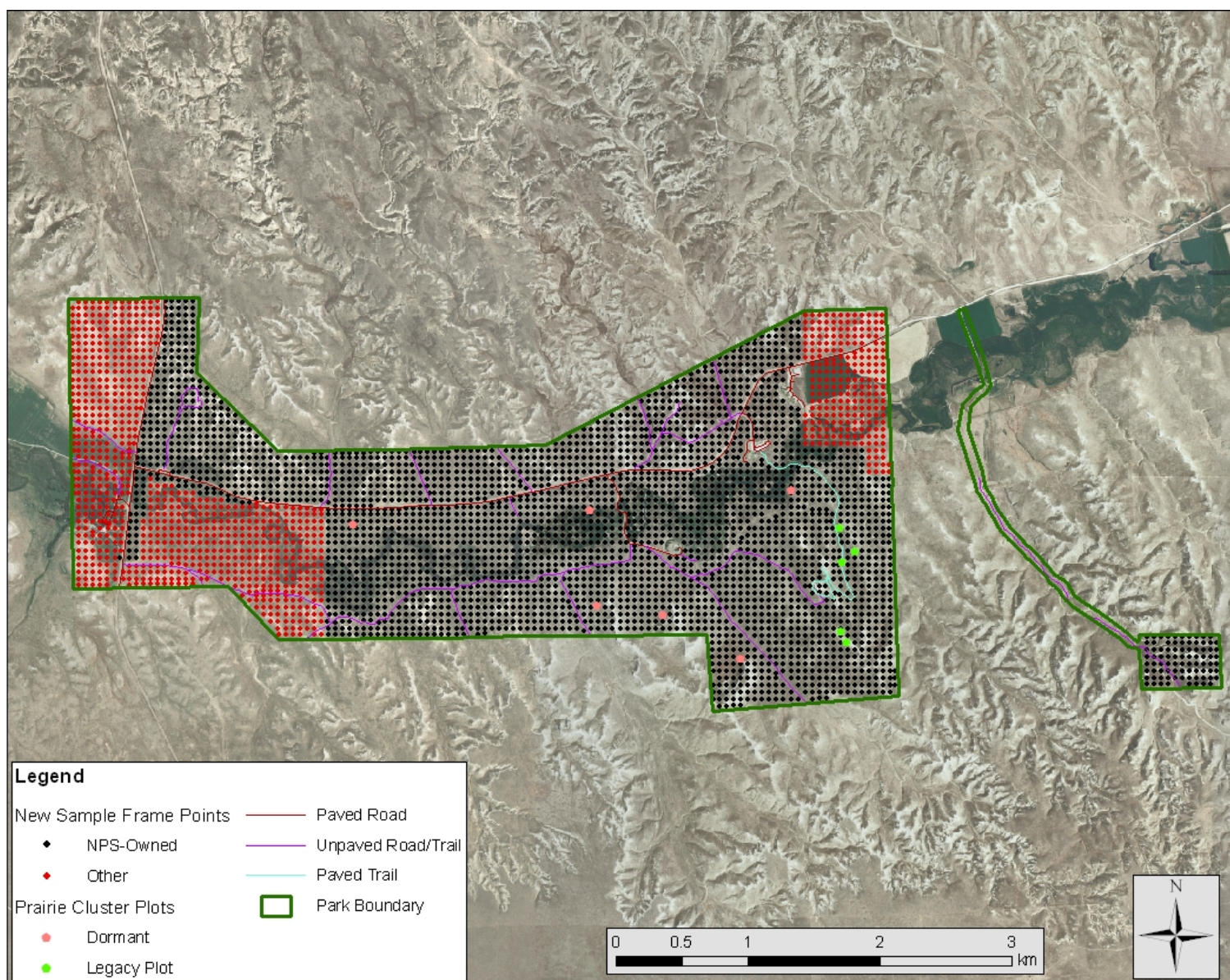


Figure B1. Sample frame for Agate Fossil Beds National Monument.

Badlands National Park (BADL)

The sample frame for this park follows the general rules described in the main text of the Protocol, with two exceptions:

- A GRTS sample was drawn only for the North Unit of the park. The Stronghold and Palmer units together comprise the South Unit, which is approximately 53,900 ha (133,300 acres) in size. The South Unit is part of the Pine Ridge Indian Reservation, which is governed by the Tribal Council of the Oglala Sioux Tribe (OST). NPS staff members have limited access to these properties and limited influence over how the properties are managed. If cooperation between the OST and the NPS increases in the future, and plant community composition and structure monitoring is desired in the Stronghold and Palmer units, a separate GRTS sample will be drawn for these units.
- Areas where bison are driven into the bison handling area or that are used for holding bison after they have been rounded up are not included in the sample frame because of the unusual concentration of animals in this area during a portion of the year.

There are no areas of differential sample allocation in this park. A small portion of the area within the North Unit's boundary (1.4%) is not owned by the park. These areas were included in the sample frame because the general intention is for the park to acquire these properties at some time in the future if possible, but they are not large enough to warrant a separate stratum. One of these areas is owned by The Nature Conservancy, which granted NPS permission to establish permanent vegetation monitoring plots on their property within the park boundary, with the condition that data from any plots that fall on their property be shared with the organization (email communication from Bob Paulson, TNC Western Dakotas Program Director, to A. Symstad, 29 January 2009).

This park has no extensive woody sampling.

Figure B2 shows the administrative boundary, sample frame points, and roads for the North Unit of BADL.

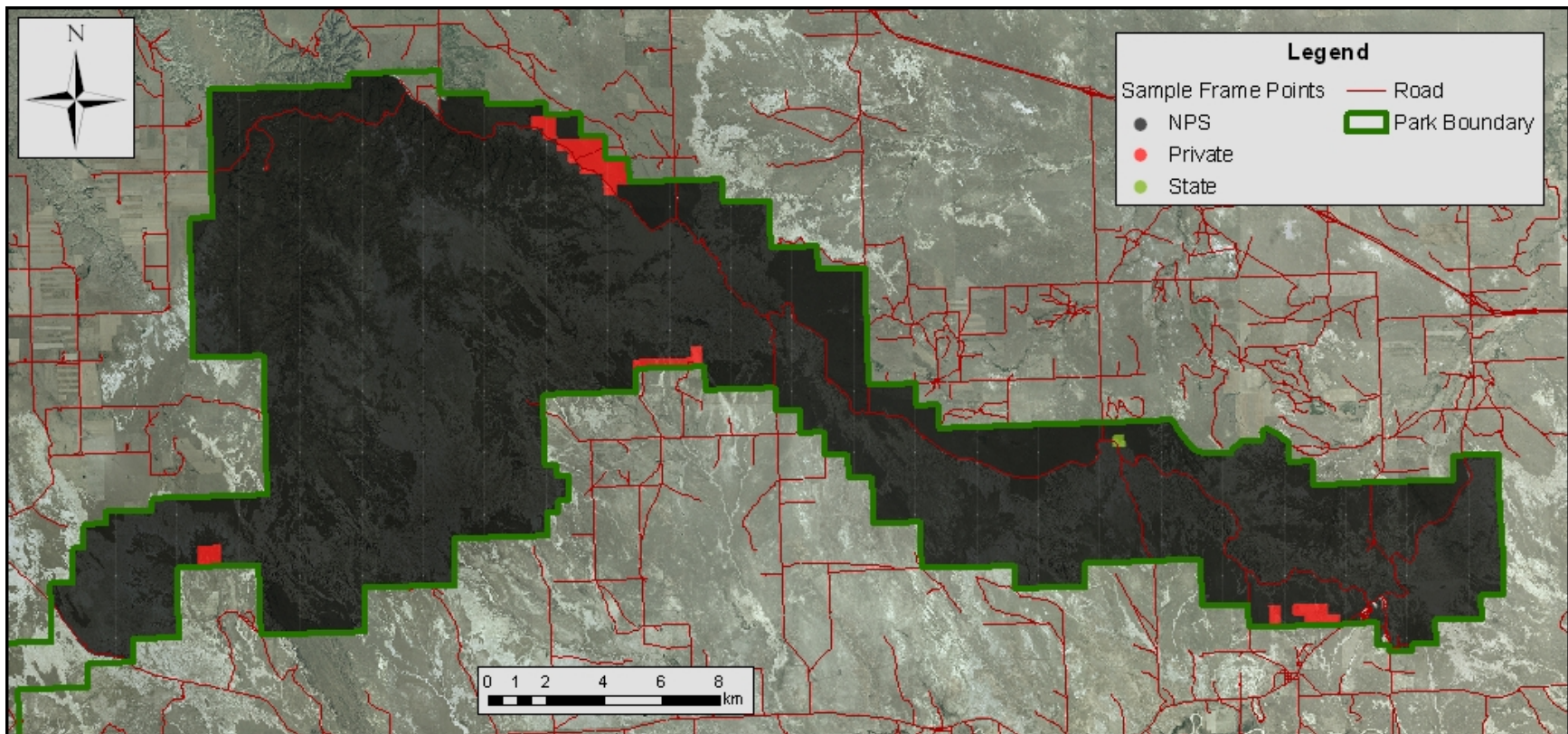


Figure B2. Sample frame for Badlands National Park. Scale is such that individual points blend to appear as shading.

Devils Tower National Monument (DETO)

The sample frame for this park follows the general rules described in the main text of the Protocol, with two exceptions.

- Unpaved fire roads, which are regularly driven on, are excluded from the sample frame.
- At the main entrance of the park (center of eastern boundary), a parking lot/shuttle loading station is planned for the near future. This area was excluded from the sample frame.

The riparian lowland stratum has a higher allocation of samples than is warranted by its area because of its ecological (e.g., sensitivity to river control) and management (e.g., invasive species) significance. We used topography to distinguish the upland and riparian lowland strata from each other. We defined the riparian lowland stratum as everything below the highest river terrace by GPSing this terrace in the field. In most locations, this river terrace butts directly up against the slope of steep hills rising up to the tower. In one portion, however, a relatively level area, currently and historically occupied by a prairie dog town, extends out from the steep slopes. This area is separated from the riparian lowland stratum by approximately 2 m in elevation. The riparian lowland stratum incorporates areas historically influenced by the Belle Fourche River and comprises 12% percent of the sample frame for this park.

The sample frame for the extensive woody plots in this park includes the whole park.

Figure B3 shows the administrative boundary, sample frame points color-coded by stratum, roads, and paved trails at DETO.

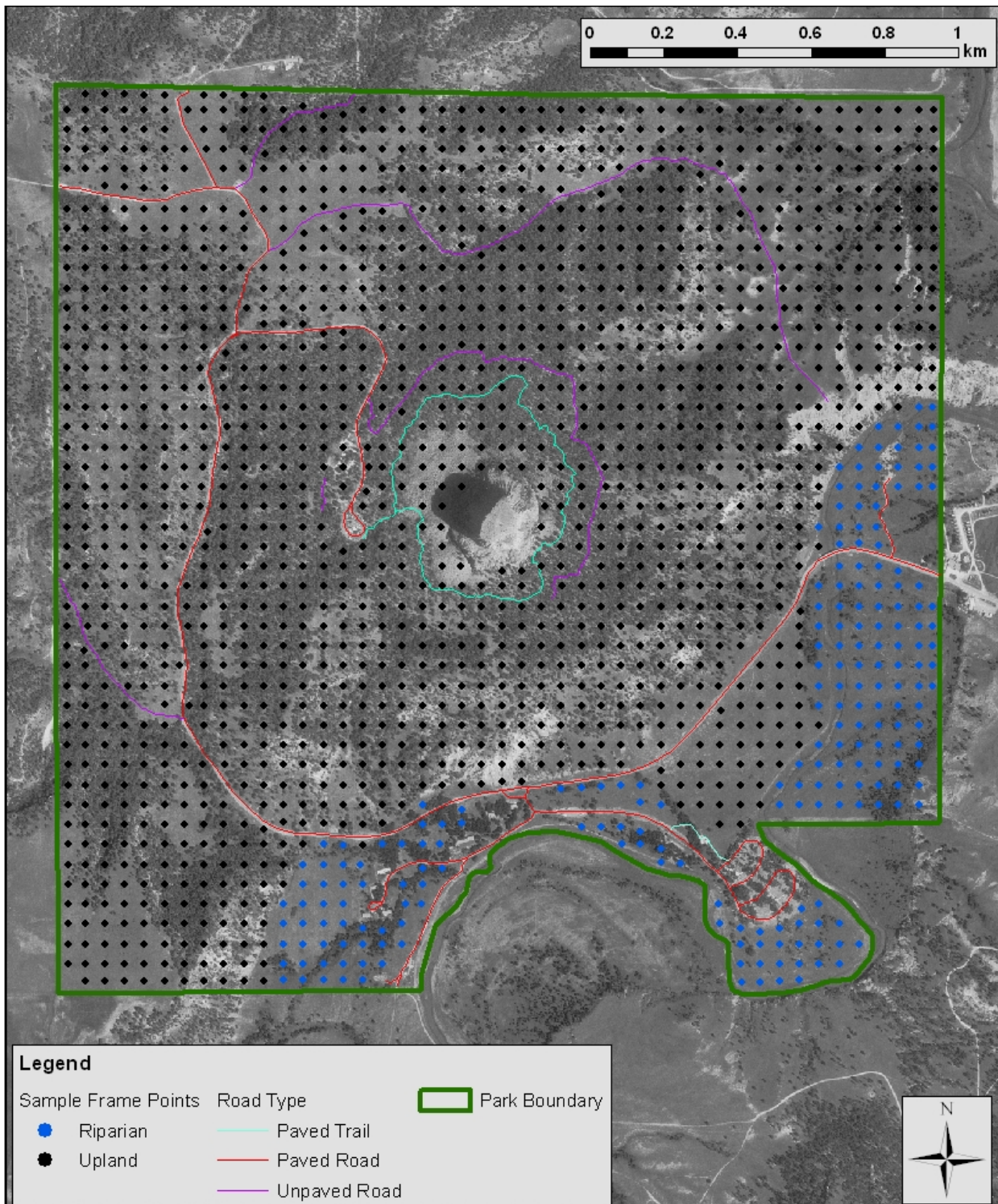


Figure B3. Sample frame for Devils Tower National Monument. For road type, “paved” refers to both gravel and asphalt/concrete surfaces. Unpaved roads are fire breaks/fire access roads.

Fort Laramie National Historic Site (FOLA)

In general, the sample frame for this park follows the rules described in the main text of the Protocol. However, this park has unique circumstances in that the park owns, in fee-title, some property outside of the official administrative boundary of the park (as of April 10, 2009). Because the park plans on ultimately adding these areas to within its boundary, these areas were included in the sample frame. In addition, a portion of land not currently owned by the park, but sandwiched between the owned-but-out-of-boundary area and the current boundary, was included in the sample frame in case this small area is acquired in the future. Figure B4 illustrates these different categories.

A relatively large portion of this small park (4% of the official boundary area) is excluded from the sample frame because a mowed lawn is maintained around the fort's ruins.

Because soils for the whole park are derived from fluvial processes, we used topography to distinguish the upland and riparian lowland strata from each other. We defined the riparian lowland stratum as everything below the highest river terrace, which was delineated by GPSing this terrace in the field. The riparian lowland stratum incorporates areas influenced by both the Laramie and North Platte Rivers and comprises 29% percent of the sample frame for this park.

The sample frame for extensive woody plots in this park is the riparian lowland zone.

Figure B4 shows the sample frame points color-coded by ownership category, boundaries of the riparian zone, the official administrative boundary, and roads at FOLA.

