



Vegetation Monitoring Protocol

Great Lakes Inventory & Monitoring Network

Natural Resource Report NPS/GLKN/NRR—2008/056



ON THE COVER

Black oak savanna at Miller Woods, Indiana Dunes National Lakeshore
Photograph by: Sam Smyrk

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Natural Resource Report NPS/GLKN/NRR—2008/056

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Background and Objectives

Rationale for Monitoring Vegetation Communities

Terrestrial vegetation was ranked third among all 46 Vital Signs evaluated by the National Park Service (NPS) Great Lakes Network for incorporation into a long-term monitoring strategy. Terrestrial vegetation serves as an integrated measure of terrestrial ecosystem health by expressing information about climate, soils, and disturbance (Randerson et al. 2002), as well as browse (Côte et al. 2004), and exotic species invasion (Ojima et al. 1991). Further, terrestrial vegetation serves as a trophic base for other ecosystem components (Fortin et al. 2005). Because of this interwoven relationship between terrestrial vegetation and both biotic and abiotic components, we have developed a comprehensive protocol that incorporates the Network's monitoring plans for terrestrial vegetation as well as those of related Vital Signs, including terrestrial pests and pathogens, problem species, succession, and soils. Because forests predominate the landscape in the Great Lakes Network national parks, this protocol will focus exclusively on forested vegetation. Protocols for non-forested terrestrial vegetation may be developed by the Network in the future, as time and funding allow (Route and Elias 2006).

Network Parks and Ecosystems

The nine park units of the Great Lakes Inventory & Monitoring Network (GLKN) extend from the boreal forests of northern Minnesota to the sand dunes of southern Lake Michigan (Figure 1) and represent the major freshwater ecosystems of the Upper Midwest.



Figure 1. Nine National Park units of the Great Lakes Inventory & Monitoring Network.

Apostle Islands National Lakeshore (APIS) is located near Bayfield in extreme northwestern Wisconsin. It consists of 21 islands, ranging in size from 1 to 4,000 hectares, and a 19-kilometer segment along the mainland shore of Lake Superior. The lakeshore is at the northwestern limits of the hemlock-white pine and northern hardwood forest and also contains elements of the

southern boreal forest. The lakeshore has a wide variety of landscapes such as barrier spits, cusped forelands, beaches, and dunes that provide unique habitats for plants and wildlife. In addition, 13,560 hectares of the park have been designated as wilderness.

Grand Portage National Monument (GRPO) is located 56 kilometers northeast of Grand Marais, Minnesota in the extreme northeastern ‘arrowhead’ region of the state near the Canadian border. The monument protects 287 hectares of land including the historic trading post of the North West Company on Lake Superior, the site of Fort Charlotte on the Pigeon River, and a 13.7 kilometer historic canoe portage trail that connects the two sites. The portage trail crosses several riparian areas and over the Grand Portage Highlands with an 240-meter rise in elevation. The area is covered by a near-boreal forest, with birch-aspen-spruce-fir communities dominating most sites. The Grand Portage trail corridor bisects the Grand Portage Band of Minnesota Chippewa Reservation. Surrounding land use greatly influences resource management at GRPO. Forestry practices on Reservation lands are carefully integrated with wildlife management objectives, and large areas are set aside to preserve the near wilderness character of the region.

Indiana Dunes National Lakeshore (INDU) runs about 40 kilometers along southern Lake Michigan and includes 6,070 hectares. Biological diversity is one of the most significant features of the lakeshore and a primary reason for its establishment. This diversity is greater than most areas of similar size because Indiana Dunes is in several ecological transition zones, including where northern conifer forests meet the temperate hardwood forests and tallgrass prairies of the Midwest. Diverse habitat types include: beaches, bogs, prairies, black oak savannas, forests, wetlands, and marshes. The lakeshore is comprised of unconsolidated soils on which landforms range from open beach and active dunes to stabilized and extensively vegetated older dunes and moraines. Some dunes, like Mount Baldy, rise to heights of over 30 meters above the shoreline.

Isle Royale National Park (ISRO) is a remote island archipelago in northwestern Lake Superior. It consists of one large island that is 45 miles long and nine miles wide surrounded by about 400 small islands. The park protects 231,395 hectares of area extending up to 7.2 kilometers into Lake Superior from the outer islands. Of this total area, 53,426 hectares have been designated as wilderness. There are many inland lakes, ponds, and streams. The island is densely forested with northern boreal spruce-fir forest near the cool, moist shoreline of Lake Superior, and northern hardwoods in the warmer, drier interior.

Mississippi National River and Recreation Area (MISS) includes 116 kilometers of the Mississippi River and six kilometers of the Minnesota River and encompasses about 21,800 hectares of public and private land and water. Less than 20 hectares of land, all on islands within the river, are actually owned and under regulatory authority of the NPS. This section of river, some of which flows through metropolitan St. Paul and Minneapolis, is a major transportation corridor and yet a place for recreation and quiet in the midst of an urban environment. Numerous private, state, county, and other federal landowners make management of access, resource use, and development complex. The rivers themselves, and the riparian zones along the shorelines and islands, are the primary biotic communities of interest.

Pictured Rocks National Lakeshore (PIRO) protects 28,893 hectares of land including 67 kilometers of Lake Superior shoreline. The park is located along the south-central shore of Lake

Superior within a transition zone between the boreal and eastern deciduous forest biomes. Hardwood forests are prevalent, but conifers dominate some sites. Wetlands are common throughout the park. The cold, moist climate along the lakeshore greatly influences the biotic communities. The park is divided into two distinct ownership and management zones; the federally owned shoreline zone, and a non-federal buffer zone. Sustained yield timber harvesting and other consumptive uses are allowed in the buffer zone; however, these uses were intended by Congress to be subordinate to public recreation and the protection of “the usefulness and attractiveness of the lakeshore.”

The St. Croix National Scenic Riverway (SACN) protects 37,529 hectares including 405 kilometers of the St. Croix and Namekagon Rivers in eastern Minnesota and northwest Wisconsin. The park spans three major biomes: boreal forest, eastern deciduous forest, and oak and pine savanna. The rivers themselves, and the riparian zones along them, greatly influence the biotic communities. Wetlands are common throughout the park. The park is divided into two distinct management zones: the upper St. Croix and Namekagon Rivers, and the lower St. Croix River. Numerous private, state, county, and other federal landowners along the corridor make management of access and resource use complex.

