National Park Service
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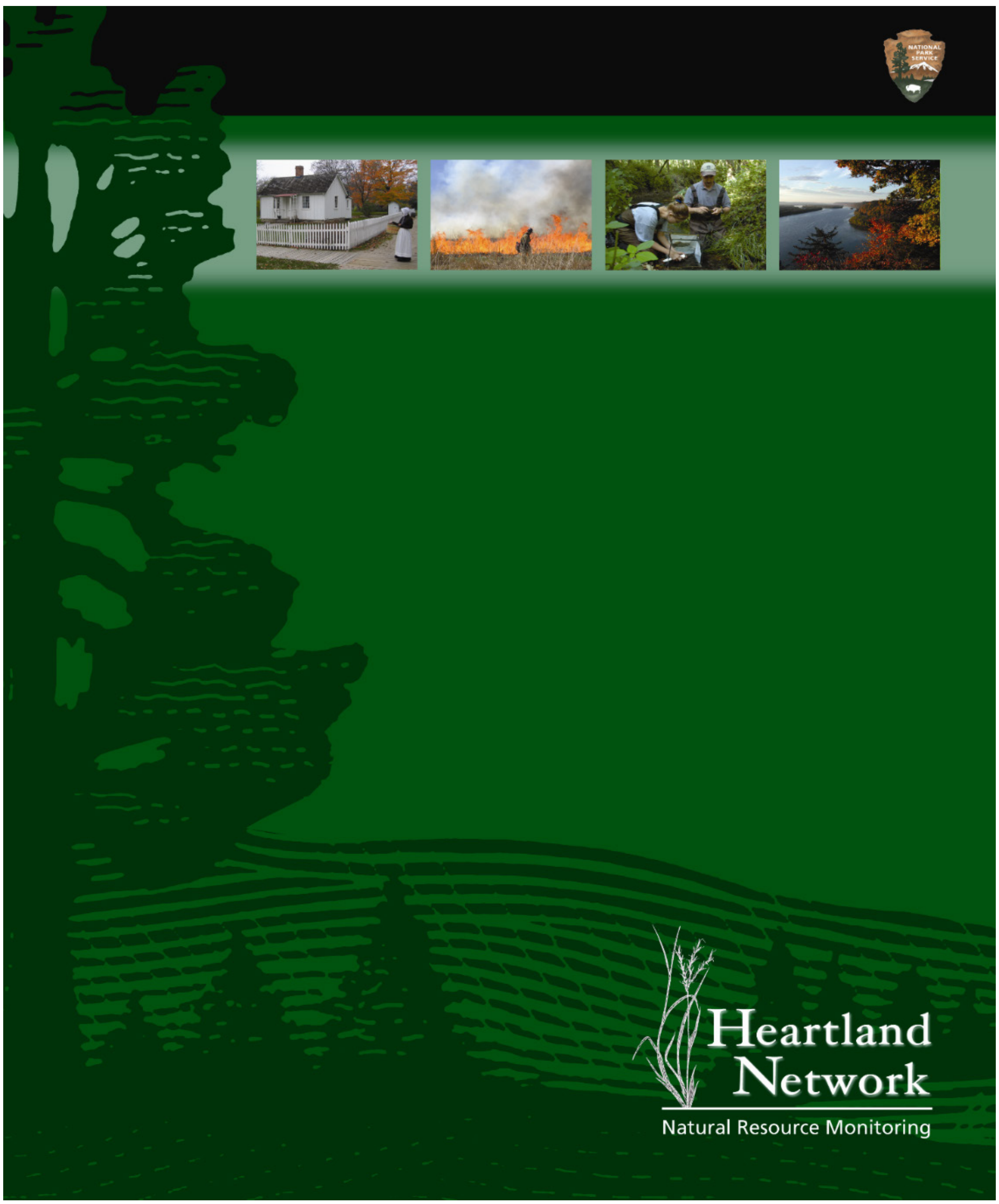
Natural Resource Stewardship and Science

Vegetation Community Monitoring Protocol for the Heartland Inventory and Monitoring Network

Narrative, Version 4.0

Natural Resource Report NPS/HTLN/NRR—2022/2477



ON THIS PAGE
Sherry Leis and Bradley Thornton monitoring plant communities at Tallgrass Prairie National Preserve.
Photography by NPS/HTLN/MARY SHORT

ON THE COVER
Herbert Hoover birthplace cottage at Herbert Hoover NHS, prescribed fire at Tallgrass Prairie National Preserve, aquatic invertebrate monitoring at George Washington Carver NM, the Mississippi River at Effigy Mounds NM.
Photography by NPS/HTLN

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are 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.

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Executive Summary

Native and restored plant communities are part of the foundation of park ecosystems and provide a natural context to cultural and historical events in parks throughout the Heartland Inventory and Monitoring Network (HTLN). Vegetation communities across the HTLN are primarily of three types: prairie, woodland, and forest. Park resource managers need an effective plant community monitoring protocol to guide the development and adaptation of management strategies for maintaining and/or restoring composition and structure of prairies, woodland, and forest communities. Our monitoring design attempts to balance the needs of managers for current information and the need for insight into the changes occurring in vegetation communities over time.

This monitoring protocol consists of a protocol narrative (this document) and 18 standard operating procedures (SOPs) for monitoring plant communities in HTLN parks. The scientific objectives of HTLN plant community monitoring are to (1) describe the species composition, structure, and diversity of prairie, woodland, and forested communities; (2) determine temporal changes in the species composition, structure and diversity of prairie, woodland, and forested communities; and (3) determine the relationship between temporal and spatial changes and environmental variables, including specific management practices where possible.

This protocol narrative describes the sampling design for plant communities, including the response design (data collection methods), spatial design (distribution of sampling sites within a park), and revisit design (timing and frequency of monitoring visits). Details can be found in the SOPs, which are listed in the Revision History section and available at the Integrated Resource Management Applications (IRMA) website (irma.nps.gov). Other aspects of the protocol summarized in the narrative include procedures for data management and reporting, personnel and operating requirements, and instructions for how to revise the protocol.

Acknowledgments

The National Park Service (NPS) Inventory and Monitoring Program provided funding for vegetation community monitoring protocol development and continues to fund monitoring across HTLN parks. The second edition of this protocol, “Vegetation Community Monitoring Protocol for the Heartland I&M Network and Prairie Cluster Prototype Monitoring Program,” was written in 2004 by Michael DeBacker, Alicia Sasseen, Dr. Gareth Rowell, Cindy Becker, Lisa P. Thomas, John Boetsch, and Dr. Gary D. Willson. Peer review of that version of the protocol was conducted by the USGS and Northern Prairie Science Center and benefited from the comments of Diane Larson, Jim Stubbendieck, Wes Newton, Jan Keough, Melinda Smith, Gerry Steinauer, Kristin Legg, David Glen-Lewin, and Don Faber-Langendoen. The 2009 version updated the protocol to reflect the network’s coordinated monitoring efforts among terrestrial projects and the turning over of Agate Fossil Beds National Monument and Scotts Bluff National Monument to the Northern Great Plains Inventory and Monitoring Network (James et al. 2009a). This protocol uses sections of text without citation from the previous protocol versions. Numerous NPS staff and volunteers have contributed to the development of this protocol. Therefore, the list of authors simply reflects those who put down on paper the work of this larger group.

Revision History

Revision history log

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
prototype	2000	Willson et al.	Transitioned to operational status.	Initial prototype for 6 prairie parks.	1.0
1.0	2004	DeBacker et al.	Transitioned methods from 6 prairie parks to 10 diverse network parks.	Include additional parks and diverse community types.	2.0
2.0	6/19/2009	K. M. James	Changed the revisit design, adjusted TAPR sampling design, included frequency analysis.	Update revisit and TAPR designs to match staff capacity.	3.0
3.0	2022	S. A. Leis	Improved equipment list, consolidated ground flora datasheets to one type of datasheet only. Added safety considerations. Included new guidance.	Provide clarity and include safety references. New administrative guidance.	4.0

Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02, etc.) for minor changes. Major revisions will be designated with the next whole number (e.g., version 2.0, 3.0, 4.0…). The previous version number, date of revision, author of the revision, and the reason for making the changes are recorded along with the new version number. The first version of this protocol was published in 2000. Citations for prior protocol revisions are listed here for ease of reference.

Previous Versions

Previous versions of the protocol are listed below. Standard Operating Procedure (SOP) documents are listed in Table 1.

Prototype

Willson, G. D., L. Thomas, M. DeBacker, W. M. Rizzo, and C. Buck. 2000. Draft plant community monitoring protocol for six prairie parks. U.S. Geological Survey, Northern Prairie Wildlife Research Center, Missouri Field Station, 302 Gentry Hall, University of Missouri Columbia, Missouri 65211.

Protocols

Willson, G. D., L. Thomas, M. DeBacker, W. M. Rizzo and C. Buck. 2002. Plant community monitoring protocol for six prairie parks. U.S. Department of the Interior, U.S. Geological Survey, Northern Prairie Wildlife Research Center Inventory and Monitoring Protocol.

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, Wilson's Creek National Battlefield, Republic, Missouri.

James, K. M., M. D. DeBacker, G. A. Rowell, J. L. Haack and L. W. Morrison. 2009. Vegetation community monitoring protocol for the Heartland Inventory and Monitoring Network. Natural Resource Report NPS/HTLN/NRR—2009/141. National Park Service, Fort Collins, Colorado.

Table 1. List of standard operating procedures (SOP) in vegetation monitoring protocol.