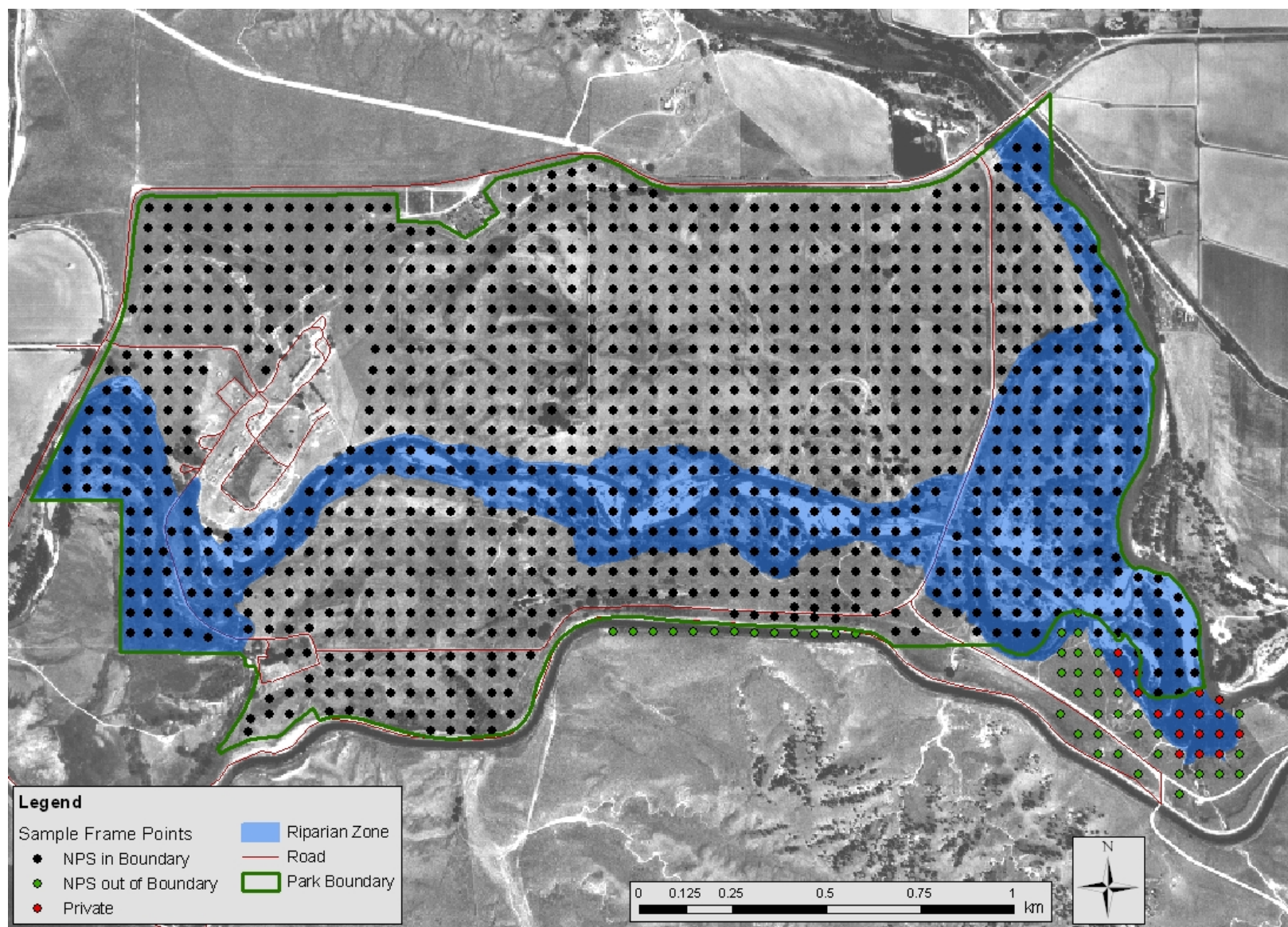


Figure B4. Sample frame for Fort Laramie National Historic Site.

Fort Union Trading Post National Historic Site (FOUS)

The sample frame for this park was revised in 2011 to better suit the needs of the park's new vegetation management plan and to better estimate the status of the upland terrace.

In spring 2011, FOUS completed a vegetation management plan (Symstad 2011) that determined desired conditions for four newly derived management units: (1) upland terraces surrounding the fort, (2) Bodmer Overlook unit; (3) riparian floodplain north of the Missouri River; and (4) terraces south of the Missouri River. The original sample frame for this park encompassed all of these management units, but the 2011 revision includes only the first two, for two reasons:

- The vegetation in the riparian floodplain is quite different from the upland vegetation. With the small number of plots that NGPN can sample at FOUS in a given year, only one or two plots would fall in the floodplain if it were included in the sample frame. With the rotating panel design, this plot (or these plots) would not provide adequate information on the status and trend of vegetation in the floodplain and would essentially dilute information on the rest of the sampling frame.
- The desired conditions for the riparian floodplain and the terraces south of the Missouri River focus on vegetation structure and have no specifics about composition, making the standard NGPN vegetation monitoring protocols in this area overkill. Regularly visited photo points, done either by park staff or by NGPN staff, combined with the land use/land coverage vital sign, are expected to provide better information for evaluating progress towards desired conditions in these two units than would the small number of plots possible as part of the standard plant community monitoring protocol.

Areas within the park boundary but designated only as an easement are not included in the revised sample frame because there are no plans for the NPS to own this land in fee title and, if NPS did acquire the property, the area would be large enough to encompass an entire panel of samples. The revised sample frame is divided into two strata – the Bodmer Overlook Unit and the Fort Unit – because they have very different management histories. Stratification ensures that adequate samples are allocated to the Bodmer Overlook unit for domain analyses focused on this unit, as well as good spatial distribution of samples within this unit. The Bodmer Overlook Unit comprises 17% of the total revised sample frame.

The Fort Unit is comprised of 10 fields, each with a unique vegetation management history. Consideration was given to designing the revised sample so that one plot occurred in each field (i.e., stratification within the Fort Unit), but this option was rejected based on the following:

- large variation in size among fields;
- loss of flexibility for data analysis;
- difficulties of analyses when field boundaries are ignored; and
- unit-wide information on status and trend of various response variables is more important than comparing individual fields.

However, to account for the known, relatively strong variation of vegetation among these fields, the GRTS draw for the Fort Unit of the revised sample frame was customized (see Appendix C).

This park has no extensive woody sampling.

Figure B5 shows the administrative boundary, ownership category of parcels, vegetation management units, and sample frame points, categorized by stratum, at FOUS.

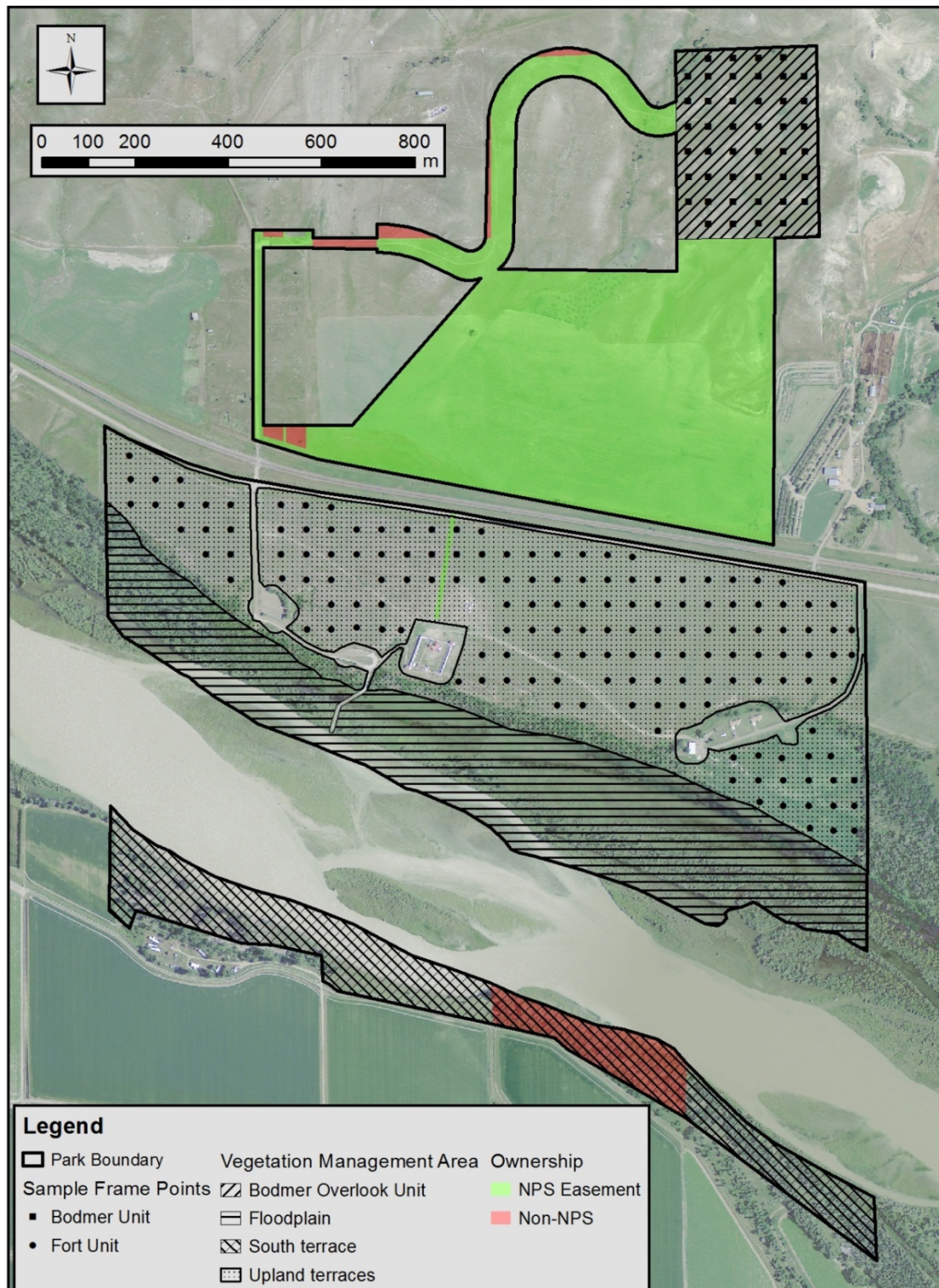


Figure B5. Revised sample frame for Fort Union Trading Post National Historic Site. Unshaded areas are owned in fee-title by NPS.

Jewel Cave National Monument (JECA)

The sample frame for this park follows the general rules described in the main text of the Protocol, and there are no areas of differential sample allocation. The entire area within the park boundary is owned by NPS.

The sample frame for extensive woody plots in this park is the entire park.

Figure B6 shows the park boundary, roads, and sample frame points for JECA.

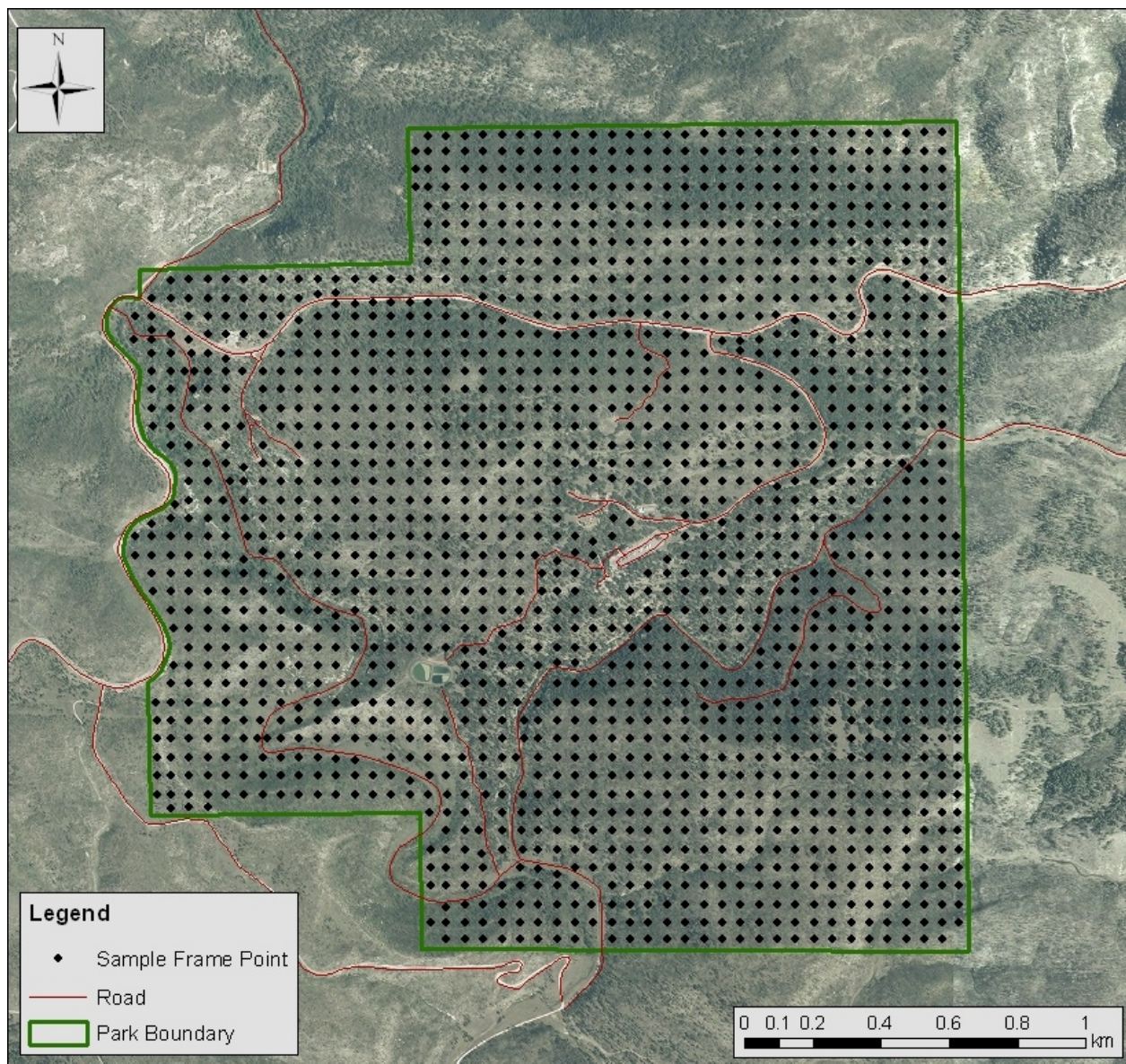


Figure B6. Sample frame for Jewel Cave National Monument.

Knife River Indian Villages National Historic Site (KNRI)

The sample frame for this park follows the general rules described in the main text of the Protocol, with two exceptions. In addition to the general exclusions, two types of area are excluded from the sample frame:

- The three village sites (Big Hidatsa, Sakakawea, and Lower Hidatsa) are excluded because of the sensitivity of their cultural resources, high visitor use, and frequent mowing. These areas were excluded from the GRTS draw.
- A network of mowed trails, wide enough to be driven on (and that often *are* driven on), provides access to the village sites and other portions of the park. No portion of a plot will fall within these mowed trails. These areas were not excluded from the GRTS draw because GIS layers were not sufficiently precise. Instead, this exclusion will be done in the field during the site evaluation process.

A small portion (2.2%) of the park is owned by the park but NPS has little control over the property (J. Moeykens, KNRI Chief Ranger, pers. comm. 11 December 2008). Although this area is included in the sample frame for the park, any sites falling within this area will be treated as dormant until further notice.

The sample frame for the extensive woody plots in KNRI is the whole park because most of the park has habitat suitable for tree growth, particularly in the absence of fire. However, trees and tall shrubs currently do not occur in a substantial portion of the park. The time required to visit plots in areas with a very low likelihood of having any tree or tall shrub species would be more efficiently used in sampling areas that have high probability of being active. Thus, when extensive woody plots are first established at KNRI, only those in or near currently wooded areas will be visited and, if acceptable, designated as active. Plots outside of this target area will be designated as dormant. We defined the target area by choosing all sample frame points that fell within forest or woodland vegetation types from the vegetation map completed for the park in 2002 (Salas and Pucherelli 2002), then adding a buffer of one grid cell around these points. Together, this currently wooded area and buffer comprise 51% of the sample frame area (Figure B7). Expansion of this target area will be re-evaluated before each extensive plot sampling effort (every five years) based on updated aerial photography and staff knowledge of on-the-ground conditions.