Sleeping Bear Dunes National Lakeshore (SLBE) protects 28,813 hectares of land and water along the northeastern shore of Lake Michigan. The lakeshore includes two large islands in Lake Michigan: North and South Manitou. There are 105 miles of Lake Michigan shoreline, 26 inland lakes, and four streams. The interior forested areas are dominated by American beech and several species of maple.

Voyageurs National Park (VOYA) is located approximately 300 miles north of Minneapolis, Minnesota in the forested lake region along the Minnesota-Ontario border. Voyageurs comprises 88,243 hectares, of which approximately 33,908 hectares (38%) are covered by lakes and ponds. Two large reservoirs, with hundreds of islands, form much of the lake area, but there are 26 smaller lakes and hundreds of beaver ponds and drainage systems. The interior of the park is typical southern boreal spruce/fir forest, but deciduous trees dominate some areas.

Current Threats to Vegetation in NPS Units

The forests of the Great Lakes Network parks are threatened by a number of direct and indirect stressors. Direct stressors include several insect pests that are now present at the eastern Network parks and are spreading westward. These include the beech scale insect (*Cryptococcus fagisuga*, causal agent of beech bark disease) which was first discovered in Nova Scotia in 1911 (Houston 1994) and is now present on beech trees in PIRO and in the counties immediately adjacent to SLBE and INDU. While there is some literature suggesting how the beech resource will respond to this threat, little is known about vegetation response following its decline, especially in network parks located at the northwestern edge of the beech range. Another insect pest, emerald ash borer was first reported near the Detroit, Michigan area in 2002 (Muirhead et al. 2006) and has been confirmed in the counties adjacent to both INDU and SLBE (Purdue University Extension, 2006). The anticipated degree of ash decline is unclear, nor is it known how the surrounding vegetation will respond following this decline.

Earthworms are another group of exotic pests adversely impacting the forests of the upper Midwest. Earthworms are believed to have been absent from areas directly affected by the Pleistocene glaciation, an expanse that includes all Network parks (Hendrix and Bohlen 2002). Although natural earthworm dispersion is relatively slow, on the order of 5 – 10 meters per year (Hale et al. 2005, Dymond et al. 1997, Marinissen and Van den Bosch 1992), the introduction of earthworms from recreational fishing greatly augments their spread into previously worm-free areas (Bohlen et al. 2004). Exotic European earthworms, which have been reported in multiple Great Lakes Network parks, rapidly change soil properties resulting in an increased thickness of the A soil horizon and a corresponding decrease in the organic horizon (Gundale 2005). Earthworm invasion impacts the plant community by removing the forest floor duff layer (Hale 2004) and by reducing regeneration (Kostel-Hughes 1995).

In addition to exotic species, changes in management and land use have led to uncharacteristic expansion of a few native taxa, such that they have become problem species. The most notable example of this is the irruption of the native white-tailed deer population. Browsing pressure by deer has reduced the abundance of certain native plant species (e.g., Canada yew (*Taxus canadensis*) (Allison 1990a, 1990b, 1992), eastern hemlock (*Tsuga canadensis*) (Mladenoff and Stearns 1993, Rooney et al. 2000), and many broad-leaved forest wildflower species to a fraction of their previous abundance (Rooney 2001, Russell 2001). Further, overbrowsing by deer is driving change at the community level by promoting the biotic homogenization of Great Lakes forests (Rooney et al. 2004). For these reasons, white-tailed deer is the major problem vertebrate threatening the health of Great Lakes forests.

While direct stressors impart obvious identifiable change to forest structure, indirect stressors can be equally detrimental. This is especially true because the change occurs in a subtle manner over time and causal agents are often not easily identifiable so that reversing this trend is difficult. Regionally, shifts in overstory composition from pine (*Pinus strobus* and *P. resinosa*) to balsam fir (*Abies balsamea*) have been documented (Frelich and Reich 1995, MacLean and Gucciardo 2005) and are likely due, only in part, to altered fire regimes. Further, long-term decline of sugar maple (*Acer saccharum*) (Auclair 2005), white oak (*Quercus alba*) (Abrams 2003), and hemlock (Kizlinski 2002) also pose problems to the health of Great Lakes Network Parks. In these instances, multiple causal agents are believed to contribute to the decline.

Routine monitoring of forest health will provide an understanding of natural variability of vegetation in ‘benchmark’ areas where direct human disturbance (e.g., logging, development) no longer occurs. In addition, monitoring will provide an early warning of undesirable trends in vegetation, allow adaptive management of forest ecosystems, and allow for inferences about the effects of the above threats on both terrestrial vegetation and overall forest health

Overview of Vegetation Monitoring at the Great Lakes Network Parks

This protocol is intended to detail a comprehensive monitoring program with consistent methods across all nine Network parks. Prior terrestrial vegetation monitoring efforts have been undertaken at five of the Network parks, although the duration, extent, and scientific credibility have varied immensely among these efforts.

Permanent forest monitoring plots were established in 1997 on four islands at the Apostle Islands National Lakeshore (Meeker 2000). On Outer Island, plots were placed in four areas: 1) an old growth mature hemlock-hardwood stand, 2) an area adjacent to the old growth that was cut in the 1960s, 3) an area cut in the 1940s but not burned, and 4) an area cut in the 1930s and burned. Other plots were established on the smaller islands with more boreal habitat. They include areas recently cut (York, cut in the early 1970s) and less disturbed forests on Devils and Raspberry Islands. Although these sites have been permanently marked, regular monitoring has not occurred since initial assessments in 1997-1998. In addition to Meeker's work, Beals and Cottam established 76 vegetation survey plots on the islands from 1955 – 1958 (Beals and Cottam 1960). While these were not intended to be long-term monitoring points, 28 of these plots were revisited in 2005 to assess 50-year vegetation changes (Mudrak et al. *in review*).