SOP #	SOP Name
1	Preparations and Equipment Setup Prior to the Field Season
2	Training Observers
3	Establishing and Marking Permanent Sample Sites
4	Documenting Site Disturbance
5	Monitoring Site Setup
6	Measuring Ground Cover
7	Measuring Ground Flora
8	Processing Unknown Specimens
9	Measuring Overstory Canopy
10	Measuring Midstory and Overstory Trees
11	Archival Photos
12	Double Sampling
13	Burned Area Mapping
14	Data Management
15	Data Summary and Analysis
16	Reporting
17	Revising the Protocol
18	Park Reference Frames with Vegetation Site Locations

Background and Objectives

Issues Being Addressed and Rationale for Monitoring Vegetation Communities

Long-term ecological monitoring of national parks contributes to the health of biological communities, including human communities. Ecological monitoring is integral to the proper management and protection of the lands entrusted to the National Park Service (NPS) while also contributing to our empirical understanding of plant communities. Furthermore, extension of that data to visitors and others improves appreciation for and understanding of the value and importance of natural resources. Park resource managers require an effective plant community monitoring protocol to guide the development and adaptation of management strategies for maintaining and/or restoring prairie, woodland, and forest community composition and structure. Our monitoring design attempts to balance the needs of managers for current information and the need for insight into the changes occurring in vegetation communities over time.

Vegetation, both native and restored, is a part of the foundation of park ecosystems and provides context for cultural and historical events in parks throughout the Heartland Inventory and Monitoring Network (HTLN). Vegetation across the HTLN is primarily of three types: prairie, woodland, and forest. Across the network, there are common land use histories affecting these communities over the past two centuries. Conserving natural communities is important for parks with both natural and cultural resource focuses because land conversion and habitat fragmentation threaten parks regardless of the park mission.

Land conversion, habitat fragmentation, invasion of non-native species, and disruption or elimination of the natural disturbance regime results in limited or altered plant community extent and quality. Scientists estimate the loss of native prairie ranges from 80 to 99.9%, with the greatest losses occurring in the tallgrass prairie (9% remaining) and oak savanna communities (White et al. 2000). Further, only 71% of shortgrass prairie and 59% of mixed-grass prairie remain (Knopf and Samson 1997). As large tracks of natural vegetation communities are lost, the communities within parks become representative of once widespread or locally unique community types. The increased significance of these park communities warrants special attention through long-term monitoring and coordinated management.

Grassland ecosystems are maintained by a complex disturbance regime including frequent large-scale and small-scale disturbances. The interactive effect of periodic fire and ungulate grazing is widely recognized as a critical component of the natural disturbance regime in tallgrass prairie ecosystems (Bragg 1995; Davison and Kindscher 1999; Howe 1999; Collins 2000). These disturbances in turn interact with climatic variation to affect spatial and temporal dynamics (Collins 1987; Knapp and Seastedt 1998; Knapp et al. 1999; Collins 2000). The complex disturbance regimes of grassland systems consist of dynamic mosaics of vegetation patches scattered across the landscape, highly variable in both space and time (Collins and Glenn 1991; Collins and Glenn 1997; Collins 2000; Fuhlendorf and Engle 2001).

Oak-hickory savannas, woodlands, and forests similarly developed under a complex disturbance regime. Oak savannas form transition zones within the eastern prairie, while oak-hickory woodlands and forests once formed large tracts across the landscape from southern Arkansas to northern Iowa and east to Ohio (McShea and Healy 2002). Oak-hickory communities can be thought of as being in a constant state of recovery from varying degrees of natural disturbances (Johnson et al. 2002). However, with the elimination or suppression of fire, much of the natural disturbance regime has changed. This disruption of ecological processes is reflected in the composition and structure of these communities (Nelson 2005). Understanding both the dominant cover types of forests, woodlands, and savannas and their structural characteristics provides insight into the recent disturbance history of the stand and yields information that can be used for silvicultural management (Oliver and Larson 1996). Further monitoring of tree seedling and sapling regeneration can act as a predictor of future forest cover types (Eyre 1980). Monitoring the structural stages along with the natural and managed disturbance regimes can be used to develop management strategies that consider multiple successional trajectories at the forest stand scale.

Focal park plant communities have differing response rates to disturbance. Prairie communities can exhibit high year-to-year fluctuations in species composition and abundance; however, in stable systems, the community structure remains constant over long periods or large spatial scales (Collins 2000; Earnest and Brown 2001). Savanna-woodland systems exhibit less annual variability yet fluctuate between prairie-dominated understory and increasing canopy cover as affected by natural disturbance and succession. Forested systems show change in species composition at a slower time scale in the absence of disturbance yet can exhibit more immediate changes following large gap-forming disturbances. Long-term studies of plant communities and individual species aide in determining appropriate temporal and spatial scales at which plant communities can be considered stable (Collins 2000).

Natural communities within national parks of the HTLN are becoming increasingly rare in the landscapes surrounding the parks. Both the cultural and ecological importance of these communities may increase with their protected status in landscapes where they are rare. Understanding long-term trends of native plant species richness and abundance is critical as ecosystems become increasingly altered or disappear. Information gathered over time will improve the understanding of vegetation community patterns and processes as well as provide insights to inform management actions.

Historical Development of Vegetation Monitoring in Network Parks

Initiated in 1994, the Prairie Cluster Prototype Long-Term Ecological Monitoring Program (PC-LTEM) was established to address monitoring concerns in NPS prairie parks in the Great Plains. From 1994–1999 the PC-LTEM, in collaboration with the USGS Biological Resources Division, initiated pilot studies in six geographically distinct prairie parks to develop a long-term vegetation monitoring protocol. In addition to providing needed information on the status of national prairie resources, a monitoring protocol for six prairie parks was designed to address long-term changes in vegetation occurring under different management strategies (Wilson et al 2002).

The original PC-LTEM park units were Agate Fossil Beds National Monument (AGFO), Effigy Mounds National Monument (EFMO), Homestead National Monument of America (HOME; now called Homestead National Historical Park), Pipestone National Monument (PIPE), Scotts Bluff National Monument (SCBL), Tallgrass Prairie National Preserve (TAPR; added in 1997) and Wilson's Creek National Battlefield (WICR). Located along an east-west precipitation gradient and a north-south temperature gradient, these parks capture much of the climatic and biotic variability of all parks in the Great Plains, containing shortgrass prairie (AGFO and SCBL), tallgrass prairie (TAPR, HOME, EFMO and PIPE) and woodland sites (EFMO and WICR). PC-LTEM served as a testing ground for long-term monitoring, emphasizing the development of sound monitoring protocols, attention to data management and data quality issues, and regular reporting of results to management. Two of the original seven PC-LTEM parks, AGFO and SCBL, were transferred to the Northern Great Plains Network (NGPN) in 2009.

In 2001, the NPS implemented park vital signs monitoring programs in approximately 270 natural resource parks (Middlemis-Brown 2016). The NPS organized these parks into 32 networks, linked by geography and shared natural resource characteristics. The Heartland Network was created to service fifteen parks in eight Midwestern states representing tallgrass prairie, Ozark highlands and eastern deciduous forest ecoregions. Initially co-located with the PC-LTEM program, the two programs were further integrated in 2003. Collectively the two programs form The Heartland Inventory and Monitoring Network (HTLN).

The HTLN park units (Figure 1) are Arkansas Post National Memorial (ARPO), Buffalo National River (BUFF), Cuyahoga Valley National Park (CUVA), Effigy Mounds National Monument (EFMO), George Washington Carver National Monument (GWCA), Herbert Hoover National Historic Site (HEHO), Homestead National Historical Park (HOME), Hopewell Culture National Historical Park (HOCU), Hot Springs National Park (HOSP), Lincoln Boyhood National Monument (LIBO), Ozark National Scenic Riverways (OZAR), Pea Ridge National Military Park (PERI), Pipestone National Monument (PIPE), Tallgrass Prairie National Preserve (TAPR) and Wilson's Creek National Battlefield (WICR). Five of the PC-LTEM Program parks (EFMO, HOME, PIPE, TAPR, and WICR) are included within the HTLN.

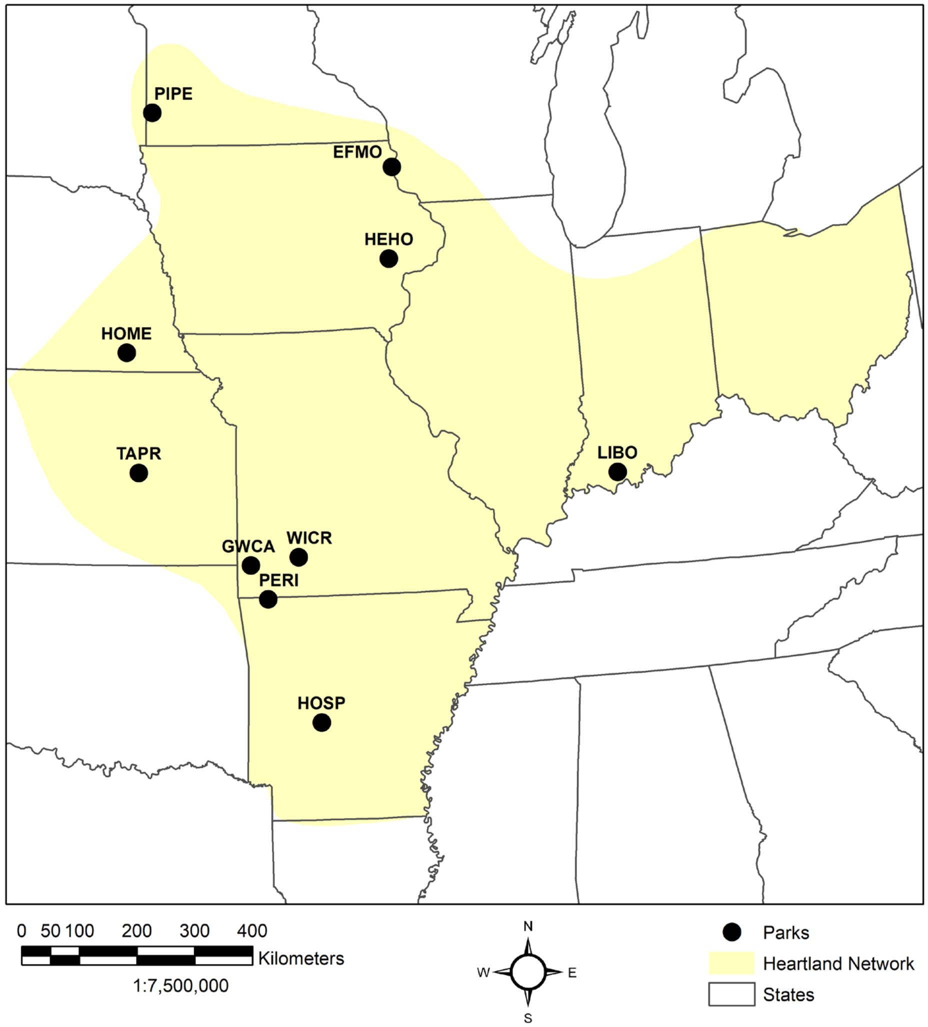

Figure 1. The Heartland Inventory and Monitoring Network park units.