Figure B7 illustrates these areas (currently wooded and buffer), the area with no current access, and sample frame points outside of these areas (“Standard” sample type), as well as the park boundary, roads in or adjacent to the park, and the mowed trails.

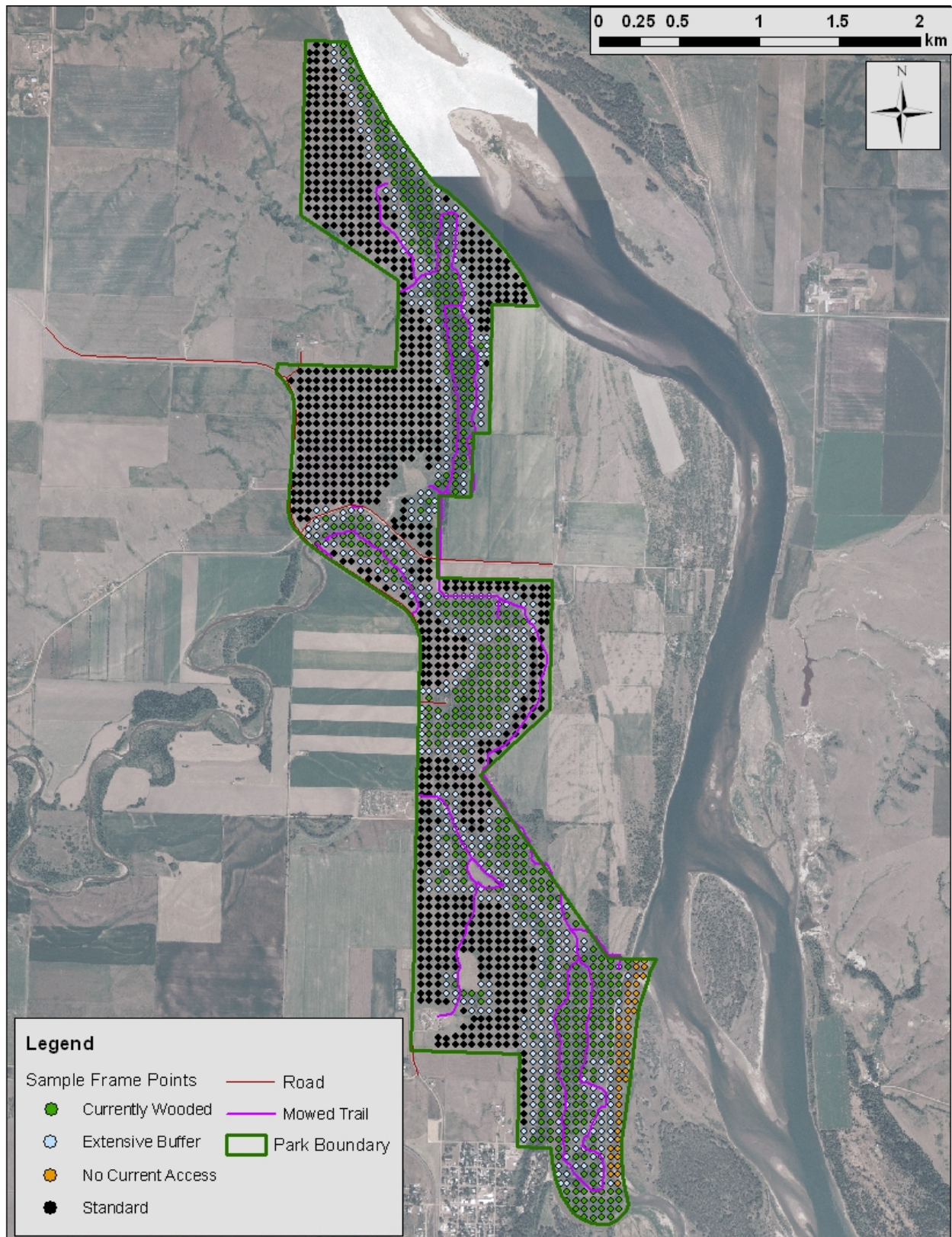


Figure B7. Sample frame for Knife River Indian Villages National Historic Site.

Missouri National Recreational River (MNRR)

The exact sample frame for this park has not yet been decided, but it will be limited to areas in the park boundary owned in fee-title by NPS.

Mount Rushmore National Memorial (MORU)

The sample frame for this park follows the general rules described in the main text of the Protocol, with two exceptions:

- In addition to the standard exclusions, a firing range, used by law enforcement personnel from MORU, other parks, and other organizations, is excluded for safety reasons.
- A parcel within the park boundary that is owned by the state of South Dakota is managed by MORU. Therefore, this parcel is included in the sample frame and any sample sites that occur within this parcel will be active.

Some portions of the park that have very high bare rock coverage were excluded from the sample frame prior to field visitation by digitizing these areas with a GIS and satellite images. Where questions about the ability of the area to support vegetation occurred, the area was *not* excluded until being field visited.

Figure B8 shows the sample frame points, state-owned land, roads, and park boundary at MORU.

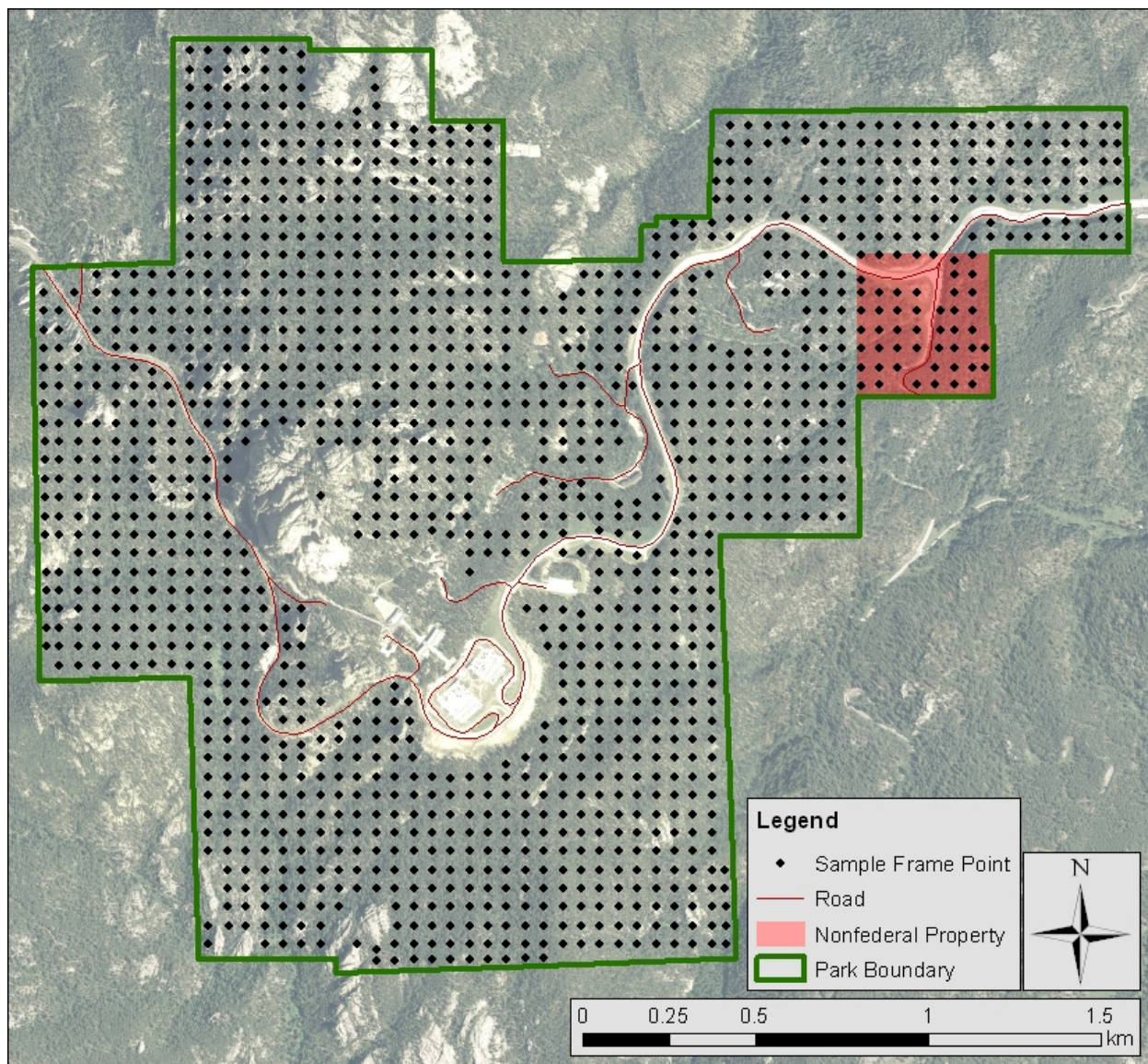


Figure B8. Sample frame for Mount Rushmore National Memorial.

Niobrara National Scenic River (NIOB)

The sample frame for this park has not yet been decided. No property is owned in fee-title by NPS at this park.

Scotts Bluff National Monument (SCBL)

The sample frame for this park follows the general rules described in the main text of the Protocol, with one exception. The riparian lowland area delimited for extensive woody sampling has a small area and high concentration of structures (roads, canals). To reduce the chance of eliminating sampleable points because of errors in GIS coverages of these structures, the structures and buffers were not excluded from the sample frame prior to field visitation of GRTS-selected sites (see Appendix C).

We used topography to distinguish the riparian lowland area, in which extensive woody sampling will occur. We defined this area as everything below the highest river terrace, which we delineated by GPSing this terrace in the field. In most locations, this river terrace butts directly up against the slope of steep hills rising up to the badlands or a railroad embankment. The riparian lowland area incorporates areas historically influenced by the North Platte River and comprises just 2 % of the sample frame for this park; 68% of this area is currently federally owned.

A very small portion (0.25%) of the upland area is currently not federally owned. This was included in the sampling frame.

Figure B9 shows the administrative boundary, roads, paved trails, railroads, canals, sampling frame points by ownership category and sampling zone, and Prairie Cluster Prototype plot locations for SCBL. Prairie Cluster Prototype plot symbols are coded as to whether the plot will continue to be monitored by NGPN as “Legacy Plots” or will become dormant (see Appendix D).

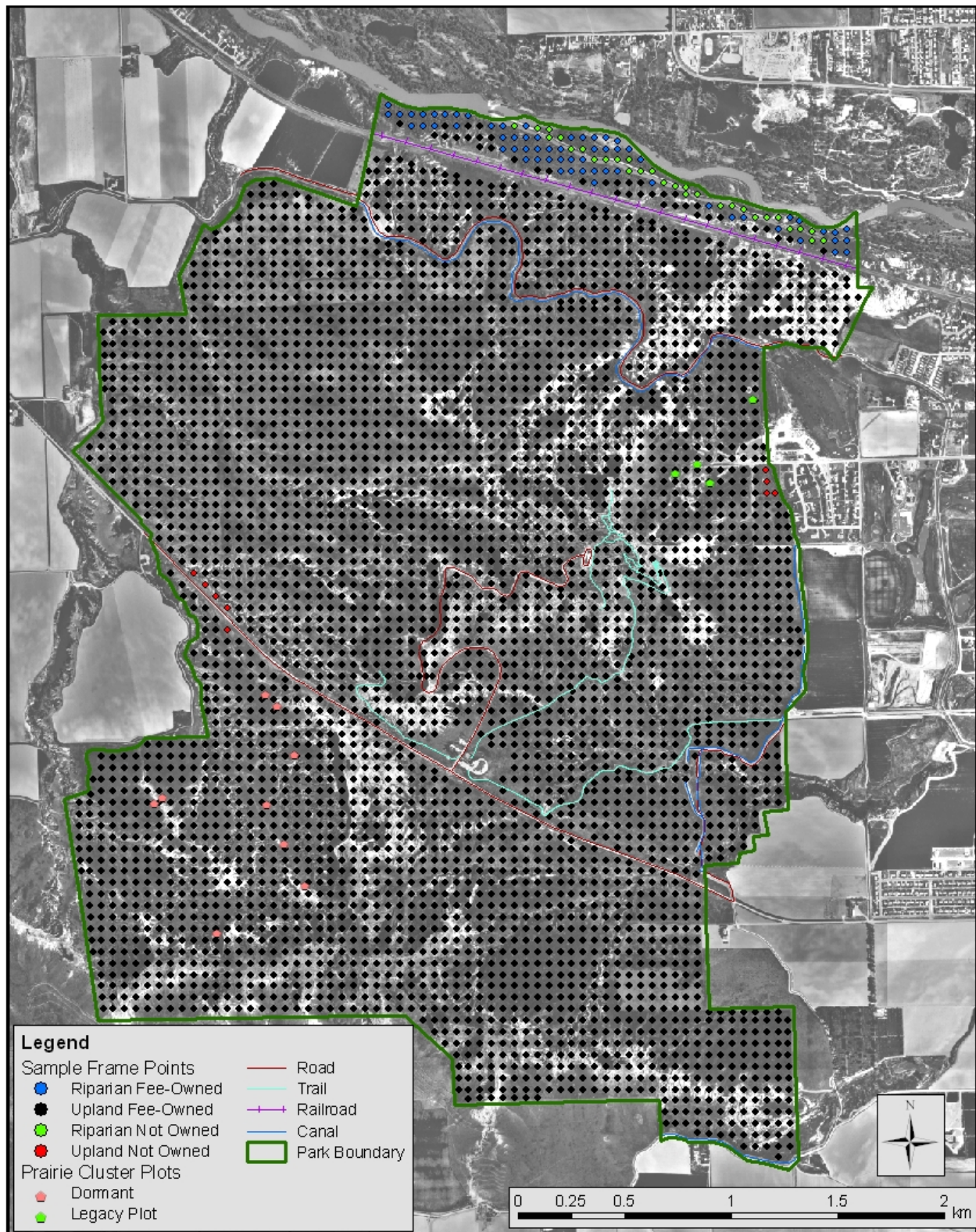


Figure B9. Sample frame for Scotts Bluff National Monument.

Theodore Roosevelt National Park (THRO)

This park consists of three distinct units, the North Unit (~9,745 ha), the South Unit (~18,688 ha), and the Elkhorn Unit (~88 ha). The sample frame does not include the Elkhorn Unit because of its small size and low management priority for natural resources, and the North and South Units are treated as separate sample frames. In each of these, the sample frame follows the general rules described in the main text of the Protocol with the following exceptions:

- The boundary fence does not always fall on the administrative boundary, often for topographical reasons. Park staff do not manage areas within the administrative boundary but outside of the boundary fence as park property¹¹, but they do manage areas outside of the administrative boundary but within the fence as park property (email communication from Chad Sexton, THRO GIS Analyst, to A. Symstad, 14 May 2009). Areas in the latter category generally were *not* added to the park's sample frame. Areas in the former category were excluded from the sample frame except for a small portion in the northeastern part of the North Unit, mostly on the eastern side of US Highway 85. This portion is treated like the adjacent private land – sites are included in the sample frame but would be considered dormant – because the park would take management control if the adjacent private land were acquired.
- Areas where bison and/or horses are driven into the wildlife handling facility or that are used for holding wildlife after they have been rounded up are not included in the sample frame because of the unusual concentration of animals in this area during a portion of the year.