At Grand Portage National Monument, a system of permanent vegetation plots was established in 1986 to compare changes over time between interior forests and forests adjacent to clear cuts. Metrics for this study were remeasured in 1992, 1999, and 2004 and an analysis of these data was published in 2005 (MacLean and Gucciardo, 2005). On all plots, abundance and basal area of balsam fir (*Abies balsamea* (L.) P. Mill.) increased, while that of paper birch (*Betula papyrifera* Marsh.) and quaking aspen (*Populus tremuloides* Michx.) declined. The observed pattern is likely due in part, to succession, although a reduction of fire is also a primary cause. Unfortunately, only two plots were placed in each treatment and the majority of statistics were descriptive (e.g., means, percent change).

Indiana Dunes National Lakeshore is one of the most botanically diverse national parks, located at the juncture of prairie, lake, and forest biomes. Approximately 30% of Indiana's state listed rare plant species occur within the park boundaries (Gucciardo et al., 2004). Not surprisingly, much of the monitoring at the park has focused on rare plant species, rather than forest vegetation.

Isle Royale National Park has the longest history of vegetation monitoring of any of the Network parks. In 1963, Peter Jordan of the University of Minnesota established plots to monitor the impact of moose on vegetation. These plots are arranged linearly into clusters that are oriented along a north – south (180 - 360°) axis (for those clusters established prior to 1980) or oriented along a 160 - 340° axis (for those clusters established in 1980). Data collected include tree species, diameter at breast height (DBH), and percent cover for multiple forest layers. The Great Lakes I&M Network is currently working with Dr. Jordan toward publication of multiple manuscripts associated with this project.

At Pictured Rocks National Lakeshore, 146 permanent plots were established over the five year period from 2000 – 2004. The plots were established using the plot layout of the Forest Service's Forest Inventory and Analysis (FIA) program (Berchtold and Scott 2005), and metrics included all of those in the FIA Phase II program, as well as select indices of vegetation and down woody materials that are part of the Phase III program. Metrics on twenty of these plots were remeasured in 2005 and a report on short term change will be completed by 2008.

The questions addressed by these studies vary, although none have focused on quantifying forest change in response to long-term environmental change. Further, these studies were limited in

scope with no attempt to integrate the results with other ecosystem attributes such as soils, insects, or mammals. Doing so will allow us to show associations between vegetation and associated attributes. Collectively, a network-wide monitoring system with clear, inferable objectives can answer questions about shifts in forest characteristics in response to increasing environmental pressures, as well as provide an assessment of overall forest health.

Measurable Objectives

The goals of this monitoring program are to detect forest change and to draw inferences about forest health, so that management recommendations can be provided to the parks. To accomplish this, the monitoring objectives are grouped into two tiers. The primary objective is to detect change directly in forest attributes. The specific questions that address this objective follow:

- 1) What is the rate and direction of change of key species? We will measure species abundance (frequency) and size (basal area) and test for change between and among sample periods. This will allow us to determine whether metrics of individual species are increasing, in decline, or remaining constant.
- 2) What is the rate and direction of change of plant community structure? We will examine the size distributions of all trees, as well as individual species to identify shifts in forest structure. This will help us understand both regeneration and succession. It will also allow us to infer potential drivers of change and, thus, potential threats to the biotic integrity of the Great Lakes Parks.
- 3) What is the rate and direction of change of plant community composition? We will measure species richness and diversity and test for change in these variables. We will also test whether biotic homogenization (Olden and Rooney 2006) is occurring within given parks.

The secondary monitoring objective is to test for change in Vital Signs and other indicators associated with vegetation. We will then attempt to relate these changes to long-term vegetation change. These indicators and specific questions are outlined below:

Terrestrial Pests and Pathogens

- Which targeted pests and pathogens are present on trees in terrestrial vegetation monitoring plots? We will search for selected pests and pathogens on trees that are included in the vegetation monitoring plots.
- Within given habitat types, what are the pest and pathogen species collectively present?
- To what extent are pests and pathogens damaging trees? We will calculate the percentage of trees are infested, and note the severity of damage on the infested part(s).

For complete methods and analyses for monitoring terrestrial pests and pathogens, please see standard operating procedure (SOP) 8.

Problem Species

- To what degree is ungulate browse evident on terrestrial vegetation? We will measure percent browse on key plant species within the vegetation plots and relate this to changes in plant species, communities, and community structure. We also will assess indirect impacts of ungulates using size metrics of herbaceous indicator species (see Ungulate Impact Monitoring SOP 9).

For complete methods and analyses for monitoring ungulate impacts, please see SOP 9.

Succession

- Are Great Lakes Network forests exhibiting expected successional trajectories? We will use information on plant community structure change and place this into context with what is known about successional trajectories. Community change will then allow us to make inferences about the successional state of forests of Great Lakes Network national parks.

For complete methods and analyses for monitoring successional change, please see SOP 10.

Coarse woody materials

- What is the volume (m^3/ha) in specific habitat types?
- What is the magnitude and direction of change in volume in each habitat between two, and among many sampling events? For complete methods and analyses for monitoring down, woody, materials, please see SOP 11.

Overall Sampling Design

Rationale for Selecting this Sampling Design over Others

Sampling sites have been selected using a generalized random-tessellation stratified (GRTS) design (Stevens and Olsen 2004). The reasons for selecting the GRTS design were twofold. First, resulting sample points are spatially balanced, whereby there is a generally even dispersion of sampling sites over the area of interest. This eliminates potential autocorrelation problems that can arise when two or more sampling points are in close proximity (Stevens and Olsen 2000), while also ensuring that all areas within the sampling frame are represented. In addition, the GRTS design allows for sites to be added to or excluded from the original sampling plan, while still maintaining the spatial balance of the overall design. This is important because it is difficult to gauge exactly how many plots can be sampled within a given time period. The second asset of the GRTS method is that it is a probabilistic sampling design, whereby sampling points are randomly chosen from among those in a systematic grid, eliminating site selection bias (Stevens and Olsen 2000). One drawback with any random design is that it does not guarantee that plots will be located in areas of key management significance. This is addressed below.