The culmination of the PC-LTEM and vital signs monitoring program collaboration was a vegetation monitoring protocol for the HTLN (DeBacker et al. 2004). With the merger of the two programs, vegetation monitoring of forested communities was expanded to include HOSP and PERI in 2007. Vegetation monitoring occurs at 10 HTLN parks: EFMO, GWCA, HEHO, HOME, HOSP, LIBO, PERI, PIPE, TAPR, and WICR.

Initially vegetation sampling occurred during two consecutive years at a park and was followed by a three-year interval of no sampling. To facilitate monitoring integration among other HTLN terrestrial projects, the revisit design was changed to match the breeding bird sampling schedule (Peitz et al. 2008; James et al. 2009b, 2009c). Beginning in 2009, parks were sampled during a single year with a three-year interval between sampling events (i.e., once every four years). Furthermore, breeding bird monitoring, invasive exotic plant species monitoring, and vegetation community monitoring now occur at the same parks during the same year.

In addition to the revisit design, the logistics of sampling prairie parks has changed. Prior to the 2009 field season, prairie parks were sampled twice during the field season to collect data throughout the growing season. To facilitate efficient data collection, data management, analysis and reporting, prairie parks are now sampled once during the early summer growing season (during the same time as the original sampling prior to 2009). Further discussion and justification for these changes can be found in James et al. 2009b and 2009c. A monitoring history has also been developed and is available from the Vegetation Ecologist (HTLN 2021a).

The National Park Service is committed to a culture of safety. The HTLN safety plan describes in detail ways to keep staff and equipment safe during field operations. Occasionally specific reconnaissance trips may be necessary to evaluate safety for monitoring crews. Every crew member is responsible for the safety of the trip, and we encourage tools like situational awareness and after-action-reviews to continuously improve safety and awareness (NPS Heartland Network 2017).

Lastly, the extension of our monitoring has transitioned through time. In early stages of the program, the network limited the amount of inference from the data and translation to managers. We now approach monitoring in a more holistic way. For example, we view the park managers as partners in understanding how results apply to management goals. Including feedback from experts in the field both within NPS and externally improves our understanding of the systems we monitor.

We also recognize that the value of sharing our data-driven ecological expertise beyond the parks themselves is immeasurable. The data and interpretation of data is an invaluable resource for improving plant and human communities simultaneously. Park plant communities that are well managed contribute to meaningful experiences for visitors. Outreach efforts of staff beyond the park boundaries similarly impress values such as the land ethic and appreciation for other species (Leopold 1949).

Objectives

Vegetation community monitoring in HTLN parks is designed to detect and describe changes in prairie, woodland, and forested communities. There are five primary objectives for the monitoring defined in this protocol.

Scientific Objectives

1. Describe the current species composition, structure and diversity of prairie, woodland, and forested communities.
2. Determine temporal changes in the species composition, structure, and diversity of prairie, woodland, and forested communities.
3. Determine the relationship between temporal and spatial changes and environmental variables, including management practices where possible.

Operational Objectives

1. Report monitoring results to park natural resource managers, other park staff, and partners, and communicate results through outreach and scientific publications and presentations when appropriate.
2. Conduct monitoring safely, ideally without accident or injury. Safe monitoring includes transportation to/from parks as well as during field operations.

Sampling Design

Response Design

The HTLN vegetation community monitoring protocol is based on the National Science Foundation's Konza Prairie Long-Term Ecological Research Program. For the HTLN, the primary sample unit consists of two permanent, parallel, 50-m transects with five sets of nested plots systematically spaced along each transect (Figure 2). The transect pair is the primary sample unit and is referred to throughout the protocol as the site. The plot is the secondary sample unit.

The plots (n = 10) are used to collect ground cover and ground flora data (SOP 6 Measuring Ground Cover, SOP 7 Measuring Ground Flora). Working from the smallest to the largest plot, all herbaceous, woody shrub, and tree seedling and sapling species are identified (Appendix A designates species as trees or shrubs). Foliar cover of non-tree species is estimated in each plot at the 10-m^2 scale using a modified Daubenmire cover class system. Trees ≤ 5.0 cm diameter at breast height (DBH) are tallied by species and regeneration type. For analysis, the site is used as the unit of replication and individual plots within the site are pooled or averaged. The 0.1 ha area between the two transects is used to collect data on tree species greater than 5.0 cm DBH in the understory and overstory canopy layers. Species, diameter at breast height, and status are recorded for each individual tree > 5.0 cm. If field teams are unsure if a plant is designated as a tree or shrub and Table A1 in Appendix A is not available, they should collect the data as if a shrub and a tree. Flag the entries and make a determination of the correct methods in the office and prior to data entry.

From the monitoring site scale, data summary variables are calculated. Summary variables include (1) plant species richness and diversity, (2) guild abundance including exotic species, (3) species abundance and frequency, (4) woody regeneration species density (5) overstory canopy cover, and (6) ground cover characteristics (See SOP 15 Data Summary and Analysis for a full list of summary variables). Changes in these summary variables are used to detect trends over time in the vegetation community.

Additional environmental variables may be included in analyses to improve understanding of trends. Examples include precipitation, fire history, and invasive-exotic plant treatments. These data may be generated by other HTLN projects or other trusted sources.

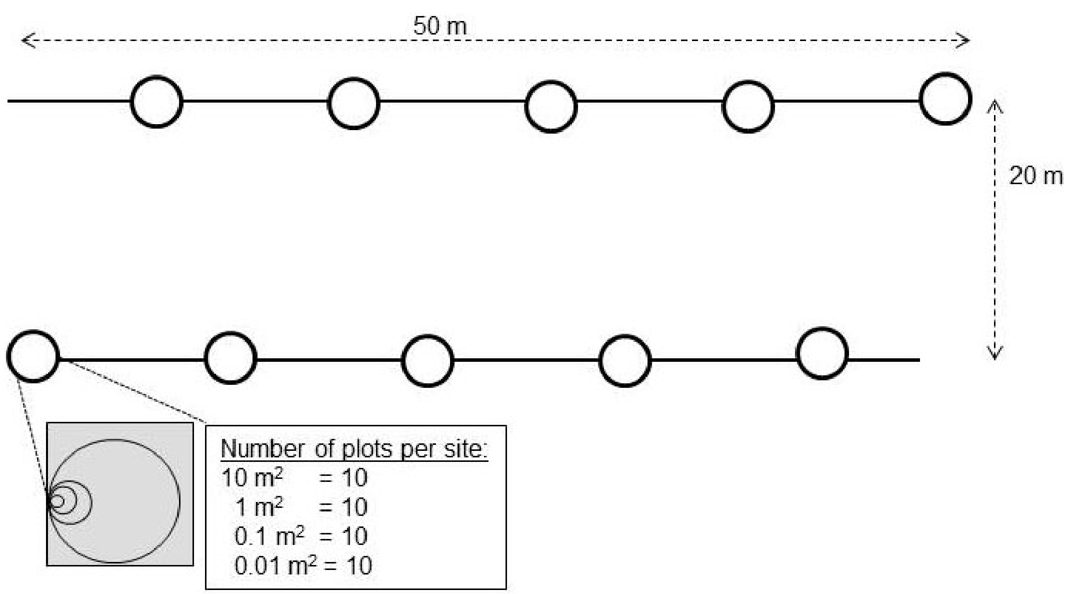

Figure 2. The Heartland Inventory and Monitoring Network vegetation community monitoring site comprised of two 50-m-long transects with ten sets of nested plots (n = 10) systematically arranged.

Data collection methods are discussed in brief below. Field Methods are discussed in detail in the standard operating procedures. Analyses of data for both status and temporal trends are discussed in detail in SOP 15 Data Summary and Analysis.

Spatial Design

To effectively use limited monitoring resources, information derived from a relatively small number of sites must be used to infer changes over a much larger area. Although our design lends itself to understanding plant community change, it does not allow us to necessarily evaluate specific management actions (i.e., a more experimental research design may be needed). For inferences from our design to be valid, a probability-based sample design within a defined reference frame is required. This section describes a stratified, random spatial design that serves as general guidance for locating monitoring sites. From time to time, deviations from this general approach are required to accommodate specific circumstances on the ground.

Defining the Reference Frame

The many different vegetation types, management practices, and park-specific data needs, as well as the logistical constraints related to fieldwork, require sampling approaches rather than a full census at each park. As a result, we are unable to treat an entire park as the area of interest. In choosing smaller subsets of a park as the reference frame, park-specific resource management issues and/or the desire to capture landscape and community heterogeneity guide the selection. The smaller subset is the reference frame for which statistical inference is made. In general, areas that represent a range of community types (prairie, woodland, and forest), conditions (high-quality remnants, restoration areas) and/or management strategies are selected.

Stratifying within the Reference Frame

The need for vegetation monitoring at parks throughout the HTLN necessitates a sample design that effectively and efficiently provides detailed species-level and community-level data that can address changes in the community over time. The sample methods employed involve intensely measured species-level sampling, necessitating small sample sizes. Stratification by physical features such as landscape position, soils, and geology provide an effective *a priori* approach to an efficient, equal distribution of sites within a reference frame.