In both the North and South Units, the riparian lowland stratum has a higher allocation of samples than is warranted by its area because of its ecological (e.g., wildlife habitat) and management (e.g., invasive species) significance. In both units, the riparian zone was based on soil types and location. Areas along the Little Missouri River corridor with alluvial soils were included, and these areas were delineated with the GIS using a soil map. Areas outside of the Little Missouri River corridor with these soil types (e.g., along Jones Creek) were not included in this stratum in order to concentrate on the Little Missouri River. Soil types included in the riparian lowland stratum are:

- Glendive and Havre soils – channeled – 0-3% slopes
- Glendive fine sandy loam – 0-3% slopes
- Glendive fine sandy loam – wooded – 0-3% slopes
- Hanly fine sandy loam – 0-6% slopes
- Hanly fine sandy loam – wooded – 0-6% slopes
- Havre silt loam – 0-3% slopes
- Havre silt loam – commonly flooded
- Havre silt loam – moderately well drained
- Havre silt loam – 1-6% slopes
- Havre silt loam – 6-9% slopes
- Kremlin-Rhoades-Ethridge Complex – 1-6% slopes

¹¹ Except in the South Unit south of Interstate 95. This area is included in the sample frame.

- Patent loam – 1-6% slopes
- Patent-Gullied Land-Glendive Complex – 1-9% slopes
- Patent-Rhoades-Slickspots Complex – 1-9% slopes
- Rhoades-Maltese silt loams – 0-6% slopes
- Water
- Wolf Point silty clay loam
- Wolf Point silty clay loam – commonly flooded
- Wolf Point silty clay loam – moderately well drained
- Zeona loamy fine sand – 1-9% slopes

In the North Unit, the riparian lowland stratum comprises 14.5% of the total sample frame. In the South Unit, this stratum comprises 4.7% of the total sample frame. The sample frame for extensive woody plots in each unit is the riparian lowland stratum.

The park boundary encompasses some property not owned by the NPS. Although there are no immediate plans for NPS to acquire most of this property, points falling in these areas are included in the sample frame because individual parcels are not large enough to encompass an entire panel of points. Any points drawn for sampling in these areas will be considered dormant until the property is acquired.

Figures B10 and B11 show the sample frame points color-coded by stratum and ownership, the administrative boundary, the boundary fence, and roads for the North and South Units of THRO, respectively.

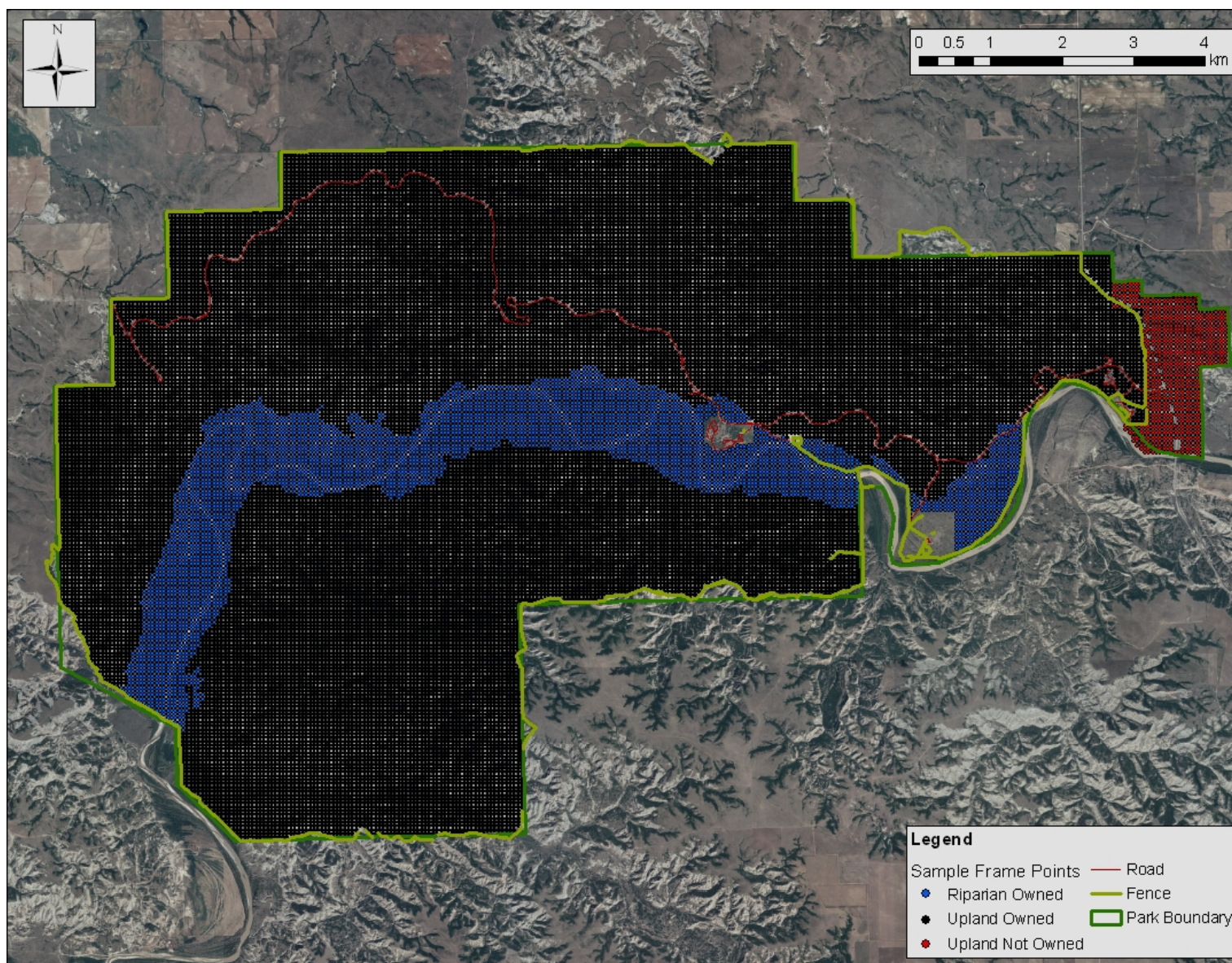


Figure B10. Sample frame for North Unit of Theodore Roosevelt National Park.

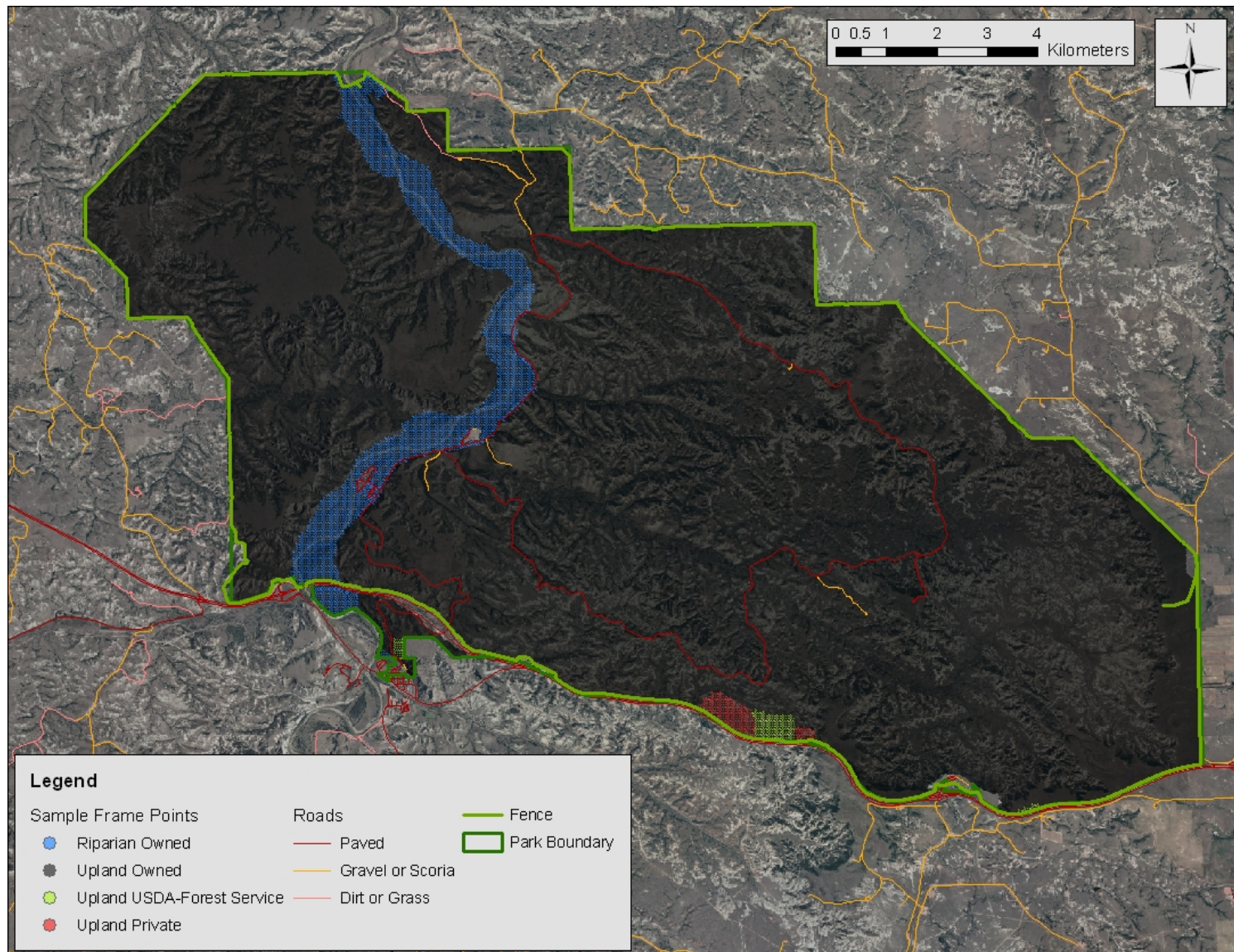


Figure B11. Sample frame for the South Unit of Theodore Roosevelt National Park. Scale is such that individual points blend to appear as shading.

Wind Cave National Park (WICA)

The sample frame for this park follows the general rules described in the main text of the Protocol with two exceptions:

- two small, isolated parcels west of the main portion of the park are not included in the sample frame because they are managed for water supply purposes only, and
- the area used for holding bison after they have been rounded up is not included in the sample frame because of the unusual concentration of animals in this area during a portion of the year.

Sampling at WICA will not be stratified. However, vegetation along one or more streams will be sampled using the small stream riparian vegetation sampling protocol under development. This protocol will accommodate the circumstances (generally in narrow canyon bottoms) and ecological concerns (e.g., trampling by large ungulates) regarding these streams and result in a greater sampling effort in this zone than is warranted by its area. The exact boundaries of the area included in this sampling will be determined as part of the small stream riparian vegetation protocol.

The sample frame for the extensive woody plots in WICA is the whole park because most of the park has habitat suitable for tree growth, particularly in the absence of fire. However, trees and tall shrubs currently do not occur or are very sparse in a substantial portion of the park. The time required to visit plots in areas with a very low likelihood of having any tree or tall shrub species would be more efficiently used in sampling areas that have high probability of being active. Thus, when extensive woody plots are first established at WICA, only those in or near currently wooded areas will be visited and, if acceptable, designated as active. All sites outside of this target area will be designated as dormant. We defined the target area from the 1999 vegetation map (Cogan et al. 1999). Vegetation types included in the target area are ponderosa pine forest and woodland (map classes 45-49), deciduous forest and woodland (map classes 40-44), tall shrubland (map classes 33-34), and areas with burned ponderosa pine trees (map classes 11-13), plus a 100 m buffer around the union of these types. This target area comprises 33% of the sample frame area (Figure B12). Expansion of this target area will be re-evaluated before each extensive plot sampling effort (every five years) based on updated aerial photography and staff knowledge of on-the-ground conditions.

Figure B12 shows the park's boundary in 2010, roads, and sample frame points (coded by current extensive woody target area or not) at WICA.

In October 2011, WICA acquired new land and increased the park size by nearly 20% (Figure B13). If time and money allow, NGPN will include this new acquisition in vegetation monitoring as a separate stratum. Within this stratum, two plots will be allocated to each of five panels. This will require increased sampling effort in WICA, which may not be possible due to limited resources. Adjustments in sample size between the original sample frame and the new acquisition stratum will be made according to NGPN capabilities.

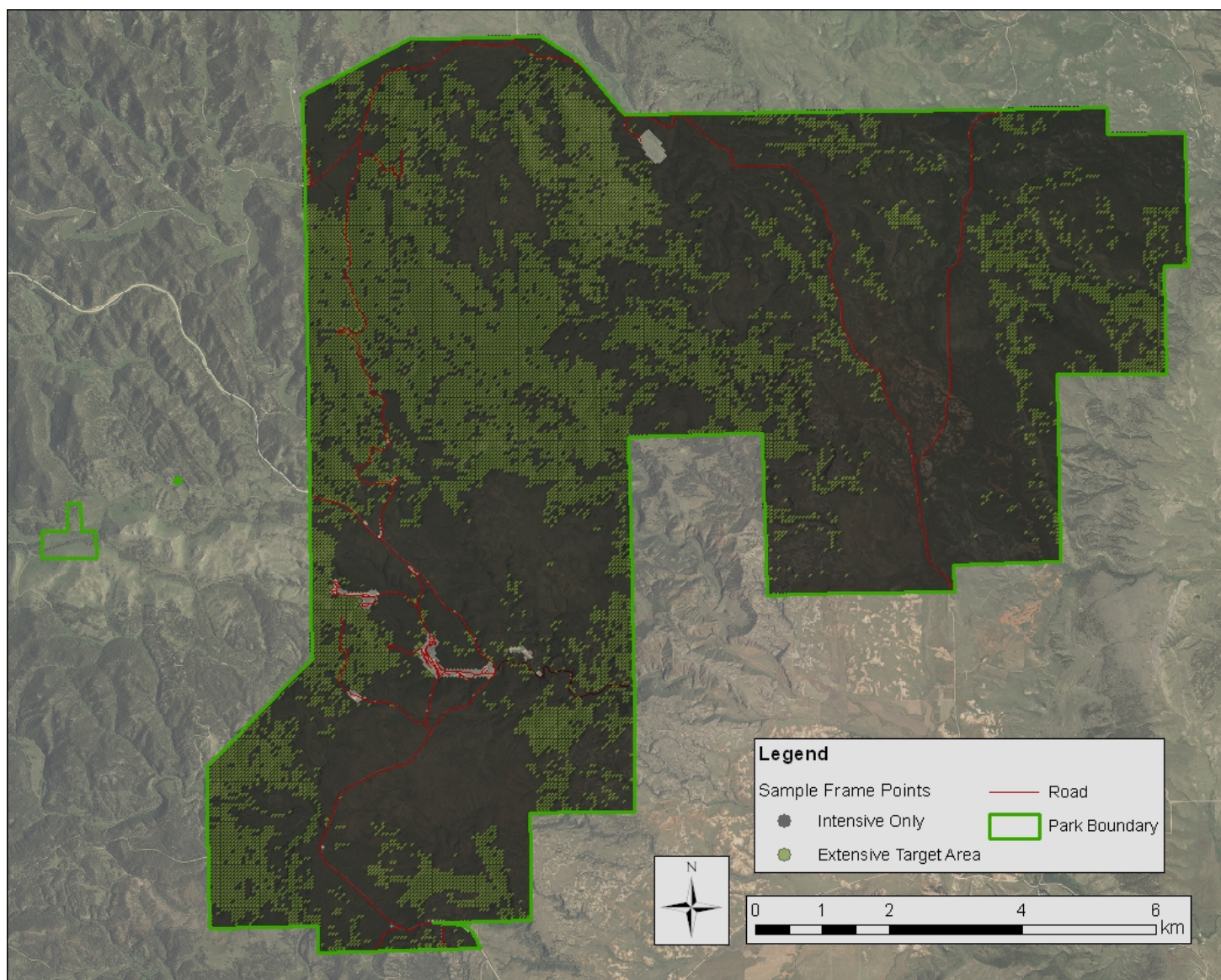


Figure B12. Sample frame for Wind Cave National Park. Scale is such that individual points blend to appear as shading.