In addition to a GRTS based design, we also considered using an intensified version of the Forest Service Forest Inventory and Analysis (FIA) hexagon based sampling design. Forest Inventory and Analysis is a national program with plots placed in forested areas throughout the country. Plots were randomly located within 2,403 ha hexagonal shaped grid cells; this resulted in anywhere from one to 19 plots per park, depending on the size of the park. To increase the sampling effort per park for this protocol, we considered intensifying the effort by reducing the size of the grid cells. Two problems emerged, however, when we tried to apply the large-scale effort to the Network parks. First, the grid cell size and, hence, the number of plots, would be defined prior to sampling and based on the anticipated number of plots that can be sampled. In reality, technical problems can result that can significantly reduce the number of plots sampled in a given park. Alternatively, sampling in some regions can also go better than planned, such that there is time for sampling more plots than was planned. The structured nature of the FIA grid system does not allow for the addition or exclusion of plots while still maintaining the spatial balance. A second drawback with using the hexagonal grid system is that the fragmented nature and irregular shapes of the parks result in numerous grid cells that span park borders, such that these grid cells are only partially occupied by NPS land. There is general disagreement about methods to include or exclude plots that are located within these border cells (Andrew Lister, U.S. Forest Service, personal communication).

Sampling Frame, Plot Design, and Metrics

The sampling frame for this protocol typically includes all federally owned, forested lands within the Network parks. Here, sampling points will be selected from the entire spatial extent of forested areas of these parks. Two exceptions to this will be at Apostle Islands and Isle Royale. At the Apostle Islands, transportation to and between islands will be time prohibitive. In this case, we have selected a subset of seven islands plus the mainland that represent a gradient of the key ecological drivers of the park (deer browse, distance to mainland, exotic invasion, wind, temperature, human disturbance). At Isle Royale, sample sites will be placed on the main island, and not on the nearly 400 peripheral islands, due to transportation limitations. In addition to federally owned land, the sampling frame contains state and county owned land at the

Mississippi National River and Recreation Area. At this park, federally owned land represents only approximately 1% of the acreage, so we included all forested land there within the sampling frame. Please see Table 1 for specific details of individual park sampling frames.

This protocol details our plans to monitor forested vegetation. We have adopted the guidelines similar to those of the FIA program to define what constitutes a “forest,” whereby there is a 10% minimum stocking requirement of tree species. The 10% requirement denotes that the site can either have 10% canopy cover at the time of sampling, or will likely return to that percentage in the future. As such, areas recovering from a blowdown will be included, as will previously managed grasslands now returning to the forested state. Tree species are defined *a priori*, and include, for example, some ‘shrubby’ species such as striped maple (*Acer pensylvanicum* L.) and paw paw (*Asimina triloba* [L.] Dunal), but not others such as speckled alder (*Alnus incana* [L.] Moench ssp. *rugosa* [Du Roi]). Based on these guidelines, habitats such as oak savannas and tamarack bogs will be included, while alder swamps will not.

Sample sites will be selected using the GRTS method described above. While this approach uses spatial stratification to ensure that sample sites are equally distributed within the sampling frame, we will not stratify on any predefined landscape characteristic or qualifiable metric, such as vegetation type. The successional nature of vegetation, coupled with the fact that much of the forested areas in the Network are recovering from logging activity that had occurred prior to establishment of the parks, precludes the use of stratification. Stratifying on a dynamic variable, such as vegetation, will ultimately result in misclassification of sites and consequent analytical error (Elzinga et al. 2001). Further, a stratified sampling design will prevent inferences about those vegetation types not sampled (Debacker and Morrison 2005). One drawback that results from failing to stratify by vegetation type is that there is no guarantee of rare habitats or areas of key management significance being included in the sampling scheme. To address this, we will designate up to 10 percent of the sampling sites at a given park as ‘index’ sites, chosen by the park natural resource manager. These sites are not part of the overall sampling design, but rather are intended to address park concerns related to specific management issues. For example, managers at Voyageurs National Park are interested in plots placed in the area burned by the Shoepack Lake fire in 2004. To avoid disrupting the spatial balance of the park sampling scheme, analysis of data from index sites will be independent of the analysis of data from the randomly chosen sites in most instances, although combined for some purposes as determined appropriate. The design of the index sites will vary depending on the park, the number of sites, and the management problem addressed.

Table 1. Sampling frame for each of the nine GLKN parks. Within these defined frames, sampling will also be restricted to forested areas.

Park	Sampling Frame
Apostle Islands NL	Mainland along with Sand, York, Raspberry, Oak, Stockton, and Devils Islands. These areas represent a gradient in the severity of ecosystem drivers.
Grand Portage NM	Entire park
Indiana Dunes NL	Entire park
Isle Royale NP	Limited to mainland
Mississippi River NRR	Entire park
Pictures Rocks NL	Entire park, including federally owned land within the inland buffer zone
Saint Croix NSR	All land within park boundaries owned by the National Park Service. This equals 61% of the designated riverway.
Sleeping Bear Dunes NL	All federally owned land
Voyageurs NP	Entire park

Parks within the Great Lakes Network will use one of two monitoring plot designs. Although our preference is to use the same plot type at all Network parks, legacy vegetation data at certain parks, along with a familiarity and preference by park managers with one of the plot types, has ultimately resulted in two plot types chosen for monitoring. Although the plot designs will differ, data collection methods and metrics will be identical for the two types. This will validate analyses incorporating both plot types, provided appropriate statistical steps are first taken (see SOP 13, Comparisons and Tests with Multiple Plot Types).

The first of the two plot designs chosen for the Great Lakes I&M Network's long-term vegetation monitoring protocol is derived from that of the FIA program (hereafter referred to as the "FIA plot"); this will facilitate integration of analyses across a regional scale. We will be collecting most of the suite of FIA Phase 2 data (see below; U.S. Department of Agriculture 2005) as well as data on selected Phase 3 indicators (pests and pathogens, coarse woody materials). In addition, we will augment the plots by adding additional sampling for some metrics (see Great Lakes I&M Network long-term vegetation monitoring plot, below).