After reference frames are defined, a secondary delineation by community type is sometimes needed (e.g., restored tallgrass prairie, remnant tallgrass prairie, and remnant Sioux quartzite prairies at PIPE). Within the reference frame or community type, soils are used to stratify the reference frame. In larger areas characterized by greater topographic gradients, aspect is also used along with soil type to stratify the reference frame. In a geographical information system (GIS), aspect is determined by using a digital elevation model to classify areas in the reference frame as dry and southerly (>135 and <315 degrees) or northerly (<135 and >315 degrees). These cutoff points are based on the Beers transformation that accounts for southwest facing slopes often being the driest (Beers et al. 1966). Within the strata defined using the above criteria, sites are randomly placed proportionally to the area within each stratum. For example, if a stratum characterized by a particular soil type encompasses 75% of the reference frame, 75% of the sites are deployed in that stratum. Rare soil types are most often excluded from the stratification so that the more common pervasive strata are the monitoring focus. See SOP 18 Park Reference Frames for details on park reference frames and monitoring.

Deploying Monitoring Sites

The number of sites to be deployed within a reference frame is determined on a case-by-case basis. Factors include field work logistics, expense, and professional judgment regarding the adequacy of a particular sample size in representing the community within the reference frame. Once the total sample size is determined, monitoring sites are distributed among strata proportionate to each stratum's area within the reference frame.

A general approach for deploying sites begins with establishing a grid overlay of the reference frame. The vertices of the grid are spatially referenced to form a matrix of potential monitoring points. Soil and aspect attributes are assigned to each vertex using a GIS to identify a pool of potential sites. In the field, points are visited in random order. When arriving at a point, the suitability of the area as a monitoring site is assessed (a point may be considered unsuitable if it is influenced by an unnatural occurrence such as a trail). If the point is suitable, a permanent monitoring location is established. Alternatively, the reason for rejection is noted and the next point visited until the target number of monitoring sites is established. Details relating to establishing monitoring sites are described in SOP 3 Establishing and Marking Permanent Sample Sites. Sites are physically marked on the ground and located in the field with a global navigation satellite system (GNSS) unit (see SOP 2 Training Observers and SOP 3 Establishing and Marking Sampling Plots for instructions regarding GNSS navigation and site establishment).

Sampling Frequency and Replication

In developing a logistical plan, the timing of sampling within the growing season is considered, with sampling limited to late May through July. Plant community sites are sampled at approximately the same time each year to help differentiate long-term trends in foliar cover from changes attributable to within-season variability. Sampling is distributed throughout a growing season in the following manner: spring/early summer sampling in prairie communities and mid-summer sampling in woodland and forested communities.

All sites within a reference frame are sampled in a single year followed by a three-year interval without sampling (Tables 2 and 3). This design is well suited for trampling-sensitive systems such as prairies, allows for a greater number of sites to be visited through time than an annual revisit panel, and coordinates sampling schedules among other terrestrial monitoring projects.

In this protocol, the reference frame within parks parallels the framework for statistical interest. Analysis and results focused on individual parks and multi-park analyses are outside the scope of this protocol.

Table 2. Sampling schedule for vegetation community monitoring in the Heartland Inventory and Monitoring Network parks, 2018 through 2028. All parks are visited every fourth year (3 years between visits. The schedule was altered because of the pandemic (from 2020 forward). “X” indicates sampling.

Region (Parks)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Ozarks-prairie (WICR–GWCA)	–	–	X	–	–	–	–	X	–	–	–
Northern prairie (HOME–PIPE–EFMO–HEHO)	–	–	–	–	X	–	–	–	X	–	–
Tallgrass prairie (TAPR)	X	–	–	–	–	X	–	–	–	X	–
Deciduous forest LIBO-HOSP	–	X (LIBO)	–	–	–	–	X	–	–	–	X
Ozarks-forest (WICR–PERI)	–	–	X (WICR)	X (PERI)	–	–	–	X	–	–	–

Table 3. Sample season for HTLN plant community monitoring.

Region	National Parks	Sample Season	Preferred window
Ozark prairie tour	WICR–GWCA	6/1–6/30	–
Northern prairie tour	EFMO–HEHO–HOME–PIPE	6/1–6/30	mid to late June
Tallgrass prairie tour	TAPR	5/30–6/20	early June
Ozark-forest tour	WICR–PERI	7/1–7/31	–
Eastern forest tour	LIBO–HOSP	7/1–7/31	–

Quality Assurance / Quality Control

The Quality Assurance Plan for Vegetation Monitoring in the HTLN describes the quality assurance and control procedures of the protocol (Leis et al. 2019). Sampling errors are most likely to occur during species recording/identification and abundance estimation. Three types of error may occur during species recording/identification: (1) overlooking error, in which the observer does not see a species that is present; (2) specificity error, in which an observer chooses to lump a species to a higher taxonomic level; and (3) misidentification error, in which an observer records the wrong name for a species (Morrison 2016). Abundance estimation errors occur when observers assign different cover classes to represent species abundance in a plot. We quantify our plant species composition errors using a double-sampling technique (SOP 12 Double Sampling).

Rationale for Selected Design

Monitoring objectives are integral to defining the sampling design. The sample design for vegetation community monitoring is driven by two main goals: (1) to assess the status of vegetation communities by estimating community parameters at distinct points in time and (2) to detect trends in vegetation communities over time by measuring net change in certain parameters.

1. *The selected design is appropriate for long-term monitoring in grassland systems*. This is a modified version of the sampling design employed by the National Science Foundation Long-Term Ecological Research (LTER) program at Konza Prairie, a long-term ecological research program in tallgrass prairie. Ongoing and prior research at Konza Prairie LTER (Gibson 1988; Collins and Glenn 1991; Collins 1992) demonstrates that permanently located 10-m^2 plots (i.e., our secondary sample unit) are effective for investigating community-level change in prairie communities. Repeated measures of the same location allow for differentiation of site and year factors, essential to measuring trend through time (Lesica and Steele 1996; Elzinga et al. 1998).
2. *The selected design is appropriate for woodland, and forested systems*. A prioritized interest in addressing management and restoration efforts in woodland (including savanna) and forested systems led to a sampling design that provides information on woody regeneration and the overstory strata. The rectangular 0.1-ha area within the paired transects serves as an overstory plot and data on regeneration is collected in the 10-m^2 plots. The overstory sampling is consistent with techniques used in the fire effects program in forested areas (USDI National Park Service 2003).
3. *The selected design accommodates habitats of varying size*. The sample design is adjustable to accommodate large and small study units. The number of sites established is dependent on habitat and community diversity within the study unit. In small study units, sampling consistency is retained by reducing the site to a single transect or reducing the length of the paired transects. Conversely, in large study units, sample units are spatially distributed using habitat stratification and randomization.
4. *The selected design addresses species-level dynamics*. Within each 10-m^2 plot, the three nested plots (0.01 m^2, 0.1 m^2, and 1.0 m^2) are comparable to a nested frequency frame used by The Nature Conservancy and the square plot design suggested by Peet et al. (1998) for plant community monitoring. Nested plots are capable of detecting shifts in frequency by optimizing the spatial scale (Elzinga et al. 1998).
5. *The selected design is easy to learn and use*. Field procedures are easy to use and repeatable over time by different sampling crews. Implementation does not require extensive time or costly equipment. Furthermore, transects increase the efficiency of finding and sampling a number of permanent plots quickly (Thompson 1992). The association of plots with permanent transect lines facilitates accurate relocation and measurement.
6. *The spatial design offers the flexibility of a stratified random approach; however, it has the grid infrastructure as an underlying feature*. The underlying grid offers two advantages. First, it ensures that any two sites will not be closer to one another than the grid cell size. Second, the grid provides an infrastructure for other studies that may be more suited to systematic sampling, thus providing some potential for co-location between vegetation monitoring sites and those of other studies (See chapter 4 in DeBacker et al. 2005).

7. *The sequence of sampling tours allows for the greatest amount of field work to be accomplished per year while minimizing cost, travel time, and impact to monitoring sites*. The one-year-on, three-years-off revisit plan protects sites from trampling effects that could occur from more frequent visits. Off years provide opportunities for resource managers to implement management actions before receiving a status check.

8. *The selected design-based approach to monitoring is advantageous over model-based approaches*. Design-based approaches are objective, unbiased and free of assumptions, whereas model-based analyses require a model and assumptions to make estimates and extrapolate results to non-sampled areas. Design-based analyses use a rigorous probability sample instead of assumptions to make estimates and extrapolate to non-sampled areas. The objectivity and unbiased nature of design-based approaches are especially important in studies where the results are often contentious.

Field Methods

Prior to the field season each year, the crew members should review this entire protocol narrative and all the SOPs. Crew leaders should pay special attention to equipment listed in SOP 1 Preparations and Equipment Setup Prior to the Field Season. All the equipment and supplies listed in SOP 1 Preparations and Equipment Setup Prior to the Field Season should be organized and made ready for the field season. Prior trip reports should also be reviewed for background information on species identification and challenges, etc. Also review safety considerations and operational leadership principles.

Review of plant identification using both live and dead plant material is particularly important each year. Plant misidentifications are difficult to trace once the summer field season begins and the learning curve in the field is greatly buffered with pre-field study. SOP 2 Training Observers contains information for the crew leader and crew members to gauge the level of quality expected.

The revisit plan outlined in Table 2 defines the annual park sampling sequence. Sampling dates should be scheduled, and logistics organized prior to the start of each field season. Staff workloads and unpredictable weather necessitate maintaining some flexibility in scheduling the sequence and duration of sampling trips.

Sampling Methods

The crew leader decides the sequence of sites to be sampled in the field. Once arriving at the park, park maps, a GNSS unit and a metal detector are used to locate each site. Ends of both 50-m-long transects are permanently monumented with reinforced metal bars (rebar) during site establishment and aid in relocation of the site. The rebar, sunk into the ground with the upper 4–6 inches exposed, are tagged with a metal tag imprinted with the site number, transect letter (A or B) and transect start (S) or finish (F) designation. The network name is also included.

Each day the crew leader splits the team into pairs, matching an observer with a scribe. The scribe is responsible for ensuring all data listed on the data sheets are collected, including plot metadata. Scribes may also collect the densiometer data. The observer is responsible for species identification, cover estimates, and seedling counts. Diameter at breast height measurements may be taken by scribes or observers. Pairing observers allows equal opportunity for all team members to work on all components of sampling, reduces observer exhaustion, and breaks up monotony. Furthermore, changing the make-up of sampling pairs reduces divergent estimates of foliar cover and increases consistent recording and tracking of unknown specimens.