Wind Cave National Park Boundary Expansion

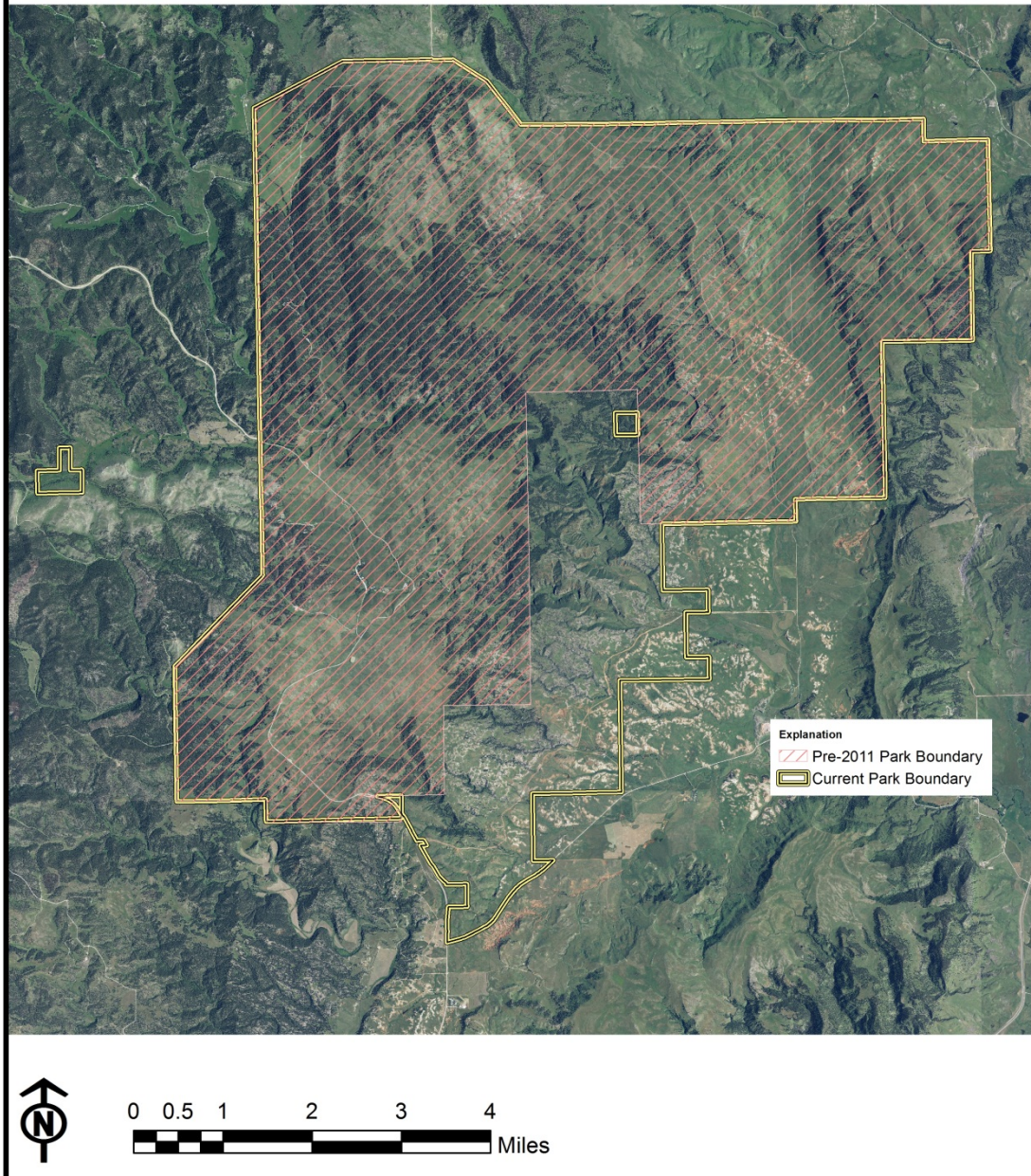


Figure B13. Wind Cave National Park including the 2011 land acquisition.

Literature Cited

- Cogan, D., H. Marriot, J. Von Loh, and M. Pucherelli. 1999. USGS-NPS Vegetation Mapping Program Wind Cave National Park, South Dakota. USDI Bureau of Reclamation, Denver, CO.
- Salas, D. E. and M. J. Pucherelli. 2002. USGS-NPS Vegetation Mapping Knife River Indian Villages National Historic Site. Technical Memorandum 8260-02-07. USDI Bureau of Reclamation, Denver, CO.
- Symstad A. J. 2011. A vegetation management plan for Fort Union Trading Post National Historic Site: Final report for interagency agreement number F154910005. National Park Service, Natural Resource Stewardship and Science. Fort Collins, Colorado. Natural Resource Report. NPS/FOUS/NRR—2011/456. Published Report-2176371.

Appendix C: Procedure/R code Used for GRTS Draws

The main text of the Protocol describes the general process of drawing samples using a GRTS (generalized random tessellation stratified) design, and Appendix B describes the sampling frames and strata used in each park. This appendix describes the specific procedures and R code we used for drawing sample sites for plant community composition and structure monitoring in the NGPN.

We used *spsurvey* (Version 2.0; Kincaid et al. 2008), a package for the R statistical programming language and environment (R Development Core Team 2008), and ArcMap (Version 9.3; ESRI Inc. 2008) to draw samples for each park.

Preparation of GIS files

For each park, we compiled all available, relevant, spatial data. Necessary and useful information included shapefiles or descriptions of the park's administrative boundary; ownership and park control of parcels within this boundary (e.g., park owns and controls parcel, park owns but has little access to or influence on the parcel, or private inholding with no park access or control); road and trail location and description (width, surface type, maintenance activities, use intensity); locations of railroad, canal, and power line and associated rights-of-way; building, cultural site (e.g., high-density archeological sites, ruins), campground, picnic site, and lawn locations; vegetation maps¹², soils maps, and digital orthophotos or high-resolution satellite imagery.

The quality and quantity of this information varied among parks. Quality ranged from GIS files for infrastructure created by on-the-ground GPS data collection in the past year or two, to infrastructure locations digitized from decades-old USGS topographic maps. Where necessary, heads-up digitizing of features based on satellite imagery or digital orthophotos was performed by the NGPN GIS specialist. Our general approach was to err on the side of including areas in the sampling frame that had any potential for meeting site acceptance criteria instead of *a priori* exclusion of areas that could be acceptable.

Using the information described above, and following the sampling frame description specific to the park, we created a single shapefile of all locations that currently or may in the future fall within the sampling frame (hereafter referred to as “possible_area”). In general, this shapefile corresponded to the area within the administrative boundary of the park with infrastructure (and appropriate buffers) and permanently unsampleable areas (e.g., Devils Tower rock formation) omitted. In parks where sampling is stratified, we created a shapefile that would aid in distinguishing among strata (e.g., a shapefile of just the area considered “riparian lowland” at FOLA).

Next, we created a grid of 53.85 m x 53.85 m cells (N-S/E-W orientation; Figure C1 describes the logic behind this cell size) and created a new shapefile (“possible_area_grid”) by clipping the grid to the possible_area shapefile. We added three fields to possible_area_grid's attribute table,

¹² All parks for which GRTS draws were done have had their vegetation mapped by the USGS-NPS Vegetation Mapping Program (<http://biology.usgs.gov/npsveg/>).

populating these fields with the northing and easting coordinates of the centroid of each cell and the cell area (calculated with the “Calculate Geometry” feature). We added more fields to the grid shapefile’s attribute table for stratum and ownership as appropriate (not all parks are stratified, and some parks are entirely owned by NPS). We then used ArcMap’s selection tools to assign appropriate values to each cell for each of these fields. The value of the field was determined by the intersection of the centroid of the cell with the appropriate layer. For example, if a portion of a cell was owned by the park and the remainder of the cell was owned by another party, the “ownership” value for that cell was park-owned only if its centroid fell in the park-owned portion. Figure C2 illustrates this assignment. We then converted the polygons in possible_area_grid to points by converting the polygon shapefile to a coverage, using the Arc createlabels command, then exporting the centroids to a new shapefile (“possible_pts_grid”). Figure C3 illustrates the attribute table of a possible_pts_grid shapefile.

The final step in preparing the GIS file that spsurvey uses was to eliminate the cells that we did not want to be in the sampling frame at this time because of ownership or because the cells were too small to encompass a randomly oriented 20 m x 50 m plot. Generally, including points in areas not currently owned by the park in the sampling frame depended on two criteria: potential for future ownership, and size/location of the parcels. If there was no intention for the park to own the parcel in the future (e.g., area is designated only as a scenic easement), points in the parcel(s) were not included in the sampling frame. If park staff stated there was a reasonable potential or intention for future park ownership of a parcel, and the size and arrangement of the parcels would accommodate at least one plot in each panel at approximately the same density as in the rest of the park, points in the parcel(s) were not included in the current sampling frame, with the intention that samples in these areas could be added in the future as a new stratum. Finally, if park staff stated there was a reasonable potential or intention for future park ownership of a parcel but the un-owned area was relatively small (could not accommodate enough plots to constitute a stratum), points in the parcel(s) were included in the sampling frame, with the intention that any points selected in these areas would be considered dormant until the property was acquired. Appendix B describes decisions regarding inclusion for ownership reasons specific to each park. After points were eliminated based on ownership, we eliminated all points for which the cell area was less than a full plot’s area (1000 m²). We then manually, point-by-point, eliminated other points that, because of their cell’s shape and size, could not accommodate a full plot in any single orientation. The remaining points were exported into a shapefile (“sample_frame_pts”) that was used as the input file for spsurvey.

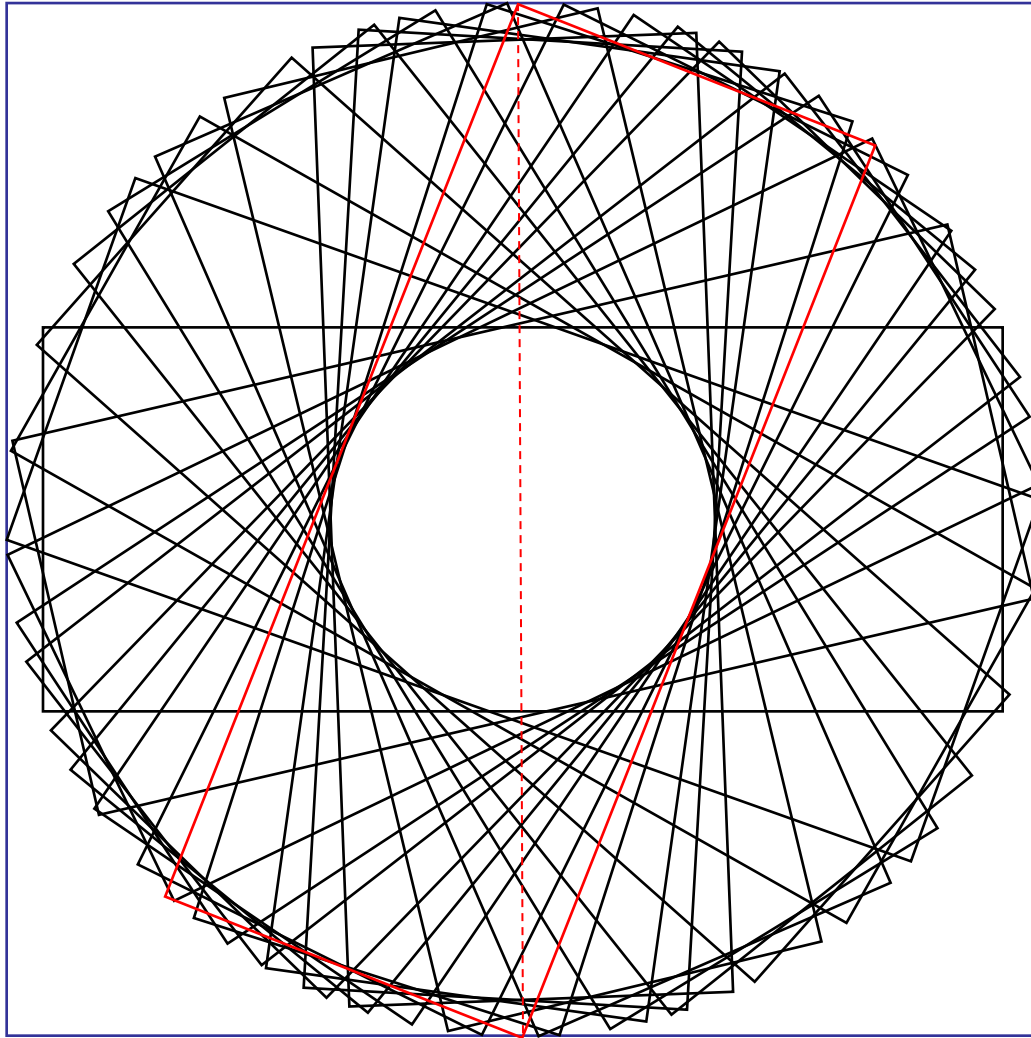


Figure C1. The height and width of a grid cell just large enough to accommodate a 20 m x 50 m plot in any orientation are the length of the diagonal of the plot: $\sqrt{(20^2 + 50^2)} = 53.85$. The corners of the cell that have 0 probability of being sampled in the plot (21% of the cell) are still part of the plant community composition monitoring, as they are searched for watch-list species.

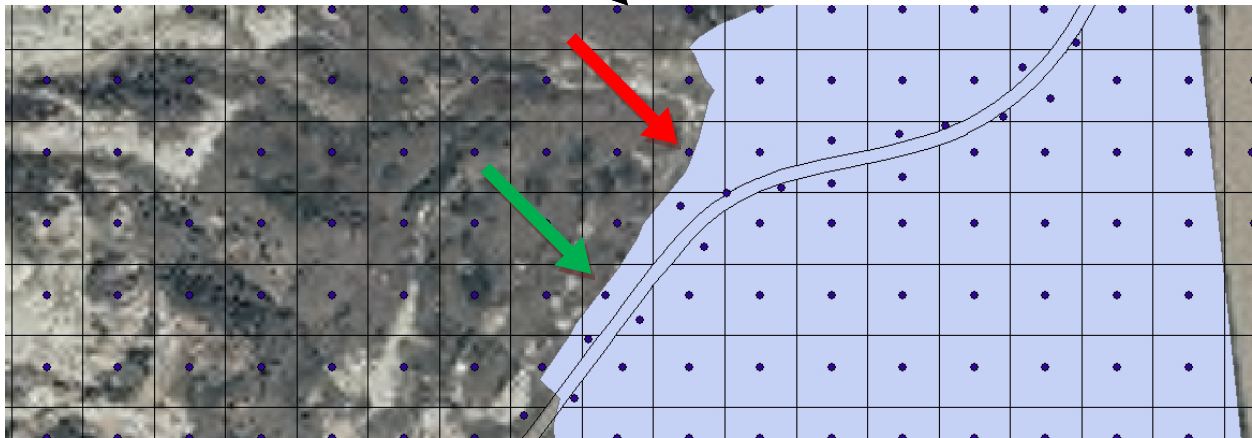


Figure C2. Illustration of the assignment of cells to categories. Black lines show edges of cells; dark blue dots are centroids of these cells. Light blue shading indicates the riparian lowland stratum. Both cells indicated by arrows have some upland and some riparian lowland. The cell indicated by the red arrow is assigned to the upland stratum, whereas the cell indicated by the green arrow is assigned to the riparian lowland stratum, based on the location of their centroids.