The standard FIA Phase 2/3 plot, without augmentation, is composed of four 7.32 m (24.0 ft) radius subplots (Figure 2a) in which the species, diameter at breast height (DBH), and height of all trees ≥ 12.7 cm (5 in) DBH are recorded. Within each subplot (Figure 2b) are transects at 30°, 150°, and 270°; along each of these transects, at 4.57 m from subplot center, a 1.0 m² quadrat is placed, from which understory data are recorded. Finally, sapling data (DBH, height, species, etc.) are collected in a 2.07 m (6.8 ft) radius microplot east of the subplot center. For a complete list of FIA Phase 2 and 3 metrics and indicators, please refer to the FIA National Core Field Guide (U.S. Department of Agriculture 2005) and the Forest Service Phase 3 indicator fact sheets available at <http://fia.fs.fed.us/program-features/indicators/>.

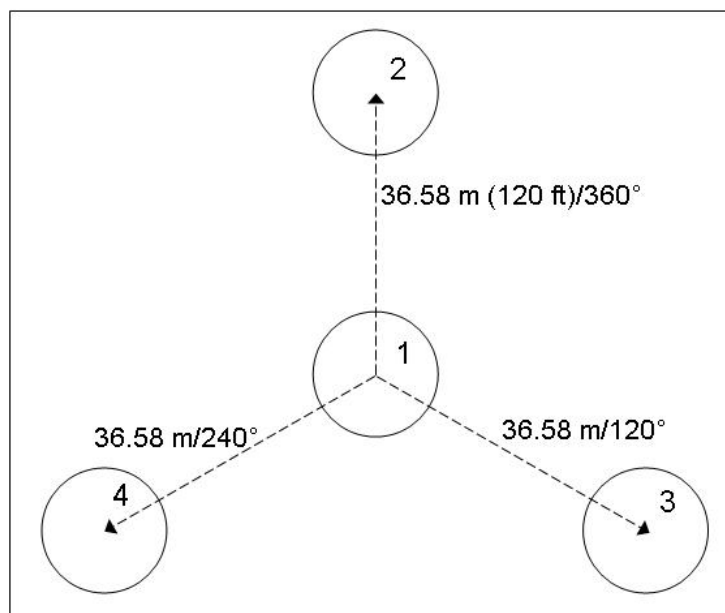


Figure 2a. FIA Phase 2/3 plot layout. Each plot is composed of four 7.32 m subplots; three of these are spaced 36.58 m (120 ft) from a central subplot at azimuths of 120°, 240°, and 360°.

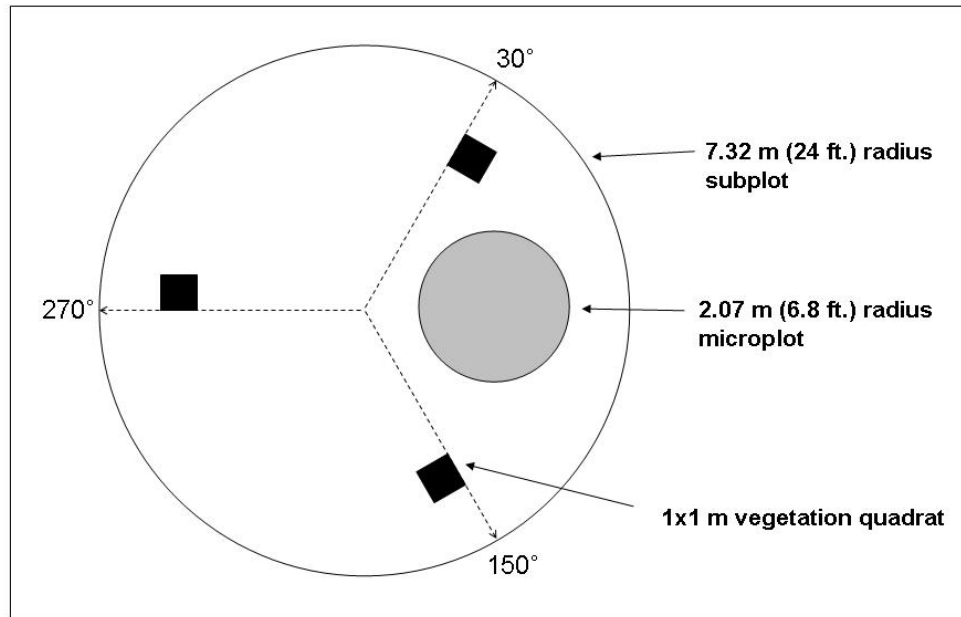


Figure 2b. Standard FIA Phase 2/3 subplot diagram. For all trees ≥ 12.7 cm (5 in.) DBH that are located within each 7.32 m (24 ft.) radius subplot, the species, DBH, and height are recorded. For additional metrics recorded within the FIA Phase 2/3 subplot, please see the text.

While it is important that the plot chosen by the Great Lakes I&M Network allow integration with the FIA program, the missions of the two programs differ. The plot layout of the FIA program was originally designed to answer questions about timber volume (McRoberts 2005); as such, data collection is skewed heavily toward overstory indices. In contrast, one of the primary goals of the Inventory & Monitoring Program is to detect forest change in response to environmental change. Because turnover occurs more frequently in the herbaceous and sapling layers, we will intensify data collection on indices in these layers where significant change can be detected in only a few years.

The Great Lakes I&M Network long-term vegetation monitoring methods will include collecting data on all of the metrics outlined above, and also the following additions. Six 1 m^2 quadrats will be added to each subplot bringing the total to nine for each subplot (Figure 3) and 36 for each plot. These will be placed on transects radiating outward from the subplot center; to avoid spatial autocorrelation problems, quadrats on the same transect will be 5.0 meters apart (Johnson et al. 2006). We will also supplement data collection at these quadrats by recording information on seedlings, in addition to herbs and shrubs. In addition to collection of quadrat data, we will also conduct walkthroughs of each 7.32 m radius subplots to note any additional species that are present that have not been recorded elsewhere. Not all quadrats fall within the subplot boundaries; hence, this will need to be taken into consideration when assessing quadrat-subplot correlations in species richness. Further, saplings will be measured on the entire subplot, rather than the smaller microplot, as is done in the FIA methods. This increased sampling effort at the herbaceous and sapling level is expected to facilitate detection of species (Johnson et al. 2006). Additionally, intensifying data collection of saplings will provide more detail about forest change. For a complete list of all indices of this protocol for which data are collected, please see the associated Standard Operating Procedures (SOPs), including SOP 6 – Field Methods and

Data Collection, SOP 8 – Pest and Pathogen Assessment, SOP 9 – Succession, and SOP 10 – Coarse Woody Materials.