Prior to beginning sampling, the site should be scanned for overstory trees (trees > 5 cm DBH). If those trees are within the site, the overstory tree SOPs (SOP 9 Measuring Overstory Canopy and SOP 10 Measuring Midstory and Overstory Trees) will be initiated in addition to SOP 6 Measuring Ground Cover and SOP 7 Measuring Ground Flora procedures. The site should be scanned for initial signs of disturbance and any disturbances should be noted on the Disturbance Assessment datasheet (SOP 4 Documenting Site Disturbance).

All sampling begins at the start of each transect to avoid errors such as mislabeling plots on the data sheet or missing trees in the overstory. For ground flora measurements, transect A plots are centered at 10 m, 20 m, 30 m, 40 m and 50 m and transect B plots are centered at 0 m, 10 m, 20 m, 30 m and 40 m. Refer to SOP 3 Establishing and Marking Permanent Sample Sites for instructions pertaining to accurate transect and plot placement.

Each team is responsible for keeping track of the equipment and data sheets. Before leaving any site, data sheets are checked and passed on to the crew leader, and all equipment is gathered. When leaving the field each day, data sheets are again checked for completeness and readability. The project manager is responsible for the safekeeping and organization of the data sheets and ensuring data entry. A trip report including weather conditions, logistical problems, any subsequent departure from the protocol, species identification problems, etc., should be written by the project manager upon conclusion of each monitoring trip (SOP 16 Reporting).

Archival photographs

Archival photos are visual documentation of site conditions over time. Photographs can be a powerful way of communicating results that complements written reports. Photos of monitoring transects were collected every 12 years (SOP 11 Archival Photos) to coincide with every third monitoring event. This schedule balances the time investment for photography during sampling with typical rates of change.

Collecting the Circular Plot Data (ground cover, ground flora, tree regeneration, densiometer)

For each 10-m^2 circular plot, structural characteristics such as cover of bare soil, bare rock, tree leaf litter, grass litter, and woody debris (see SOP 6 Measuring Ground Cover for definitions) are estimated using the modified Daubenmire cover value scale (Daubenmire 1959; Table 4). Each individual percentage value alone cannot exceed 100%, but when combined the cover value for a plot may be greater than 100% because layers overlap at the ground level. These attributes are measured in circular plots to describe changes in ground cover and allow for exploration of the correlative relationships between compositional changes and environmental attributes (SOP 6 Measuring Ground Cover).

After collecting ground cover estimates, the observer nests the 0.01-m^2, 0.1-m^2, and 1.0-m^2 circular frames within the 10-m^2 frame. Meanwhile, the scribe should measure the litter depth (one measurement) from a position opposite the botanist (finish side of the 10-m² plot). Beginning with the 0.01-m² plot, all species rooted in the plot are identified by the observer(s). Once all species in the plot are recorded, the observer moves onto the 0.1-m² frame. Only species not observed in the 0.01-m² frame are recorded. This is repeated in the 1.0-m² frame and then in the 10-m² frame. Once species presence has been recorded, the observer estimates foliar cover for each species in the entire 10-m² plot. Only species rooted in the plot are included in estimates of foliar cover. A reference list provided for each plot lists the names, but not the associated cover values, of species previously collected in the plot. Comparison with the cumulative plot species list maintains consistency in species identification and creates a check for missing species.

Foliar cover serves as the estimate of abundance for herbaceous and shrub species. Foliar cover is defined as the area occupied by the perpendicular projection of the aerial parts of individual plants of the plant species under consideration to the ground (Greig-Smith 1983). A cover class index modified from Daubenmire (1959; Table 4) is used for all cover estimates. Using cover classes reduces the problem of observer bias through partitioning all possible values into seven classes with broader cover classes in the middle of the scale and narrower cover classes at the lower and upper ends of the scale. Details of how to conduct cover estimates and for filling in data forms are given in SOP 7 Measuring Ground Flora and SOP 6 Measuring Ground Cover.

Table 4. Modified Daubenmire cover value scale.

Cover Class Codes	Range of Cover (%)
7	95.1–100
6	75–95
5	50.1–75
4	25.1–50
3	5.1–25
2	1.1–5
1	present–1.0

After the non-tree plants are assessed in the plot, tree regeneration is sampled. Seedling and sapling information is collected in each 10-m² plot and midstory and overstory tree data (individual trees ≥5.0 cm DBH) are collected within the rectangular 0.1-ha site delineated by the paired transect lines. All tree seedlings and saplings in the 10-m² plot are identified to species and tallied in three size classes: (1) seedlings = stems <0.5 m tall, (2) small saplings = stems ≥0.5 m tall but <2.5 cm DBH, and (3) large saplings = stems >0.5 m tall and ≥2.5 cm DBH but <5.0 cm DBH. Either standard DBH tapes or calipers can be used to measure DBH.

After all ten plots are sampled, 10% of plots are double sampled by a different observer-scribe team in order to measure species identification and foliar cover error rates (SOP 12 Double Sampling).

Collecting Midstory and Overstory Tree Data

In woodland and forest communities (EFMO, HOME, HOSP, LIBO, PERI, and WICR), stem density is used to estimate abundance of tree species. In woodland and forest settings, after the ground flora data are collected, a densiometer is used to collect canopy closure data where a canopy occurs. See SOP 9 Measuring Overstory Canopy.

After the plot data have been collected, the transect lines are left on the ground and the internal rectangular 0.1-ha area delineated by the paired transect lines is surveyed for all trees >5.0 cm DBH. This may also happen simultaneously with plot work if the crew size and expertise allow. Each tree is recorded by species on a field data sheet. For each tree, the DBH to the nearest 0.1 cm is determined. Each tree is also assigned a condition code (L= live or D = dead) and coppice status for use in structural analysis. The tree data will be used to understand succession and stand development. Refer to SOP 10 Measuring Midstory and Overstory Trees for additional details on collecting tree species data. For the majority of tree-like species in our database, we have designated whether the species may be treated as a tree or a shrub. Because some species may function as a tree or shrub depending on the context, we have created a list to provided consistency that is presented in Table A1 of Appendix A.

Processing Unknown Plant Species

Plants not immediately identified in the plot are collected and recorded on the data sheet with an unknown specimen code. If at least 10–15 individuals of the unknown species are present at a site, a specimen is collected outside the plot and placed in a plant press for later examination. A small or partial specimen is kept in a field notebook with the description and unknown code to ensure consistent application of unknown codes among sites. Location, description, and habitat information are recorded using an unknown specimen datasheet. If a specimen cannot be found outside the plot or the plant is rare, a description and location in the plot are recorded. Photographs may also be used in conjunction with samples and descriptions or in the case that a suitable specimen is not available.

Collected material may be mounted on acid-free herbarium paper, kept in insect-proof containers, and become reference specimens. Rare, threatened, or endangered species are not collected. Those species are known from each park and should be studied prior to sampling so that they are not collected. Reference specimens are housed in the HTLN herbarium at Wilson's Creek National Battlefield. The current version of the U.S. Department of Agriculture, Natural Resources Conservation Service Plant List of Accepted Nomenclature, Taxonomy and Symbols (PLANTS) (USDA, NRCS 2018) is used to standardize plant taxonomy. Species new to the VegMon database will refer to the current taxonomy in PLANTS. Updates to the existing taxonomy in the VegMon database are intentionally infrequent to avoid introduction of error and confusion, however. The last major update was done circa 2009. The Species lookup table for the VegMon database provides synonyms from the previous update as reference, see SOP 8 Processing Unknown Specimens.

Burned Area Mapping

Mapping of burned areas within seven parks (EFMO, GWCA, HEHO, HOME, PIPE, TAPR, and WICR) supplements the vegetation monitoring data (SOP 13 Burned Area Mapping). Wildland fire is a key ecosystem process affecting vegetation and occurs frequently in many of these parks. Perimeters are mapped using remote sensing via the Monitoring Trends in Burn Severity Program whenever feasible. Field mapping data of burned areas with GNSS units are processed within a GIS. The burned area perimeters are stored in a geodatabase and collectively contain the fire history for these parks. From the history, we can derive metrics such as fire frequency, fire return intervals, and time since fire (SOP 15 Data Summary and Analysis).

Data Management

Data management procedures are an important part of any long-term monitoring program in that they provide data consistency, data security, and availability over time. Therefore, care must be taken to ensure that adequate time and personnel are available for accurate data recording, data entry and verification, and analysis.

Data processing typically involves the following steps: data entry, data verification, data validation and backups/storage (see pages 6–10 in SOP 14 Data Management for details on each step). Data entry consists of transferring field data from field sheets into a monitoring database using data-entry forms. Data verification immediately follows data entry and involves checking the accuracy of computerized records against the original source, usually paper field records. Validation procedures seek to identify generic errors, such as missing, mismatched, or duplicate records, as well as logical errors specific to particular projects. Spatial validation of location coordinates can be accomplished using GIS. GNSS points are validated against imagery for their general location.

Overview of Database Design

There are two databases for the plant community monitoring project. One is a tabular Microsoft Access database, which henceforth will be referred to as the database. The database used for vegetation community monitoring is called VegMon. It is based on the Microsoft Access™ platform (Microsoft Access 2016 or newer). Like other natural resource monitoring databases, observation events (tbl_SamplingPeriod) in VegMon form the center of the database. Monitoring events include observations for species frequency, diameter at breast height, or percent cover. Other types of data discussed in this protocol include ground cover, vegetation structure, and canopy cover. VEGMON observations reference parameter tables (i.e., lookup tables) such as plant species, cover classes, plant guilds, and ground cover type tables. This database also documents the protocol version and QA/QC results.

The other primary database is an ESRI ArcGIS file geodatabase, henceforth referred to as the geodatabase. The geodatabase houses all the spatial data associated with the project, including the sampling locations. The geodatabase facilitates fieldwork as well as in-office mapping projects and communication. Data in the database and geodatabase are coordinated using a unique LocationID.

Field Forms

The database includes the primary field data forms for ground flora and overstory data collection (See SOP 1 Preparations and Equipment Setup Prior to the Field Season for descriptions of these forms). These data forms were revised in 2018 to allow for efficient production of forms that are synchronized with field collection sequences and data entry. The project leader is responsible for producing the field data forms.