Attributes of fola_possible_pts_grid

FID	Shape *	FID_folala	AREA	PERIMETER	POLYFOLAFE	POLYGONID	NAME	POINT_X	POINT_Y
39	Point	1280	2899.827885	215.4002	1283	1283	UPLAND	537062.78178	4671742.22208
40	Point	1281	2899.827885	215.4002	1284	1284	UPLAND	537116.63178	4671742.22208
41	Point	1282	2606.434925	247.887754	1285	1285	UPLAND	537162.910737	4671742.22208
42	Point	1283	650.864254	101.607126	1286	1286	UPLAND	537210.155938	4671752.75248
43	Point	1285	1234.742167	148.597768	1288	1288	RIPARIAN	538893.68178	4671754.97311
44	Point	1286	875.040113	127.221901	1289	1289	RIPARIAN	538943.852947	4671756.12695
45	Point	1284	140.110843	53.498374	1287	1287	RIPARIAN	538862.035115	4671758.44843
46	Point	1269	55.453614	34.5669	1272	1272	UPLAND	536548.656258	4671772.69434
47	Point	1267	1221.718248	156.992283	1270	1270	UPLAND	536578.13178	4671776.15454
48	Point	1252	2339.503703	198.79075	1255	1255	UPLAND	536631.98178	4671782.60962
49	Point	1268	0.834332	5.580812	1271	1271	UPLAND	536550.737905	4671784.57381
50	Point	1253	2899.8225	215.4	1256	1256	UPLAND	536685.83178	4671796.07212
51	Point	1254	2899.8225	215.4	1257	1257	UPLAND	536739.68178	4671796.07212
52	Point	1255	2899.8225	215.4	1258	1258	UPLAND	536793.53178	4671796.07212
53	Point	1256	2899.8225	215.4	1259	1259	UPLAND	536847.38178	4671796.07212
54	Point	1257	2899.8225	215.4	1260	1260	UPLAND	536901.23178	4671796.07212
55	Point	1258	2899.8225	215.4	1261	1261	UPLAND	536955.08178	4671796.07212

Record: 0 Show: All Selected Records (0 out of 1316 Selected) Options

Figure C3. Illustration of the attribute table of a "possible_pts_grid" shapefile. NAME is the stratum designation, POINT_X and POINT_Y are the UTM coordinates of the cell centroids, and AREA is the area of the cell in square meters.

Using spsurvey (version 2.0) to draw samples

We obtained the R installation program for Windows (R-2.8.1-win32.exe) from <http://streaming.stat.iastate.edu/CRAN/> and used this to install the R programming language and environment (RGui) on a desktop computer with ArcMap also installed. Once it was installed, we used the “Packages” menu in RGui to obtain and install (Packages – Install Packages) two packages: “foreign” (R-core members et al. 2008) and “spsurvey”. We use Fort Laramie National Historic Site (FOLA) as an example park to describe the sequence of steps and code that we used.

Step 1: Load spsurvey.

```
library(spsurvey)
```

Step 2. Load the ‘foreign’ package; this package reads data stored by a variety of software packages, including the dbf format that ArcMap uses.

```
library(foreign)
```

Note that this step foreign package must be loaded after spsurvey is loaded so that the read.dbf object in foreign over-rides the same object in spsurvey; as of December 2008 the read.dbf object in spsurvey is not reliable.

Step 3. Read in the file of points in the sampling frame, thereby creating an attribute frame.

```
FOLA.attframe <- read.dbf("C:/.../fola/fola_sample_frame_pts.dbf")
```

Step 4: State the sampling design. The first line of code below is for a stratified design, the second for a simple, unstratified design. The code states that 128 samples are drawn for just one panel (one panel in each stratum in the stratified design). Although spsurvey does have the capability to draw samples for different panels and an overdraw, the spatial balance of samples within panels drawn using this feature is not optimal. Particularly with complicated nested designs, the spatial balance obtained by manually assigning panels is better (T. Philippi, NPS I&M quantitative ecologist, pers. comm. November 18, 2008). In this example, we drew 128 samples for each stratum, both of which follow a 5-panel design. The desired endpoint is to have 2 monitoring plots in each UPLAND panel (10 plots in this stratum) and 1 plot in each RIPARIAN panel (5 plots in this stratum). The assignment of samples drawn to panels is described in the next section. This large overdraw provides ample room for sites to be rejected according to the rejection criteria in SOP Site Evaluation, or for additional sites to be sampled in the future (e.g., if a large sample to estimate status in some future year is desired and feasible). Sample units (grid cells) are chosen with selection probability proportional to the area of each cell (after omitting areas outside of the sample frame), thus giving all areas within the sample frame equal probability of selection.

```
design.FOLAstrat <- list("UPLAND"=list(panel=c(Panel=128),seltype="Continuous",caty.n=NULL),  
"RIPARIAN"=list(panel=c(Panel=128),seltype="Continuous",caty.n=NULL))
```

```
design.FOLA1 <- list(None=list(panel=c(Panel=128),seltype="Continuous",caty.n=NULL))
```

Step 5: Draw GRTS sample. The first section of code is for a stratified design, the second for a simple, unstratified design. The final line of code designates the output shapefile in which the drawn points are listed in sampling order. This file retains the fields of the input file (foia_sample_frame_pts), placing them at the end of the table. It also contains new fields, many of which contain the same information as the input fields, but they have new field names according to the statements in the text of the grts command: "POINT_X" in fola_sample_frame_pts becomes "xcoord" in fola_strat_panel128; "NAME" in fola_sample_frame_pts becomes "stratum" in fola_strat_panel128. The output file also contains new fields with new information: "siteID" (populated as "bigpanel-001" to "bigpanel-128" in this example, showing the order in which the drawn points should be visited); wgt (the standardized weighting factor used for calculating the probability of a point's selection); panel (here, simply filled as "Panel" because there was only one panel in the design); "EvalStatus" (filled with the default "NotEval") and "EvalReason" (blank). An example of the output is shown in Figure C4.

```
FOLAstrat.grts <- grts(design=design.FOLAstrat, DesignID="bigpanel", SiteBegin=1,
  type.frame="finite", src.frame="shapefile",
  in.shape="C:/.../foia/foia_sample_frame_pts",
  sp.object=NULL, att.frame=FOLA.attframe,
  id=NULL, xcoord="POINT_X", ycoord="POINT_Y",
  stratum="NAME", mdcaty="AREA", startlev=NULL,
  maxlev=11, maxtry=1000, shift.grid=FALSE,
  do.sample=rep(TRUE, length(design.FOLAstrat)),
  shapefile=TRUE, prjfilename=NULL,
  out.shape="C:/.../foia/foia_strat_panel128")
```

```
FOLA1.grts <- grts(design=design.FOLA1, DesignID="bigpanel", SiteBegin=1,
  type.frame="finite", src.frame="shapefile",
  in.shape="C:/.../foia/foia_sample_frame_pts",
  sp.object=NULL, att.frame=FOLA.attframe,
  id=NULL, xcoord="POINT_X", ycoord="POINT_Y",
  stratum=NULL, mdcaty="AREA", startlev=NULL,
  maxlev=11, maxtry=1000, shift.grid=FALSE,
  do.sample=rep(TRUE, length(design.FOLA1)),
  shapefile=TRUE, prjfilename=NULL,
  out.shape="C:/.../foia/foia1panel128")
```

In these grts calls, arguments are as follows:

design is a named list of stratum design specifications, where each element of design is a list containing the design specifications for a stratum. In our example, we defined this list in a previous step (step 4).

DesignID is a user-chosen name for the design that is used to create a site ID for each site.

SiteBegin is the number to use for the first site in the design (default = 1).

type.frame specifies that our sampling frame is a finite grid of points defined in GIS.

src.frame is the source of the sampling frame; for the procedure described above, this is a shapefile.

in.shape is the name (with no extension) of the input file of gridpoints created in ArcMap.

sp.object is not relevant when input file is a shapefile (default is NULL).

att.frame is a data frame composed of attributes associated with elements in the frame; it must contain the columns used for stratum and mdcaty. If the procedures above were followed,

this is set to the attribute frame name set in step 3 (i.e., FOLA.attframe in this example), which contains the input shapefile's attribute table.

id is the name of the column from the attribute frame (input file) that identifies the ID value for each element in the frame. If id = NULL (the default), a column named "id" is added to att.frame.

xcoord and ycoord are the names of the columns containing x- and y-coordinates in the attribute frame (input file).

stratum is the name of the column containing the strata designations in the attribute frame (input file).

mdcaty is the name of the column containing the unequal probability category for each element in the frame. The default is NULL. In our example, we state that grid points in fola_sample_frame_pts will be selected with probability proportional to the area of the grid cell. Therefore, the probability values come from the "AREA" column in the attribute frame. Since this is not a categorical variable, the design statement (step 4) must assign the value of "Continuous" to seltype (selection type).

startlev is the initial number of hierarchical levels to use for the GRTS grid. We used the default NULL value.

maxlev is the maximum number of hierarchical levels to use for the GRTS grid. We used the default value of 11.

maxtry is only relevant when type.frame = "area", so we used the default value of 1000.

shift.grid = FALSE specifies that the frame should not be converted into a continuous torus. The default on this object is TRUE, which places the origin of the grid in a new location and changes the spatial connection of the cells. We always used the FALSE option because it is better when strict spatial stratification by hierarchical grid cells is desired.

do.sample is a named vector that provides the option of controlling sample selection for each stratum, where TRUE means select a sample from a stratum. The code above creates a vector of TRUE's for the design stated in step 3. Note that FALSE can only be used when type.frame equals "points" and seltype (in design statement in step 3) = "Equal". This condition is not met in our example.

shapefile is the option to create a shapefile containing the survey design information, where TRUE creates a shapefile and FALSE does not.

prjfilename is the name (without any extension) of the projection file for the input shapefile, which is used to name the projection file of the output shapefile. The default is NULL, which we used. This requires the projection of the output shapefile to be defined when the file is used in a GIS.

out.shape is the name (without any extension) of the output shapefile containing the survey design information.

More detailed information about the arguments in the grts statement, including those in the design statement, are available by typing "help(grts)" in the R program after the spsurvey library is loaded.

Attributes of fola_strat_panel128_good

FID	Shape	siteID	xcoord	ycoord	mccat	wgt	stratum	panel	EvalStatus	EvalReason	FID_folala	PERIMETER	POLYFOLAFE	POLYGONID	POINT_X	POINT_Y
0	Point	bigpanel-001	536416.58178	4673034.622024	2899.8225	5.607086	UPLAND	Panel	NotEval		63	215.4	65	65	536416.58178	4673034.622024
1	Point	bigpanel-002	537116.63178	4671796.072124	2899.8225	5.607086	UPLAND	Panel	NotEval		1261	215.4	1264	1264	537116.63178	4671796.072124
2	Point	bigpanel-003	536470.43178	4672011.47208	2899.827885	5.607075	UPLAND	Panel	NotEval		1035	215.4002	1038	1038	536470.43178	4672011.47208
3	Point	bigpanel-004	537762.83178	4672065.322124	2899.8225	5.607086	UPLAND	Panel	NotEval		1006	215.4	1009	1009	537762.83178	4672065.322124
4	Point	bigpanel-005	537170.48178	4672980.772068	2899.817115	5.607096	UPLAND	Panel	NotEval		119	215.3998	121	121	537170.48178	4672980.772068
5	Point	bigpanel-006	537224.33178	4672603.822124	2899.8225	5.607086	UPLAND	Panel	NotEval		479	215.4	482	482	537224.33178	4672603.822124
6	Point	bigpanel-007	536847.38178	4672226.872024	2899.8225	5.607086	UPLAND	Panel	NotEval		829	215.4	832	832	536847.38178	4672226.872024
7	Point	bigpanel-008	537870.53178	4672388.422124	2899.8225	5.607086	UPLAND	Panel	NotEval		687	215.4	690	690	537870.53178	4672388.422124
8	Point	bigpanel-009	536793.53178	4672819.22208	2899.827885	5.607075	UPLAND	Panel	NotEval		263	215.4002	265	265	536793.53178	4672819.22208
9	Point	bigpanel-010	537224.33178	4672873.072124	2899.8225	5.607086	UPLAND	Panel	NotEval		222	215.4	224	224	537224.33178	4672873.072124
10	Point	bigpanel-011	537601.28178	4673034.622024	2899.8225	5.607086	UPLAND	Panel	NotEval		81	215.4	83	83	537601.28178	4673034.622024
11	Point	bigpanel-012	537978.23178	4672819.22208	2899.827885	5.607075	UPLAND	Panel	NotEval		285	215.4002	287	287	537978.23178	4672819.22208
12	Point	bigpanel-013	536955.08178	4672119.172124	2899.8225	5.607086	UPLAND	Panel	NotEval		939	215.4	942	942	536955.08178	4672119.172124
13	Point	bigpanel-014	536901.23178	4672496.122024	2899.8225	5.607086	UPLAND	Panel	NotEval		573	215.4	576	576	536901.23178	4672496.122024
14	Point	bigpanel-015	538516.73178	4672873.072124	2899.8225	5.607086	UPLAND	Panel	NotEval		246	215.4	248	248	538516.73178	4672873.072124
15	Point	bigpanel-016	538193.63178	4672334.572124	2899.8225	5.607086	UPLAND	Panel	NotEval		747	215.4	750	750	538193.63178	4672334.572124
16	Point	bigpanel-017	536631.98178	4672980.772068	2899.817115	5.607096	UPLAND	Panel	NotEval		113	215.3998	115	115	536631.98178	4672980.772068
17	Point	bigpanel-018	536901.23178	4671903.72068	2899.817115	5.607096	UPLAND	Panel	NotEval		1171	215.3998	1174	1174	536901.23178	4671903.72068
18	Point	bigpanel-019	536524.28178	4671910.946708	1956.646061	8.30991	UPLAND	Panel	NotEval		1164	180.068132	1167	1167	536524.28178	4671910.946708
19	Point	bigpanel-020	537978.23178	4672065.322124	2899.8225	5.607086	UPLAND	Panel	NotEval		1010	215.4	1013	1013	537978.23178	4672065.322124

Record: 14 1 Show: All Selected Records (0 out of 256 Selected) Options

Figure C4. Example attribute table of shapefile output from GRTS draw using spsurvey.