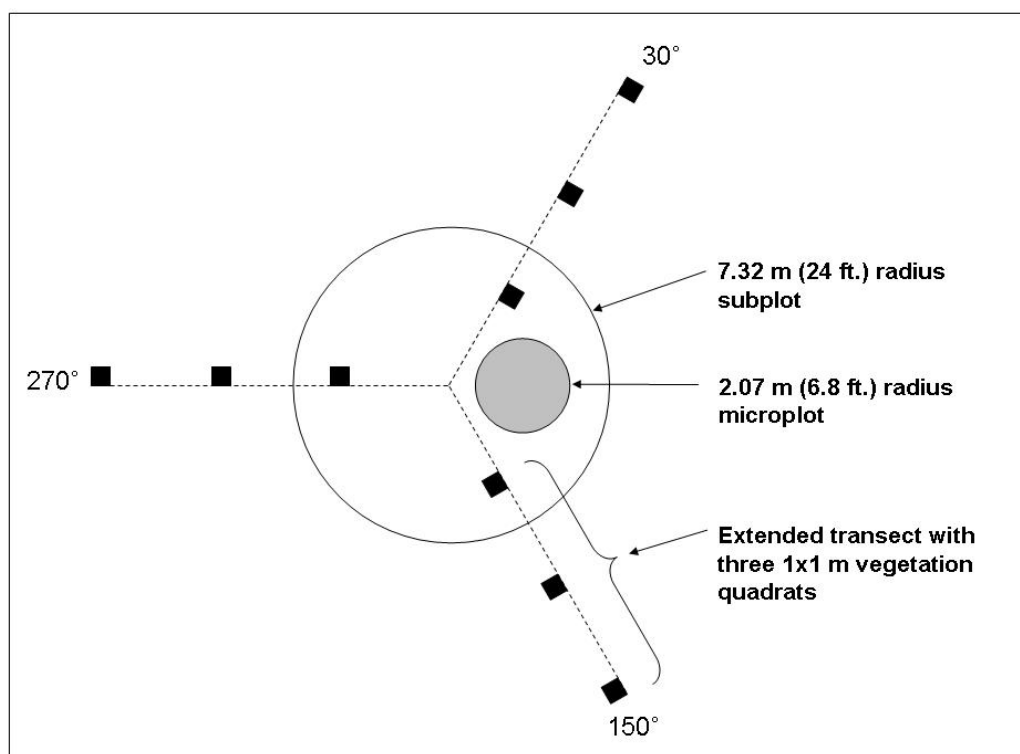


Figure 3. GLKN subplot, modified from the standard FIA Phase 2/3 subplot. The three transects on the GLKN subplot have been extended to include two extra quadrats, for a total of 36 quadrats spaced 5-m apart.

The second of the two plot designs chosen for the Great Lakes I&M Network’s long-term vegetation monitoring protocol was developed specifically for our monitoring effort and combines features from two established plots: the FIA plot described above, the Plant Ecology Lab (PEL) plot developed by John Curtis and used extensively in the upper Midwest throughout the 1950s and 60s. Consequently, this second plot design has been designated the “hybrid plot” (Johnson et al. 2006).

The hybrid plot consists of three parallel 50 m east-west transects, spaced 50 meters apart (Figure 4). The species and DBH of all trees ≥ 2.5 cm DBH will be recorded in a 6 m wide belt around each transect (3 m on either side of center line). Because we are using 2.5 cm as the lower DBH limit, we are thus including “trees” (≥ 12.7 cm (5 in) DBH in FIA standards) *and* “saplings” (≥ 2.5 cm (1 in) and < 12.7 cm DBH (5 in)) within this area. Shrubs will be measured in each of six 2.82 m radius shrub circles, centered at the endpoints of each transect. We record the species present and an estimate of percentage of cover for each of these species. The groundlayer will be assessed in 1×1 m quadrats spaced every 5 meters along each of the transects for a total of 30 quadrats in each plot. As in the FIA style plot, above, we will record all herbaceous species present, shrubs, and tree seedlings.

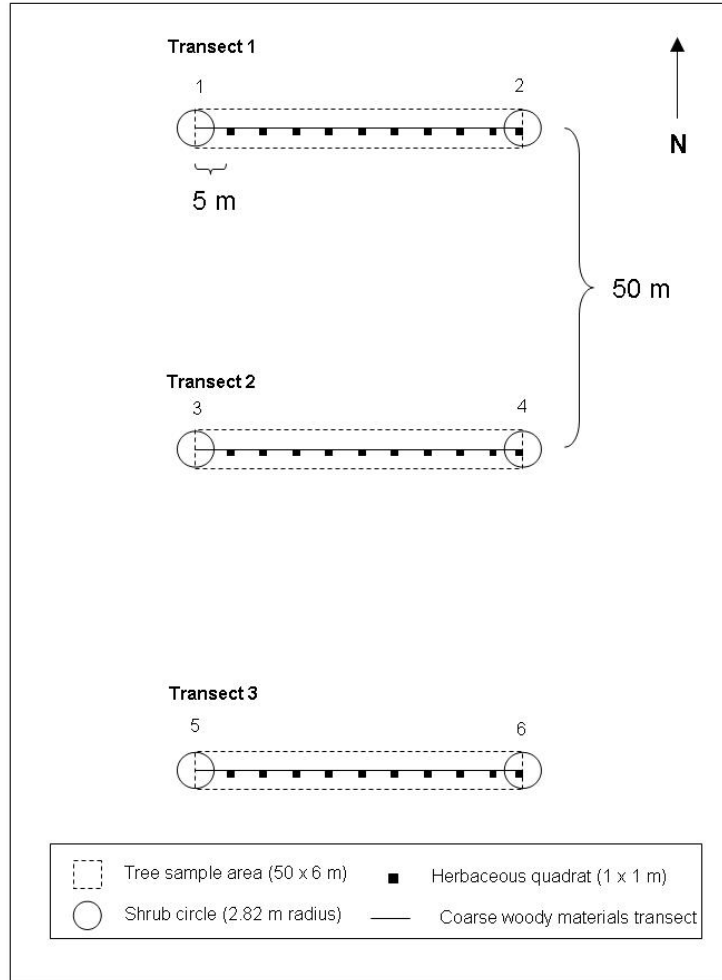


Figure 4. Scale diagram of the hybrid plot, showing three parallel belt transects and areas for data collection of metrics.