Data Entry

Several features have been designed into VEGMON to minimize errors during the data entry process. The user interface helps to create a logical relationship between field datasheets and database records. Standardized identifiers for sample location and year are selected from choices provided by the user interface. Species and plot sizes are selected from lists linked to appropriate lookup tables. Other fields contain project-specific data and prohibit entry of values not included in lookup tables. Consequently, only valid names or measures may be entered and spelling mistakes are eliminated.

Quality Assurance and Quality Control

The database design includes fields to document the completion and results of QA/QC procedures and assessments:

- Inventory and Monitoring Division Database Standards (Frakes et al. 2015) require every datum to be unambiguously traceable to a specific version of a monitoring protocol, a quality assurance plan (QAP) where available, and suite of standard operating procedures (SOPs).
- Certification guidelines for I&M data products (NPS 2016) and Minimum Implementation Standards for Network Projects v. 3.0 (Frakes and Kingston 2017) call for every datum to have an associated QA/QC processing level (e.g., raw, provisional, certified).

- An annual operational review is required for all active monitoring protocols (Mitchell et al. 2018). Completion of an operational review, a summary of any flagged data, and a link to the review report are stored in the monitoring database.

Metadata Procedures

The Federal Geographic Data Committee (FGDC) now provides a range of options as guidance for metadata of spatial and non-spatial federal agency data. Most recommendations are variations of the ISO191xx standard which is typically used for natural resource datasets. Creation of ISO metadata has been greatly facilitated by ESRI ArcGIS utilities that automatically generate spatial metadata. Once metadata has been created, it should be saved in XML format following ISO metadata standards. Metadata is archived in the geodatabase and by the Washington Office Inventory and Monitoring Division (WASO I&M) in the Integrated Resource Management Applications website (IRMA). Metadata is archived by WASO with the submission of the monitoring protocol. It should be updated with each protocol revision. New Guidance for monitoring datasets will soon be available from the IMD IT Governance Board Metadata Working Group, and SOP 14 Data Management will be updated accordingly.

Data Backup Procedures

HTLN backs up all spatial and non-spatial data (including tabular documents) regularly. Weekly and monthly backups are incremental while quarterly and annual backups are mirrored copies of the server. Quarterly and annual copies of the server are stored off-site in a bank safe deposit box.

Like other monitoring databases/geodatabases, the plant community monitoring database and geodatabase are secured by file archives stored on the server. The databases are maintained under a directory called VegMon under the HeartlandCommon production drive. The database immediately below this directory is the production copy of the database. Under VegMon is also a subdirectory called "dev" that is short for "development." All backups and earlier versions are stored under this directory.

Annually, in fulfillment of the Data Analysis and Reporting Requirements (Gallo, K. memorandum dated 4/23/2018), the dataset will be uploaded to the NPS Integrated Resource Management Application (IRMA). The dataset is currently flagged as "read only" for all users except the Project Leader and Data Manager.

Data Management Staff Roles and Responsibilities

Staff roles and responsibilities overlap between project leader and data manager. The project leader is primarily responsible for data quality. The project leader must ensure data quality throughout the process of data collection, data entry, data verification, and data validation. The data manager may assist by identifying or implementing validation methods that will reduce the risk of error. The data manager's primary role is to assure functionality of database applications prior to and during data processing. Importantly, the database manager is responsible for secure backups of all project data. Lastly, the data manager is also responsible for uploading the data to the NPS Integrated Resource Management Application (IRMA).

Data Analysis

A critical component of any long-term monitoring protocol is a consistent and systematic way of analyzing and reporting on information (data) collected. Further, the information must serve two purposes: to describe the current condition, or status, of a plant community; and be robust enough to detect community changes through time. Long-term monitoring data should provide park natural resource managers with high-quality information to evaluate objectives and support management decisions. Scientific interest and public information are additional needs that require analysis and reporting of plant community data.

The strategy for analysis of long-term monitoring data is critical to meeting these goals. The plant community variables and indices selected for data summary purposes are scalable, comprehensive, descriptive, and easily interpretable. A subset of the variables may be selected for specific analyses relative to park vegetation communities and management objectives. The focus is on temporal and spatial change in community composition and structure and how it is related to environmental and management measurements. SOP 15 Data Summary and Analysis gives instructions for summary and analysis of vegetation community monitoring data. SOP 15 details the core data analysis for vegetation monitoring data. Additional statistical analyses that are park-, community-, or objective-specific will be detailed in the methods section of the individual reports. SOP 12 Double Sampling describes analysis of quality control, double sampling data.

Summary reports will provide information to park managers on the status of the target communities and feedback on the effects of implemented management efforts (e.g., restoration efforts or disturbance regime) when possible.

Data Analysis Approach

Analyses for community change detection begin with relatively simple approaches (exploratory analyses, parameter estimation, and control charts) and progress to more complicated analyses when biologically important changes seem to be occurring and the simpler analyses do not yield all the necessary information. These more comprehensive analyses can include the use of environmental variables. SOP 15 Data Summary and Analysis contains more details on constructing control charts and conducting trends analysis.

We take a scaled approach to analysis in that data are summarized at the species scale, community scale, functional scale, and at the study unit or park scale. The study unit or park scale can include environmental or management type metrics such as precipitation and fire history. All summaries are made with the site as unit of replication, so means and confidence intervals or other measures of variability can be calculated for each study unit or for park-wide inferences. We describe a suite of metrics and methods for analysis (SOP 15 Data Summary and Analysis, Table 15.1), including details on (1) species abundance and occurrence, (2) community diversity, (3) species diversity, (4) abundance of plant guilds, (5) density and basal area of overstory trees in forested communities, and (6) tree regeneration in forested communities. SOP 15 describes the need to include each metric in a standard status and trend report. Metrics listed as optional are more likely to be used in the context of a synthesis type project. Data elements not included in the SOPs may include externally sourced data that can be used with confidence such as precipitation data provided by national data centers, fire occurrence metrics, or data from other HTLN protocols.

Many variables collected in vegetation community monitoring are spatially and temporally dynamic yet serve an important purpose in providing descriptive information about the communities monitored. Community composition describes the spatial distribution of plants using a basic measurement of foliar cover. From these variables, other important ecological measures (indices or metrics) are determined. These variables and indices are the basis for assessing changes in vegetation communities through time.

The null hypothesis in most statistical significance tests is no change. This is usually unrealistic for long-term monitoring; populations and communities are dynamic, and no change null hypotheses are trivial. Null hypothesis significance testing may be useful for elucidating effects of variables if a design is present. Generally, however, focus should be on measuring the magnitude of change and evaluating the biological importance of change, rather than simply testing for statistical significance (Morrison 2007).

Reporting

Reporting of plant community monitoring observations is done for a variety of reasons. As a scientific principle, data has little value unless it is in some way shared or presented. Because an objective of monitoring is to provide quantitative support to natural resource managers, it is incumbent on staff to report field observations. Reporting needs can drive analysis and communication of results. Reporting may also create awareness of park plant community issues or trends for partners and the science community. Although standard operating procedures differ somewhat between woodland and grassland communities, the need for and types of reports will not vary by community type. The content will, however, clearly reflect the communities themselves. This section describes the types of plant community reporting the network intends to do and the standard elements or metrics that will be included.

Report writing will be done by the Project Leader with support from members of the HTLN terrestrial team including the Quantitative Ecologist as needed (SOP 16 Reporting). The audience for reports includes natural resource managers, superintendents, HTLN staff, NPS program managers, and the public, as well as external scientists and partners. Reporting is based on data collected using the data collection SOPs and summary and analysis detailed in SOP 16 Reporting. Trend reports are published as Natural Resource Reports in the NPS Natural Resource Report Series and uploaded to the NPS Integrated Resource Management Application (IRMA).

Report Types and Frequency

We define four categories of reporting to facilitate communication of results: (1) trip reports, (2) operational reviews and reports, (3) trend and synthesis reports, and (4) resource briefs (web article or data visualizer). We draw upon recent guidance for descriptions of each type (Mitchell et al. 2018).

Report Content

A scaled approach to data reporting can assist ecologists in organizing data as well as screening for change at different levels. Scales we address are species, functional group, community, and environmental. Table 15.1 in SOP 15 Data Summary and Analysis includes descriptions of metrics by scale and their recommended inclusion for reference.

The *species scale* of analysis and reporting is helpful for understanding plant communities. All scales of analysis depend on the basic species-level observations of species name and abundance. Because the systems we work in are typically very species rich, it is not always practical to provide species-by-species analyses. When species richness is high, we will report species of special interest to a park and/or a suite of species determined through a ranking process. Analyses that allow us to understand species trends in a holistic way are also useful. For example, including environmental variables or ordination approaches can provide insights.

Groupings of species that relate to function of plant communities is the next scale important to plant community assessment. These groups are often referred to as *guilds* or *functional group*s; we maintain consistency with prior versions of the protocol by using the term guild. Guilds include fern, forb, grass, grass-like, and woody. (See Appendix A for more on woody species guild designations.) Native versus exotic characterization is often critical for screening for community change. Another optional guild assignment relates to life history (annual, biennial, perennial). All guild designations are derived from the USDA Plants database, growth habit field (USDA, NRCS 2018). HTLN previously developed another guild designation called “PCLTEM-guild” that has not been maintained and will not be provided in status and trend reports at this time. If a plant has multiple growth forms listed, the dominant form observed in the field will be selected among the suite of guild types listed above.

Community level metrics (such as species diversity) provide an integrated look at large-scale changes of interest. The thresholds for detecting plant community change are likely to be high at this scale and subtle changes may not be as easily detected. Community metrics provide a simplified way to report on the community as a whole.