Assigning drawn samples to panels

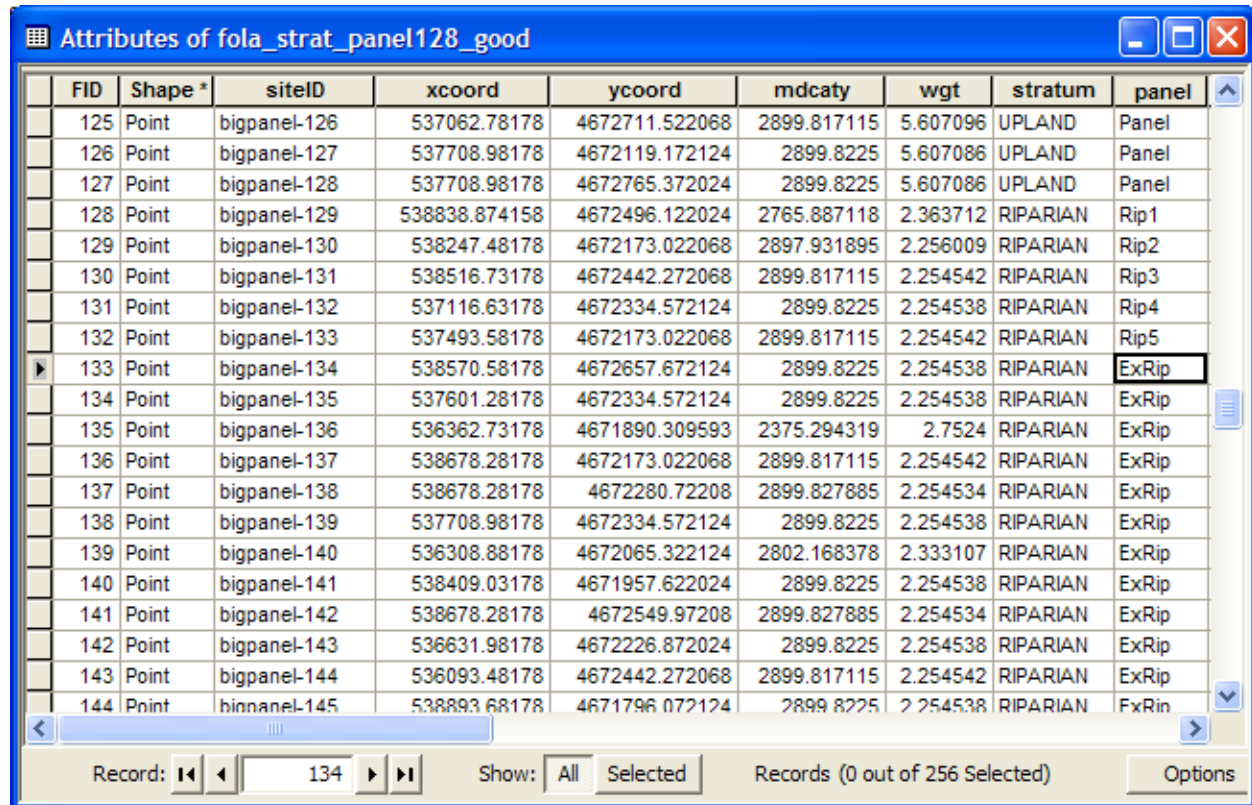
We assigned sites to panels in sequence, simply by editing the panel name in ArcGIS. The UPLAND stratum is listed first. Therefore the first and second sites in this stratum were assigned to panel “Up1”, the third and fourth to panel “Up2”, and so on. The remainder of the points in the upland stratum were left with the generic “Panel” designation; these are overdraw sites used if a site is rejected in the field. Riparian sites were assigned to panels similarly, beginning with site “bigpanel-129”, the first site in the riparian stratum (Figure C5). Since this park will have extensive woody plots, the next 20 sites (bigpanel-134 through bigpanel-153) were assigned to the extensive riparian panel (“ExRip”). The remainder of the points in the riparian stratum were left with the generic “Panel” designation and serve as overdraw for riparian sites rejected in the field. Figure C6 shows a map of the points from this draw. SOP Site Evaluation details the process of evaluation, rejection, and replacement of rejected sites using the generated list.

Customizing the FOUS Sample Frame

To account for the known, relatively strong variation of vegetation among these fields, the GRTS draw for the Fort Unit of the revised sample frame was customized (see Appendix B for revised details and map of the revised sample frame). The standard method for panel allocation gives an unbiased estimate of terrace-wide variability and mean, but this estimate may be messy because of the potential for strong spatial variability having an effect on yearly values measured. Earlier scoping suggested that using the “shift.grid = TRUE” option in spsurvey produced better spatial balance (less clumping) than did using “shift.grid = FALSE”, which is what we used for GRTS draws in all other parks (see above). We performed a few GRTS draws using the TRUE option and two sample sizes, 32 and 64, then evaluated each draw for overall spatial balance by looking at the first 10 sites in the draw. We used five field groups, where a field group contained fields with relatively similar management histories, for this evaluation. Acceptable overall spatial balance required

- at least one plot each in the western and eastern extremes of the Fort Unit;
- reasonable proportionality of plots based on area of a field group;
- minimal occurrence of plots in adjacent grid cells.

None of the draws of N=32 met these criteria. The one 64-point draw that best matched these criteria was chosen as the final, permanent sample for FOUS.



FID	Shape *	sitelD	xcoord	ycoord	mdcaty	wgt	stratum	panel
125	Point	bigpanel-126	537062.78178	4672711.522068	2899.817115	5.607096	UPLAND	Panel
126	Point	bigpanel-127	537708.98178	4672119.172124	2899.8225	5.607086	UPLAND	Panel
127	Point	bigpanel-128	537708.98178	4672765.372024	2899.8225	5.607086	UPLAND	Panel
128	Point	bigpanel-129	538838.874158	4672496.122024	2765.887118	2.363712	RIPARIAN	Rip1
129	Point	bigpanel-130	538247.48178	4672173.022068	2897.931895	2.256009	RIPARIAN	Rip2
130	Point	bigpanel-131	538516.73178	4672442.272068	2899.817115	2.254542	RIPARIAN	Rip3
131	Point	bigpanel-132	537116.63178	4672334.572124	2899.8225	2.254538	RIPARIAN	Rip4
132	Point	bigpanel-133	537493.58178	4672173.022068	2899.817115	2.254542	RIPARIAN	Rip5
133	Point	bigpanel-134	538570.58178	4672657.672124	2899.8225	2.254538	RIPARIAN	ExRip
134	Point	bigpanel-135	537601.28178	4672334.572124	2899.8225	2.254538	RIPARIAN	ExRip
135	Point	bigpanel-136	536362.73178	4671890.309593	2375.294319	2.7524	RIPARIAN	ExRip
136	Point	bigpanel-137	538678.28178	4672173.022068	2899.817115	2.254542	RIPARIAN	ExRip
137	Point	bigpanel-138	538678.28178	4672280.72208	2899.827885	2.254534	RIPARIAN	ExRip
138	Point	bigpanel-139	537708.98178	4672334.572124	2899.8225	2.254538	RIPARIAN	ExRip
139	Point	bigpanel-140	536308.88178	4672065.322124	2802.168378	2.333107	RIPARIAN	ExRip
140	Point	bigpanel-141	538409.03178	4671957.622024	2899.8225	2.254538	RIPARIAN	ExRip
141	Point	bigpanel-142	538678.28178	4672549.97208	2899.827885	2.254534	RIPARIAN	ExRip
142	Point	bigpanel-143	536631.98178	4672226.872024	2899.8225	2.254538	RIPARIAN	ExRip
143	Point	bigpanel-144	536093.48178	4672442.272068	2899.817115	2.254542	RIPARIAN	ExRip
144	Point	bigpanel-145	538893.68178	4671796.072124	2899.8225	2.254538	RIPARIAN	ExRip

Figure C5. Assignment of riparian sites to panels, including a single “ExRip” panel for extensive woody plots in the riparian stratum.

Example GRTS Draw for Fort Laramie National Historic Site (FOLA)

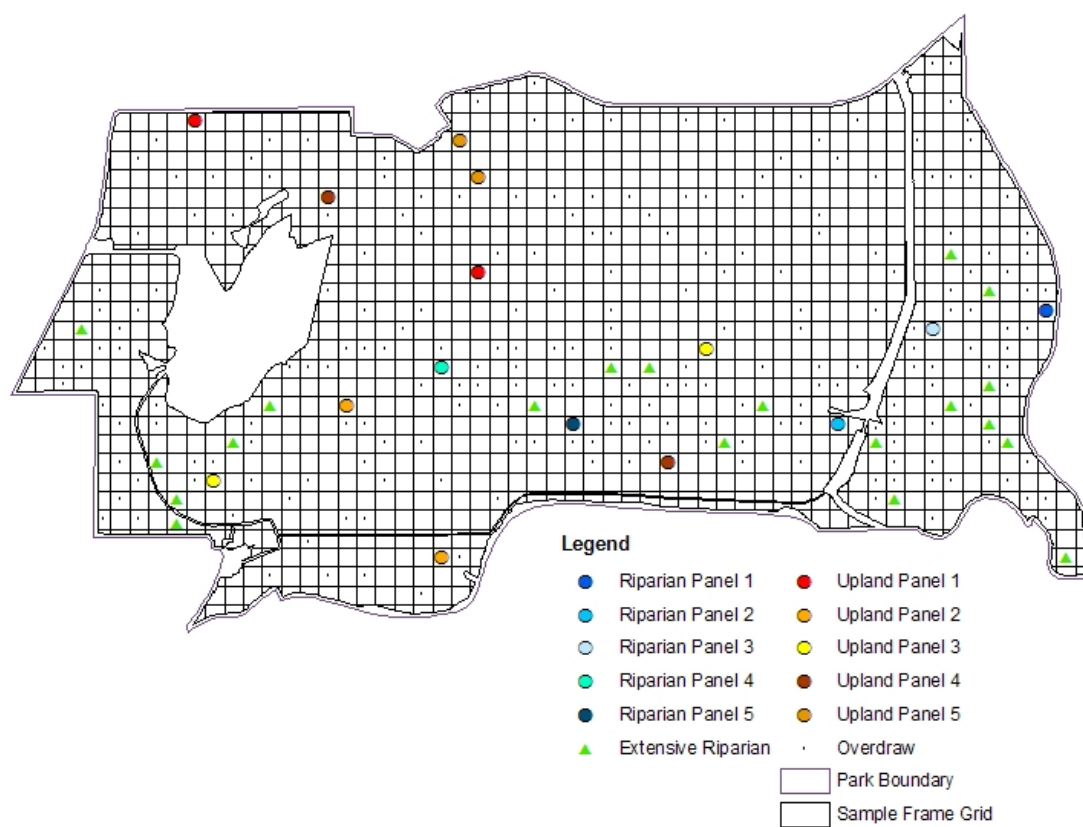


Figure C6. Example GRTS draw for Fort Laramie National Historic Site.

Literature Cited

- Kincaid, T., T. Olsen, D. Stevens, C. Platt, D. White, and R. Remington. 2008. spsurvey: Spatial Survey Design and Analysis. R package version 2.0. Available from <http://www.epa.gov/nheerl/arm/analysispages/software.htm>.
- R-core members, DebRoy, S., and R. Bivand. 2008. Available from <http://cran.r-project.org/web/packages/foreign/index.html>.
- R Development Core Team. 2008. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Appendix D: Transition from PCP/HTLN to NGPN at AGFO and SCBL

Agate Fossil Beds (AGFO) and Scotts Bluff (SCBL) National Monuments were part of the original Prairie Cluster Prototype Long-Term Ecological Monitoring Program (PCP) established in 1996. PCP later became part of the Heartland Inventory and Monitoring Network (HTLN). Because AGFO and SCBL fit better ecologically and administratively with the Northern Great Plains I&M Network (NGPN), NGPN will take over ongoing monitoring for AGFO and SCBL during FY 2010.

As described in the main text (“NGPN Monitoring in the Context of PCP and NGP FireEP Legacies”), there are several reasons why NGPN will not continue vegetation monitoring following the PCP monitoring protocol. Instead, NGPN has used the lessons learned from the prototype to build a more robust vegetation monitoring program for these two parks that is also compatible with monitoring throughout the NGPN and other networks (including HTLN). Two of the main improvements of NGPN’s protocol over that of the PCP are:

- Inference to the entire park. PCP monitoring was limited to one or two management units in each park, which precluded making statistical inference to the whole park.
- Connectivity in the revisit design. In an ecosystem with high interannual variability in the components being monitored, this connectivity provides more power for detecting trends.

Ideally, NGPN would have incorporated at least some of the existing PCP plots into its sampling design at each of these two parks, potentially as a separate stratum. Unfortunately, this is not statistically feasible because the exact methods (boundaries of strata, randomization procedure, etc.) used for establishing the plots originally are not clearly documented. Thus, there is no way to make design-based inferences to unsampled locations from those plots.

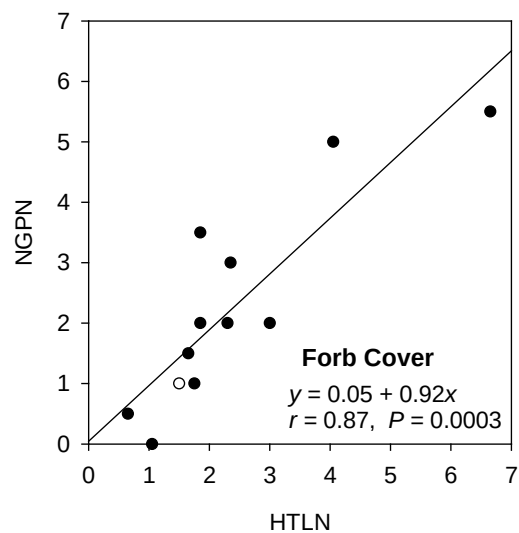
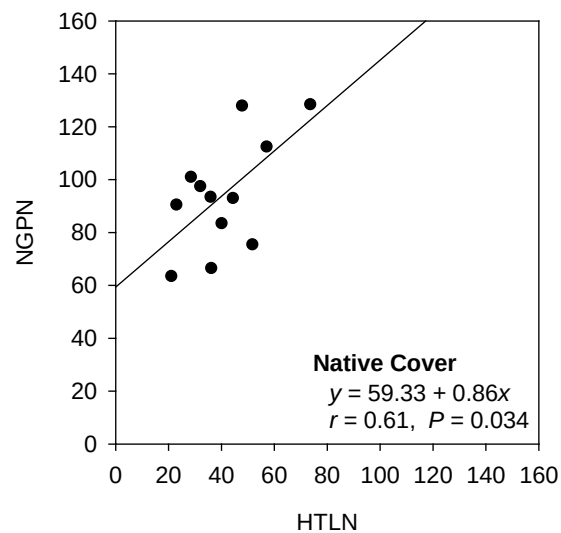
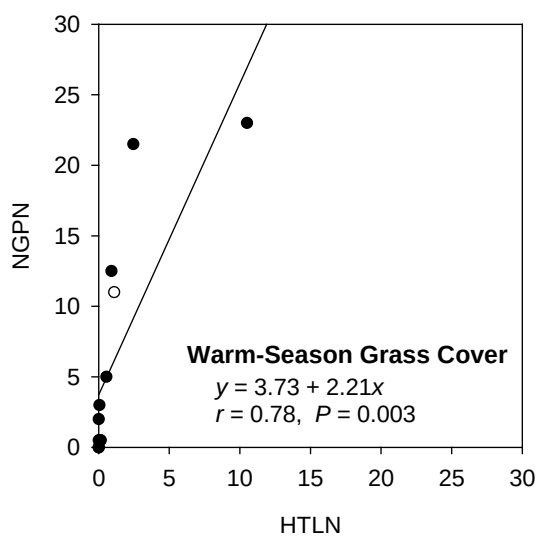
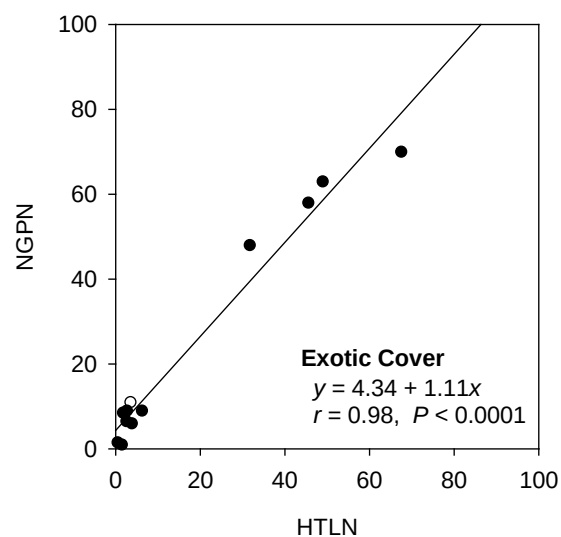
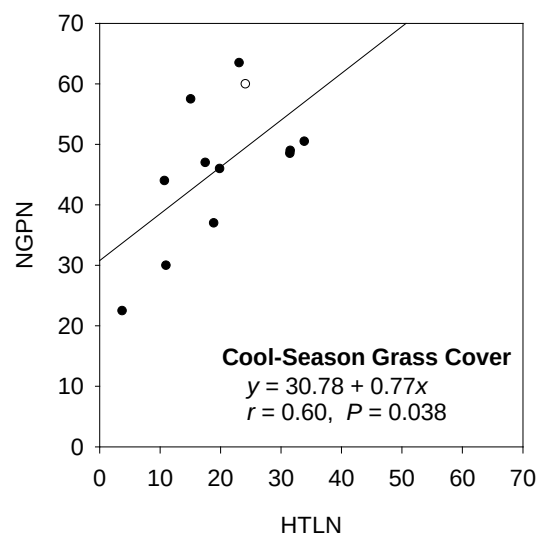
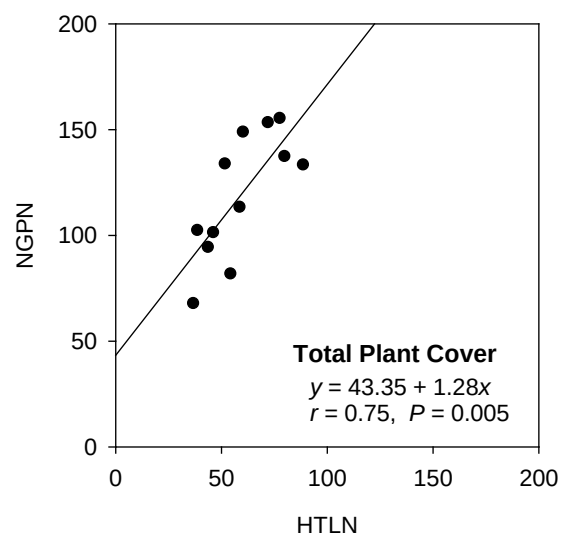
NGPN made strong efforts to balance the disadvantages of discontinuing a 10-year monitoring protocol and the advantages of a new, stronger monitoring program. The result was the following plan. NGPN will initiate new sampling techniques and a new sampling design that will allow inference to the entire park when NGPN monitoring begins in 2011. NGPN will continue to monitor some PCP plots (“legacy plots”) at each park using the PCP/HTLN sampling techniques and revisit schedule (DeBacker et al. 2004) *and* the NGPN point-intercept plant cover measurement technique. The remaining PCP plots will be considered dormant; their plot markers will not be removed, but NGPN will not collect data from or visit these plots until further notice.