Due to the different plot designs, the area sampled for each metric will differ between them. This is shown in Table 2, where the unaugmented FIA plot is also included, for illustration purposes.

Table 2. Area sampled for each metric under the FIA and hybrid designs.

Metric	Plot design		
	FIA plot (unaugmented)	FIA plot (augmented)	Hybrid
Trees (DBH and abundance)	672 m ²	672 m ²	900 m ²
Saplings	54 m ²	672 m ²	900 m ²
Shrubs (percent cover)	0 m ²	54 m ²	150 m ²
Herbs (presence)	12 m ²	36 m ²	30 m ²
Coarse woody materials	88 m	88 m	150 m

Although the layout of the two plots differ, the criteria for sampling trees, shrubs, saplings, and herbs is similar. Pooling data between multiple parks, or pooling park data with FIA data from the surrounding region, will be possible.

The methods of permanent marking of plots will vary between parks. In parks with a large percentage of designated or proposed wilderness (Apostle Islands NL, Isle Royale NP, Voyageurs NP), permanent marking will be minimal. In these cases, each subplot will be marked with a 30 cm piece of rebar, sunk into the ground at either the four subplot centers or the six transect ends. Where we are permitted, we will add yellow endcaps on the top of the rebar to facilitate relocations. At these parks, there may be no additional permanent marking, although the distance and angle to each permanent mark from each of three notable nearby trees (“witness trees”) will be recorded. At other parks, we will tag the witness trees using a nail and identification tag at the base of the tree. Additionally, extensive photographs may be taken at multiple distances and angles from the subplot center to aid in relocation. At other parks, permanent marking will be more thorough, but will still remain inconspicuous. Here, rebar (or other suitable marking material) will be sunk into the ground as in the wilderness parks, and possibly also at the ends of each FIA plot transect. Additionally, small metal pins (or similar material) may be placed at one corner of each 1 m² herbaceous quadrat to ensure exact relocation. Perfect relocation and placement of transects is key for two facets of this protocol. First, it is on these transects that woody materials will be assessed (see SOP 12). The erroneous inclusion or exclusion of woody materials can result in marked errors in the calculated fuel loads. Second, shifts in the location of the 1 m² herbaceous quadrats result in sampling errors that incorrectly show species turnover is occurring (Lynch and Johnson 1974). Finally, metal pins may also be placed at the base of each witness tree. All plots will be relocated with the aid of a metal detector, GPS, and map, showing the permanently marked points.

Sampling Frequency, Replication, and Timing

Vegetation monitoring will be conducted on a six year rotation, with each park visited once every six years (Table 3). Initially, we had planned a five year rotation, with two smaller parks (Indiana Dunes NL and Grand Portage NM) sampled in the same year as a mid-size park. While this was accomplished during the first year of implementation, 2007, problems were encountered, relating to species phenology, training the field crew on vegetation at three sites, and a tight schedule prohibiting the ability to make up lost sampling due to inclement weather. Hence, sampling at these three parks will occur over two field seasons; this will allow additional plots to be established here and alleviate the problems noted above.

During each visit to a given park, all plots within that park will be resampled. Cycles of forest surveys typically range between five and twenty years (Scott 1988). We feel that a six year rotation is a good balance between sampling too frequently, where trampling of the site can adversely impact the plant community, and sampling too intermittently, which reduces the ability to detect change over a given time period. Sampling at six year intervals will allow time for some change to occur, yet provide relatively frequent feedback to park natural resource managers. Additionally, annual monitoring would require sampling teams at all parks every year. Any statistical benefits accrued by monitoring a plot annually are outweighed by logistical and financial constraints.

Table 3. Park rotation schedule for the first two monitoring rotations.

Park	Year										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Indiana Dunes	X					X					
Grand Portage	X					X					
Saint Croix	X						X				
Voyageurs		X						X			
Sleeping Bear			X						X		
Dunes											
Pictured Rocks			X						X		
Isle Royale				X						X	
Mississippi River					X						X
Apostle Islands					X						X

We concede that an ideal scenario would be to visit one sixth of the plots in each park each year. Thus, the plots at any given park would be sampled throughout the six year rotation, not only during one year. This would capture interannual variation and better assess the impact of cyclic insects and/or disease cycles. Unfortunately, this scenario is both logistically and financially not feasible. Seasonal field assistants (see Section V, below) are only expected to be familiar with the vegetation in the one or two parks in which they will be working in a given year, and training assistants on the vegetation of all Network parks is time prohibitive. Further, travel time between parks would result in the loss of valuable sampling time in the middle of the field season. Finally, in the current plan, the seasonals are duty-stationed at the park(s) in which they will be working. Under this arrangement, the Network does not pay travel costs, nor daily costs of meals and incidental expenses. Taking on these additional burdens would be cost prohibitive for the Network.

Recommended Number of Sampling Sites and Frequency

The division of sampling effort between the parks was determined by both top-down and bottom-up approaches. For the top-down approach, the forested acreage in each park was used to calculate the percentage that this represents, of the total Network forested area (Table 4). These percentages were then used to assign the percentage of sampling effort (i.e., time) at each park. Since we are sampling on a six year rotation, a park with 17% of the overall sampling effort represents one full field season at that park, while a 8% effort represent half of a season, or roughly 6 – 7 weeks. We then estimated the minimum number of sites monitored by calculating both field crews completing one plot per field day and then slightly lowering this value to obtain a conservative estimate, accounting to weather and unforeseen setbacks.

Table 4. Sampling effort and minimum expected sample number at each park, calculated by a top-down approach.