Another class of metrics that might be included in reports is environmental variables. Often these variables are observed at the park or management unit scale. Environmental variables include precipitation as obtained by national data sources (summarized by year or growing season; NOAA National Center for Environmental Information) and the Palmer Drought Severity index (PDSI) or Keetch Byram Drought Index (KDBI), indices that integrate a variety of weather-related factors (Heggen 1999; Keetch and Byram 1968 ; Palmer 1965; also see citations at the NOAA National Integrated Drought Information System Keetch-Byram Drought Index webpage: https://www.drought.gov/drought/data-gallery/keetch-byram-drought-index). KBDI is often used to determine fire risk. Fire management, exotic plant management, and grazing are additional variables that may contribute to understanding plant communities in the park context. Fire management metrics commonly used include fire occurrence (time since fire, in years or months, presented as a mean or maximum for a period and reporting unit, or frequency reported as mean number of fires for a time period), fire severity, and fuel load. Fire metrics can be presented as frequency maps when available, but site-by-site data will best coordinate with plant community data because fire ecology data are collected in the vegetation monitoring sites. Nonnative plant management data are generated from the Invasive Plant Management Team (IPMT) as area treated (m^2) summed to a unit/time period by treatment type. Treatments (spot spraying) conducted by the parks may not be included in these data. Grazing data are reported as a stocking rate per land unit (e.g., animal unit months per acre [AUM/ac]). Grazing data from TAPR are not collected by HTLN but are curated by HTLN. Thus, the quality of data collection is not under our control.

The report templates for the Natural Resource Publication Series (NRPS; https://www.nps.gov/im/publication-series.htm) should be followed. Consult the NRPS website to choose the correct template with which to begin writing. Always start with a fresh template as templates change periodically and old templates can become corrupted.

The Natural Resource Data Series (NRDS) is a non-scholarly series intended for the timely release of basic data sets and data summaries. Data reported in the NRDS are limited to those collected, processed (undergone quality assurance and quality control procedures), and analyzed following methods prescribed in peer-reviewed and published NPS Inventory & Monitoring protocols.

The Natural Resource Report Series (NRR) is used to disseminate information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision making, and the achievement of the National Park Service mission. The series also provides a forum for presenting lengthy results that may not be accepted by publications with page limitations. Peer review procedures will be conducted as described in the Network peer review process guidance (HTLN 2021b).

Additional modes of summary communications may be employed when relating results to non-science audiences through the web or public speaking. These modes often require simplified language and interpretation. Visual media, such as pictures and graphs, are often critical for communicating difficult material. Outreach opportunities are valued because educating the public meets objectives of the project.

Personnel Requirements and Training

Project Roles and Responsibilities

The project manager is the lead ecologist for implementing the vegetation community monitoring protocol and is supervised by the terrestrial program leader for the HTLN program. Because of the need for a high level of consistency in implementing the protocol, the project manager will be responsible for training the seasonal and permanent personnel assisting with the monitoring efforts.

Field crews will consist of a minimum of two staff with botanical expertise. Ideally, a crew of four consisting of two botanists and two scribes would conduct plant community field monitoring. Additional staff for field crews can include qualified botanists and less technical scribes that may be botanists, interns, students, park staff, or other available field help. Scribes are responsible for making sure data are correctly and completely transcribed to datasheets, keeping the botanist on track within the plot, and communicating observations as requested.

Support staff for the project include the GIS specialist, data manager, and quantitative ecologist. Each play an important role in supporting field functions as well as data handling and security, analysis, and reporting.

Qualifications and Training

A competent, detail-oriented observer is essential for collecting credible, high-quality data in vegetation communities. Observer bias in the estimation of cover and misidentification of species will affect the ability to detect valid trends or changes in vegetation communities through time (Elzinga et al. 1998). Field observers must be proficient at accurately identifying plants and estimating plant cover. Observers should also have good organizational skills, memory retention, and an ability to work methodically and consistently under difficult conditions.

Training is essential for developing competent observers. Herbarium specimens and comparative notes on difficult or uncommon species should be provided for field observers. Observers should be tested frequently on their ability to identify plant species, tailoring the testing for the more problematic look-alike species. Time should also be invested in training personnel on cover estimation. Estimating cover is best taught at the start of the season in the field with all crew members present and then reviewed periodically throughout the summer to reduce within-year observer differences in cover estimation. Observers should familiarize themselves with the HTLN standard cover classes and vegetation guilds described in SOP 6 Measuring Ground Cover. Prior to the field season, observers should practice estimating cover of plant species and ground cover categories using practice plots. Differences in cover estimation between observers will strongly affect survey results. Refer to SOP 2 Training Observers to review techniques helpful in training observers in both plant identification and cover estimation.

Operational Requirements

Annual Workload and Field Schedule

Monitoring will require a crew of two botanists at a minimum. A crew of four is preferred so that each botanist is paired with a scribe and two transects can be read simultaneously. Field person-days will be dependent upon the parks sampled, logistics, weather, and crew skill level. For example, in 2008, 85 sites were sampled in five parks in 108 field person-days.

Facility and Equipment Needs

The nature of vegetation monitoring work does not require special facilities beyond normal office space and equipment and herbarium storage. A list of field equipment needs for one crew can be found in SOP 1 Preparations and Equipment Setup Prior to the Field Season. If two or more crews work simultaneously, equipment requirements will increase accordingly.

Budget Considerations

Approximately 2–10 days, including travel, are required to complete the sampling for each park. Personnel expenses for fieldwork are based on a preferred crew size of four people: ecologist, botanist, and two seasonal biological science technicians. Field costs will vary from year to year depending on the skill level, size of the crew, and parks to be sampled (number and distance from duty station; Tables 2 and 3). Data management personnel expenses include staff time of biological science technicians, project manager, and data manager. The project leader also invests time in preparation for field trips (2 or more days) and data evaluation and reporting. These steps can include a month or more of the project leader's time per report, not including peer reviewer's time. Additional shared support staff include the quantitative ecologist and geographic information systems specialist. Network vehicles are shared, and fuel/maintenance costs are incurred at the network level. Costs include the purchase of equipment and supplies listed in the SOPs, especially SOP 1 Preparations and Equipment Setup Prior to the Field Season, as well as maintenance and or replacement of equipment shared among multiple projects (e.g., GNSS units, cameras, vehicles).

Procedures for Revising the Protocol

Over time, revisions to the protocol narrative and to 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. Mitchell et.al. (2018) describe the types of documentation and review that are needed for modifying a protocol (SOP 17 Revising the Protocol).

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Appendix A. Woody Plant Categorization

Rationale

In the field, questions often arise as to whether a plant qualifies as a tree, which triggers overstory monitoring methods. When this has happened in the past, institutional knowledge of past monitoring history has been the authority. In order to provide a consistent, documented authority, we developed the following list of plants to be considered trees in terms of sampling protocols. We constructed the initial list as species in the HTLN parks listed as woody, tree, and/or shrub (with potential height of > 3 m) in the USDA Plants database (USDA, NRCS, 2018) and/or *Flora of Missouri* (Yatskievych 199, 2009, 2013). We refined the list based on monitoring history (maintaining as much consistency as possible to minimize data loss), a paper by Ladd and Thomas (2015), and other regional flora (Great Plains Flora Association and McGregor 1986; Kaul et al. 2011; Gentry et al. 2013; Chadde 2019; Yatskievych 1999, 2009, 2013).

Encountering one of the species designated as a tree in either prairie or woodland sites will trigger regeneration and overstory monitoring protocols (Table A1). For example, if *Carya tomentosa* is found in the prairie, it will be treated as either regeneration or overstory based on its height and DBH (SOP 7 Measuring Ground Flora, SOP 10 Measuring Midstory and Overstory Trees). This will be advantageous in the event that a prairie plot transitions to woodland. The protocol and data will remain stable and consistent despite the ecological transition. It will also remove any guesswork or confusion in the field regarding which SOPs to implement.

We have listed tree species that can cause confusion in the field along with a designation to aid in field monitoring in Table A1.

Field implementation

If any of the species in Table A1 are found in a plant community monitoring site, implement the prescribed data collection method. Midstory and overstory trees will be sampled according to SOP 10 Measuring Midstory and Overstory Trees, regeneration size trees will be sampled according to methods for *Regeneration* within SOP 7 Measuring Ground Flora, and shrub species will be sampled as per the remainder of SOP 7 Measuring Ground Flora. If questions arise, collect the data in both ways. The appropriate methods can be chosen prior to data entry.

Table A1. Woody species plant type categorization. This list includes the vast majority of species that have potential to cause confusion in the field. See SOP 7 Measuring Ground Flora and SOP 10 Measuring Midstory and Overstory Trees for methods for trees, tree regeneration, and shrub plant types.

Species Code	Species Name	Plant Type
ACNE2	*Acer negundo*	tree
ACRU	*Acer rubrum*	tree
ACSA2	*Acer saccharinum*	tree
ACSA3	*Acer saccharum*	tree
AEGL	*Aesculus glabra*	tree
ALNUS	*Alnus* spp.	tree
AMELA	*Amelanchier spp.*	tree
AMAR3	*Amelanchier arborea*	tree
AMLA	*Amelanchier laevis*	tree
ARSP2	*Aralia spinosa*	shrub
BETUL	*Betula* spp.	tree
BENI	*Betula nigra*	tree

Table A1 (continued). Woody species plant type categorization. This list includes the vast majority of species that have potential to cause confusion in the field. See SOP 7 Measuring Ground Flora and SOP 10 Measuring Midstory and Overstory Trees for methods for trees, tree regeneration, and shrub plant types.