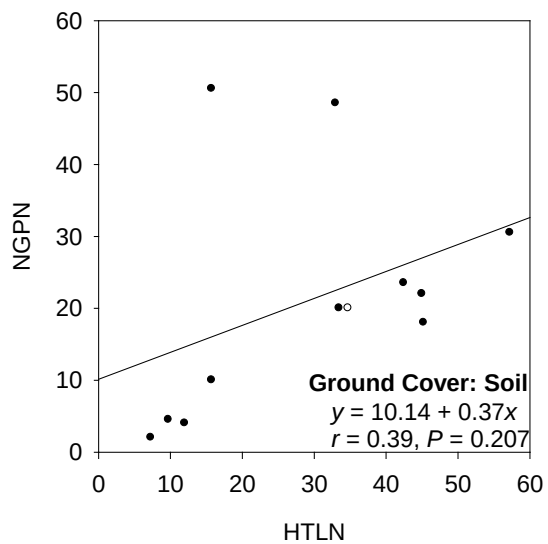
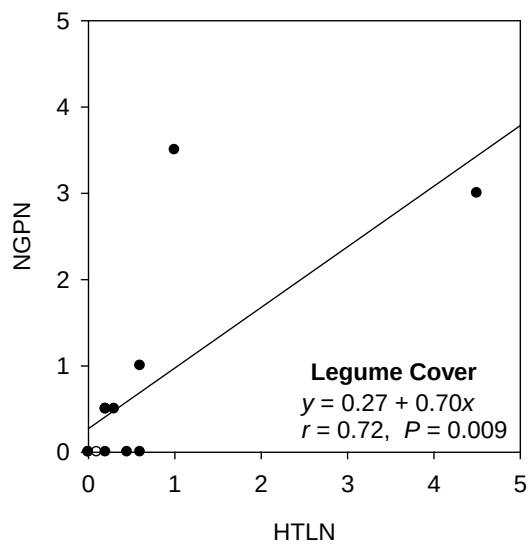
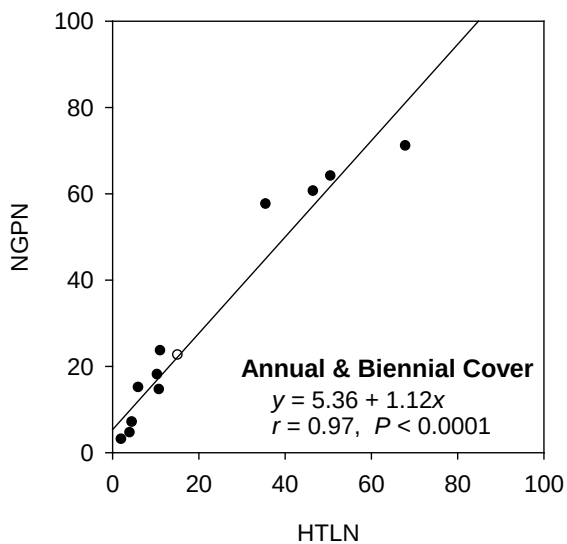
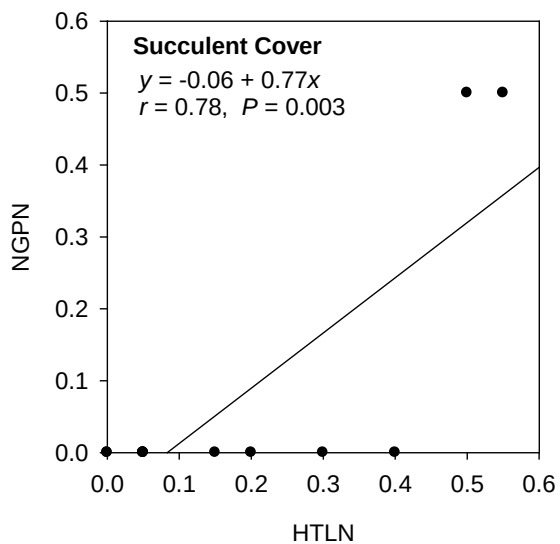
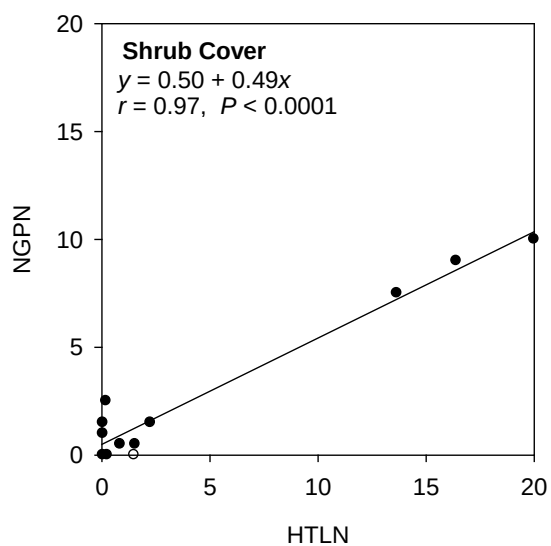
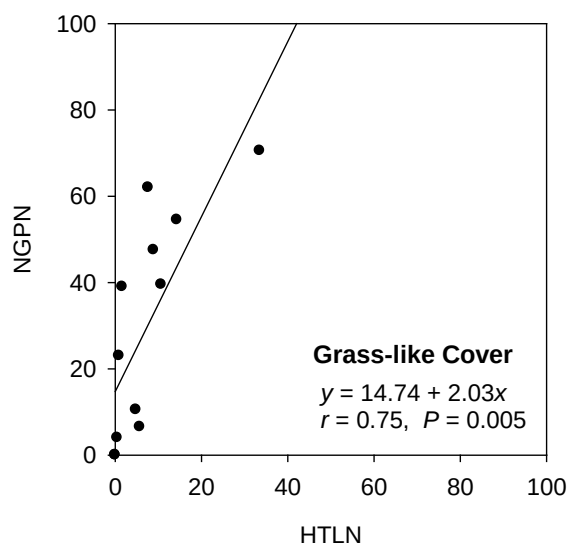
The legacy plots were chosen for their importance to specific park management issues. At AGFO, the legacy plots provide information about vegetation impacts from construction of a new trail to University and Carnegie Hills in 2006-07 and the vegetation’s recovery following that construction. Three legacy plots are near the trail, and two are in the same management unit but further from the trail and serve as reference sites. At SCBL, the legacy plots are those

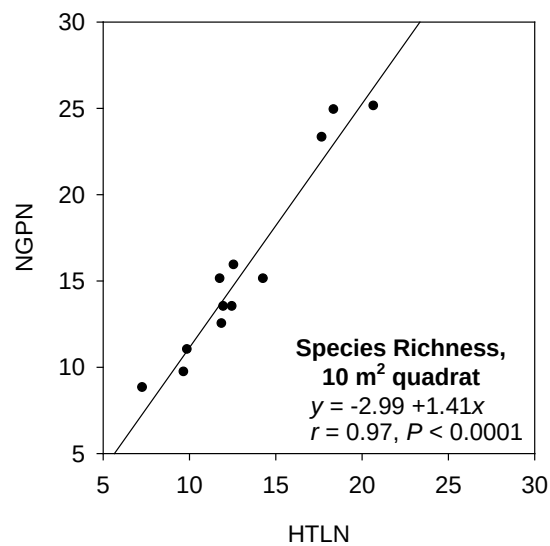
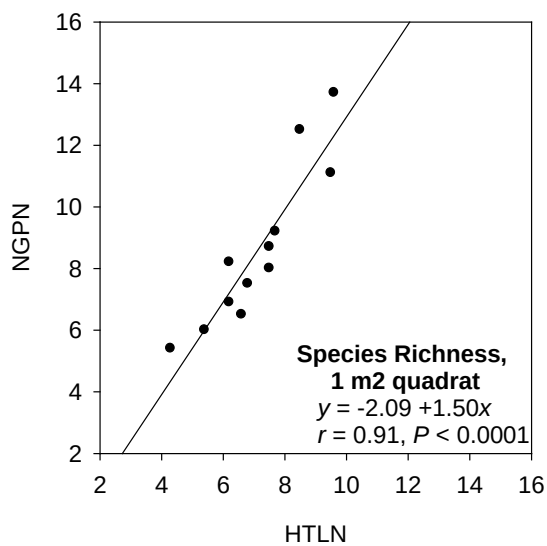
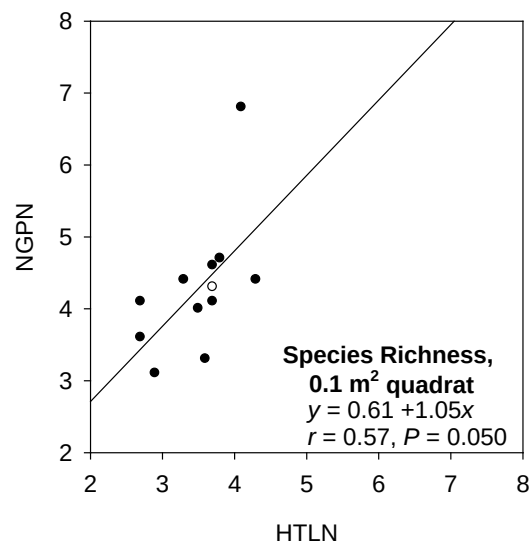
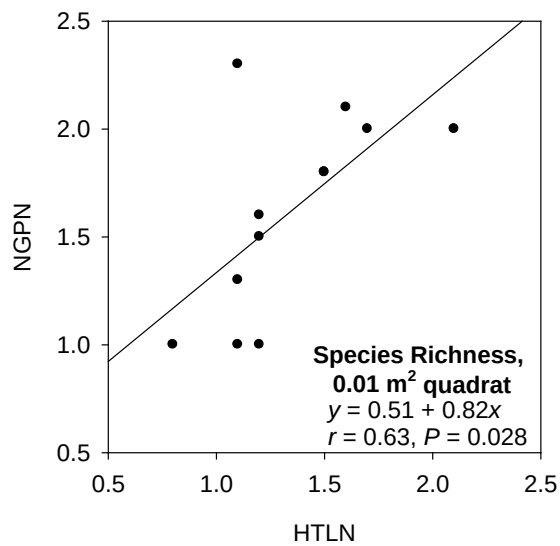
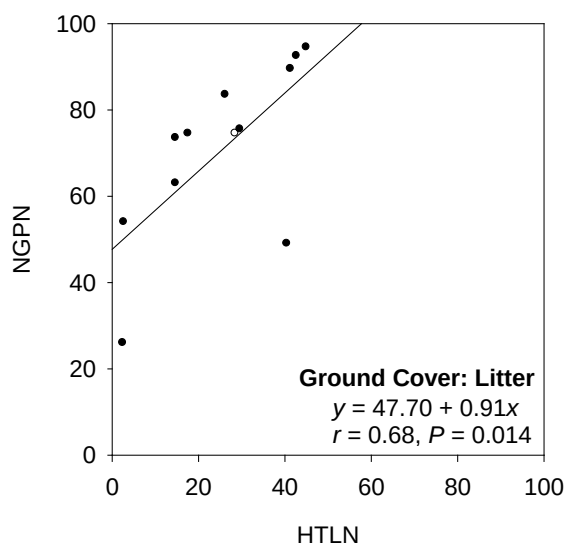
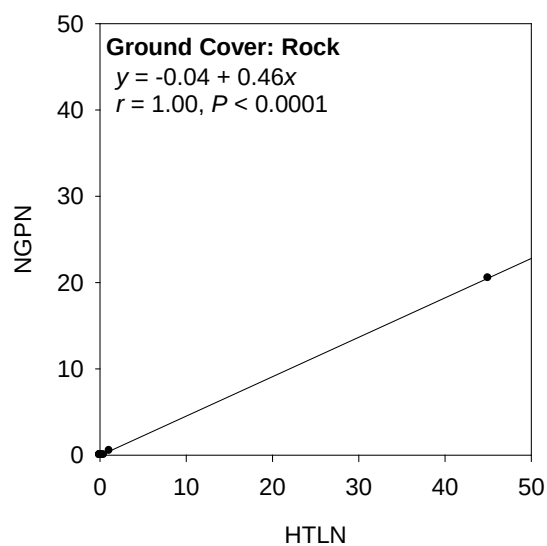
established by PCP specifically to evaluate the success of a vegetation restoration effort in a former golf course. Three of the plots are in the restoration area, and one is outside the restored area in adjacent grassland; the latter serves as a reference plot. Appendix B shows the exact location of these plots and the PCP sites that will become dormant.

The combination of sampling techniques in the legacy plots serves multiple purposes. First, continuing the PCP methodology ensures continuity of data. Second, using the NGPN plant cover measurement method ensures comparability of data from the legacy plots to the new NGPN plots throughout the rest of the park. Nested frequency measurement methods in the two protocols are comparable (differing only in shape and location of quadrats along transects), and therefore do not need to be done using both protocols. Finally, using both plant cover measurement methods at these sites will increase the amount of data for cross-walking PCP data with NGPN data. In 2008, NGPN and HTLN sampled the same 5 plots at AGFO and 7 plots at SCBL using their own techniques and within a day of each other. Data from this double-sampling effort showed that values of a variety of parameters derived from the two sampling methods were not identical, but most were highly significantly correlated (see graphs below). However, the specific relationship between the values derived from the two sampling methods varied considerably among the parameters (e.g., total plant cover vs. warm-season grass cover). This variability suggested that continuity of data in the legacy plots would require continuation of the PCP sampling techniques. More data of this type may improve the strength of the relationships between the values derived from the two sampling methods. This could help with interpreting differences in PCP and NGPN data in the long term.

The graphs below show the values of various parameters derived from data collected in early June, 2008, by HTLN and NGPN at 12 PCP vegetation monitoring plots at AGFO and SCBL. The plots at AGFO in this study are those that NGPN will continue to monitor as legacy plots. The plots from SCBL in this study will become dormant. The parameters shown are those commonly reported by HTLN in their annual reports and are parameters that NGPN will also report on.







The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 920/112656, February 2012

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™