Species Code	Species Name	Plant Type
BEPA	*Betula papyrifera*	tree
CACA18	*Carpinus caroliniana*	tree
CARYA	*Carya* spp.	tree
CAAL27	*Carya alba*	tree
CACO15	*Carya cordiformis*	tree
CAGL8	*Carya glabra*	tree
CAOV2	*Carya ovata*	tree
CATE9	*Carya texana*	tree
CAPUO	*Castanea pumila* var. *ozarkensis*	tree
CEOC	*Celtis occidentalis*	tree
CELTI	*Celtis* spp.	tree
CETE	*Celtis tenuifolia*	tree
CECA4	*Cercis canadensis*	tree
CORNU	*Cornus* spp.	shrub
COAL2	*Cornus alternifolia*	tree
CODR	*Cornus drummondii*	shrub
COFL2	*Cornus florida*	tree
COFO	*Cornus foemina* (ID likely drummondii)	shrub
CORA6	*Cornus racemosa*	shrub
CORU	*Cornus rugosa*	shrub
CRATA	*Crataegus* spp.	tree
DIVI5	*Diospyros virginiana*	tree
ELUM	*Elaeagnus umbellata*	shrub
EUAT3/EUAT5	*Euonymus atropurpureus*	shrub
FRCA13	*Frangula caroliniana*	tree
FRAXI	*Fraxinus* spp.	tree
FRAM2	*Fraxinus americana*	tree
FRNI	*Fraxinus nigra*	tree
FRPE	*Fraxinus pensylvanica*	tree
GLTR	*Gleditsia triacanthos*	tree
ILDE	*Ilex decidua*	tree
ILOP	*Ilex opaca*	tree
JUNI	*Juglans nigra*	tree
JUNIP	*Juniperus* spp.	tree
JUVI	*Juniperus virginiana*	tree
LIVU	*Ligustrum vulgare*	tree
LIBE3	*Lindera benzoin*	shrub
LIST2	*Liquidambar styraciflua*	tree
LITU	*Liriodendron tulipifera*	tree
MAPO	*Maclura pomifera*	tree

Table A1 (continued). Woody species plant type categorization. This list includes the vast majority of species that have potential to cause confusion in the field. See SOP 7 Measuring Ground Flora and SOP 10 Measuring Midstory and Overstory Trees for methods for trees, tree regeneration, and shrub plant types.

Species Code	Species Name	Plant Type
MALUS	*Malus* spp.	tree
MORUS	*Morus* spp.	tree
MOAL	*Morus alba*	tree
MORU	*Morus rubra*	tree
NYSY	*Nyssa sylvatica*	tree
OSVI	*Ostrya virginiana*	tree
PIEC2	*Pinus echinata*	tree
PIPO	*Pinus ponderosa*	tree
PIST	*Pinus strobus*	tree
PLOC	*Platanus occidentalis*	tree
POPUL	*Populus* spp.	tree
POGR4	*Populus grandidentata*	tree
POTR5	*Populus tremuloides*	tree
PRUNU	*Prunus* spp.	tree
PRAM	*Prunus americana*	shrub
PRHO	*Prunus hortulana*	tree
PRPU3	*Prunus pumila*	shrub
PRSE2	*Prunus serotina*	tree
PRVI	*Prunus virginiana*	shrub
PTTR	*Ptelea trifoliata*	tree
QUERC	*Quercus* spp.	tree
QUAL	*Quercus alba*	tree
QUCO2	*Quercus coccinea*	tree
QUEL	*Quercus ellipsoidalis*	tree
QUIM	*Quercus imbricaria*	tree
QUMA2	*Quercus macrocarpa*	tree
QUMA3	*Quercus marilandica*	tree
QUMU	*Quercus muehlenbergii*	tree
QUPA2	*Quercus palustris*	tree
QURU	*Quercus rubra*	tree
QUSH	*Quercus shumardii*	tree
QUST	*Quercus stellata*	tree
QUVE	*Quercus velutina*	tree
REDOAK	*Red oak group*	tree
RHAMN	*Rhamnus* spp.	shrub
RHCA3	*Rhamnus cathartica*	shrub
RHLA	*Rhamnus lanceolata*	shrub
RHCO	*Rhus copallinum*	shrub
RHGL	*Rhus glabra*	shrub
ROPS	*Robinia pseudoacacia*	tree

Table A1 (continued). Woody species plant type categorization. This list includes the vast majority of species that have potential to cause confusion in the field. See SOP 7 Measuring Ground Flora and SOP 10 Measuring Midstory and Overstory Trees for methods for trees, tree regeneration, and shrub plant types.

Species Code	Species Name	Plant Type
SANIC4	*Sambucus nigra* ssp. *canadensis*	shrub
SAAL5	*Sassafras albidum*	tree
SILAA4	*Sideroxylon lanuginosum* ssp. *albicans*	shrub
SILAL3	*Sideroxylon lanuginosum* ssp. *lanuginosum*	shrub
STTR	*Staphylea trifolia*	shrub
TIAM	*Tilia americana*	tree
ULMUS	*Ulmus* spp.	shrub at HOME and PIPE prairie; tree elsewhere
ULAL	*Ulmus alata*	tree
ULAM	*Ulmus americana*	tree
ULPU	*Ulmus pumila*	tree
ULRU	*Ulmus rubra*	tree
VIBUR	*Viburnum* (both)	shrub
VIDE	*Viburnum dentatum*	shrub
VILE	*Viburnum lentago*	shrub
VIPR	*Viburnum prunifolium*	shrub
VIRU	*Viburnum rufidulum*	shrub
WHTOAK	White oak group	tree
ZAAM	*Zanthoxylum americanum*	shrub

To fully implement Table A1, some observations have been or will be converted to the appropriate data type. Table A2 documents these decisions and actions. The VegMon database will be updated as the appropriate conversion factors are developed. To create the conversion factor, it is helpful to measure the species using a cover class and stem counts or DBH. Doing so over multiple size classes will inform changes to past observations, archived data prior to adjusting species to the corrected data classification. Sites are occasionally retired and these sites will not be included in recommended data conversions. Furthermore, preliminary data collected prior to the stabilization of the protocol will not be converted.

Data Conversion Procedure

We will not be able to exactly recreate the abundance of a species in a method that differs from how the original data were collected because of the challenge of knowing how a stem count or DBH will convert to a cover class or vice versa. However, the increased data consistency that results from converting data from one collection method to another will increase the value of and confidence in the dataset as a whole. This conversion procedure starts with a plant species being sampled using both herbaceous and regeneration procedures to provide samples of data that can be used as background for data conversion. This could take up to four years (one sampling cycle) to complete because we may need to visit parks where a species is unique to that park or where identifications need local confirmation. A conversion matrix was developed where estimation was reasonable (Table A3).

This sampling could be done in a single park if enough samples of the target species are available. Past data collection can be used to identify locations where observations are needed to inform the data conversion process. Several observations with differing levels of abundance will likely be necessary to create a conversion matrix. A range of stem counts will be needed to develop a regeneration conversion to cover class. To convert cover classes to regeneration stem counts, the upper range of number of stems for a class will be used.

Table A2. Completed and recommended changes to data related to tree and shrub species. Herbacious refers to ground flora. See Table A1 for methodological recommendation for each species.

Code	*Species Name*	**Correction**
CODR	*Cornus drummondii*	Converted 3 LIBO regeneration records to herbaceous (cover = 1).
COFO	*Cornus foemina* (ID likely drummondii)	Changed ID to CODR and removed from lookup table.
CORA6	*Cornus racemose*	Converted 5 regeneration records to herbaceous.
CORU	*Cornus rugose*	Converted regeneration records from 2017 to herbaceous.
EUAT3/EUAT5	*Euonymus atropurpureus*	Converted 7 WICR regeneration records to herbaceous
FRAM	*Fraxinus americana*	Converted 2 records to regeneration.
FRPE	*Fraxinus pensylvanica*	Converted 1 PIPE record to regeneration.
GLTR	*Gleditsia triacanthos*	Converted 16 herbaceous records to regeneration records.
ILDE	*Ilex decidua*	Check ID at HOSP in 2024. Converted 1 herbaceous record to regeneration.
ILOP	*Ilex opaca*	Check ID at HOSP in 2024. Converted 1 herbaceous record to regeneration.
LIBE3	*Lindera benzoin*	Converted 8 of 19 regeneration PERI records to herbaceous.
MAPO	*Maclura pomifera*	Deleted 1 herbaceous record.
MOAL	*Morus alba*	Converted 18 herbaceous records to regeneration. Develop conversion for 5 more herbaceous records to regeneration.
MORU	*Morus rubra*	Converted 1 herbaceous record to regeneration.
PRUNU	*Prunus* sp.	Work through each park as it comes up in rotation. These are most likely shrub, but validate trees at future visits. Develop conversion or positive identification.
PRAM	*Prunus americana*	Converted 25 regeneration records to herbaceous.
PRHO	*Prunus hortulana*	Converted 15 herbaceous records to regeneration.
PRSE2	*Prunus serotina*	Convertedt 1 herbaceous record to regeneration. GWCA 2016, site 3.
PRVI	*Prunus virginiana*	Converted regeneration to herbaceous. During future monitoring events, validate overstory observations (HEHO, EFMO)
RHCA3	*Rhamnus cathartica*	Converted 3 regeneration records from EFMO to herbaceous.
RHLA	*Rhamnus lanceolata*	1 regeneration record converted to herbaceous from 2017 remains.
SILAA4	*Sideroxylon lanuginosum* ssp. *albicans*	Converted regeneration data to herbaceous except record 5779 (need a conversion).
SILAL3	*Sideroxylon lanuginosum* ssp. *lanuginosum*	Changed ID to ssp. albicans (11 records overstory) and deleted species from lookup table.
STTR	*Staphylea trifolia*	Converted 3 LIBO regeneration records to herbaceous. One record requires field work to convert.
ULMUS	*Ulmus* spp.	GWCA records from 2012, 2016 develop conversion from herbaceous records to regeneration. EFMO: converted 2 regeneration records to herbaceous, TAPR: converted 1 herbaceous record to regen. HOME prairie and PIPE: will remain herbaceous.
ULPU	*Ulmus pumila*	Converted 5 records from herbaceous to regeneration.
ULRU	*Ulmus rubra*	Changed herbaceous to *Ulmus* spp. Keep the HOME and PIPE *Ulmus* spp. as herbaceous.
VIPR	*Viburnum prunifolium*	Converted 2 WICR records to herbaceous.
VIRU	*Viburnum rufidulum*	Converted 22 regeneration records to herbaceous records. For 7 overstory records, convert to herbaceous during future monitoring events. Validate species at HOSP.

Table A3. Matrix used to convert herbaceous cover and regeneration count data.

Seedlings	Small Saplings	Large Saplings	Cover Class
1	0	0	1
2	0	0	1
3	0	0	2
4	0	0	2
3	1	0	3
0	2	0	3
0	1	0	2
0	0	1	3
6	2	0	3
8	0	0	3

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