Park	Forested Area (hectares)	Percentage of total network forested area	Percentage of sampling effort	Minimum number of samples
Apostle Islands	17,037	7.75	8	35
Grand Portage	281	0.13	6	25
Indiana Dunes	6,095	2.77	17	60
Isle Royale	53,823	24.48	17	60
Mississippi River	5,581	8.99	8	35
Pictured Rocks	24,724	11.25	8	35
Saint Croix River	26,828	12.20	11	40
Sleeping Bear Dunes	25,981	11.82	8	35
Voyageurs	45,325	20.61	17	60
total	219,862		100	365

The bottom-up approach used statistical power analyses to estimate the degree of change that can be detected. The target of the GLKN monitoring program is to be able to detect a 20% change in metrics over a given time period with 80% power and $\alpha = 0.1$ (National Park Service 2006). This approach projects whether there is adequate sample size at all parks, but is especially relevant at the smaller parks where sample time might be limited. For these analyses, both plot types were compared and the results are outlined below.

Sample Method Selection and Level of Change That Can be Detected

In a direct comparison of the FIA and Hybrid plot designs, both methods detected a 20% change in species frequency and abundance for woody vegetation. Data from 20 sites showed that both plot designs had over 99% power to detect a 20% change in both tree basal area and tree density. Similarly, 80% power to detect change in shrub richness was attained with both plot types. However, higher power was attained with the Hybrid method (95.5 vs. 86.1), while surveying fewer sites (17 vs. 20) (Johnson et al. 2006).

For herbaceous species, the Hybrid method was consistently better able to detect trends than the standard FIA method. For example, the Hybrid method had greater than 80% power to detect changes in fern frequency and forb species richness (87.2 and 89.9, respectively) while the FIA method had only 41.0 and 18.3%, for these two indicators, respectively (Johnson et al. 2006).

Because of legacy data from FIA type plots at one Network park, and because of a familiarity with this plot by many park natural resource managers, we will use this plot style at selected parks, while opting for the hybrid plot at others. To address the low power observed in the standard FIA plots, we are modifying the plot layout of the FIA method.

Based on the findings of Johnson et al. (2006), we will strive to sample at least 25 plots in each park. At two of these parks, Indiana Dunes NP and Grand Portage NM, the anticipated number of plots sampled will barely meet this threshold. In the event that at least 25 plots are not established and sampled at the end of the scheduled time in these parks, we will extend the visit to ensure that this minimum target is reached. For a detailed account of the plot comparisons and

power analyses, please refer to Supplemental Document 1: A comparison of sampling methodologies for long-term forest vegetation monitoring in the Great Lakes Network National Parks (Johnson et al. 2006).

Field Methods

Field Season Preparations and Equipment Setup

Preparations for the field season are numerous, and must begin before the calendar year. Many of these preparations will necessarily overlap with the duties associated with concluding the previous season, such as report writing (see SOP #14, Procedures after the field season). Because of these demands, meticulous care must be taken to ensure all preseason procedures are followed in a timely manner.

Early preseason preparations (November – February) are primarily of an administrative nature. Job announcements for seasonal employees must be submitted in November so that they can be posted in early January. Also during this time, a preliminary field schedule should be developed and submitted to the parks to determine whether the proposed sites and timeframes can be accommodated. In addition to submitting the preliminary field schedule, the project manager should also submit requests for park housing and permits (camping, collecting, research) and any other special requests (e.g., boat transportation). Once this schedule is finalized, the project budget for the season should be refined. Prior to the end of February, arrangements should be made for any needed training for the crew leader and crew members. This includes boat operation and first aid. Finally, during this time the project manager should ensure that the federally mandated background checks for employees have been initiated.

Later preseason preparations (March – April) focus on equipment preparation and field readiness. The equipment list should be reviewed and all equipment should be inspected, with repairs made and new equipment ordered as needed. This includes checking all tapes for worn parts, assembling tents and looking for torn material, checking backpacks, and inspecting personal protective clothing. In addition to equipment, data collection procedures should be readied. Programming of personal data assistants (PDAs) will be completed, coordinates for the starting points for each site should be loaded into the field GPS, and park maps and notes for site locations should be organized. The plant list(s) for parks visited should be reviewed and printed and taxonomy changes addressed at this time. Finally, local experts in botany, entomology, and soils should be contacted and notified of the field crew's work plans for the summer. This will open up a line of communication between the field crew and local experts as identification or other questions arise during the summer.

Sequence of Events During Field Season

Final preseason preparations involve training the field crew in preparation for sampling plots. Employment for the GS-7 field crew leader (see Personnel Requirements and Training, below) will typically begin two weeks prior to Memorial Day, while two GS-5 seasonal field assistants will start two weeks after the crew leader. Typically, the first two weeks following Memorial Day will focus exclusively on training. This includes undergoing mandatory federal training and first aid training. The crew will also participate in practice plots where the plot is established, and data are collected and entered into the database using hand-held PDAs. During this two week period, the crew will undergo taxonomic training as well as learn how to use the Trimble GPS units. The crew will also be briefed on use of park radios and work etiquette. This latter point will address how to interact with other park employees and how to answer questions from the public about the work of the vegetation monitoring program specifically, as well as the Inventory

and Monitoring Program in general. Finally, all field crew members will be required to pass a master proficiency test in plant identification before sampling can begin.

The field crew (excluding the Program Manager) will always be duty stationed at the park where they are sampling, except when sampling at Grand Portage NM, where the community is very small and housing is limited. While at Grand Portage, they will be permanently based at St. Croix. Throughout the field season, the field crew and Program Manager will work on a four 10-hour day schedule. This schedule will accommodate for travel time between Ashland and the parks by the Program Manager, allowing him/her to accomplish necessary administrative duties at the Network office. Although there is not a great deal of flexibility in the schedule, at most parks there are sufficient numbers of planned sampling sites that the loss of some due to poor weather or unforeseen circumstances will not compromise statistical power. At both Indiana Dunes NL and Grand Portage NM, we will ensure that at least 20 sites have been sampled. In the event that this is not initially accomplished, we will extend the duration of time at those sites until 20 have been sampled.

Details of Taking Measurements

We will be following many of the same measurement criteria and standards as the FIA program for both the FIA style plot and the hybrid plot. This includes details such as how to measure forking trees and how to treat leaning or down live trees. For more details on this, please see the Forest Service Phase 2 Field Guide (U.S. Department of Agriculture 2005) and Standard Operating Procedure 6: Field Methods and Data Collections. This will allow comparability between the two plot types used in the GLKN monitoring program. It will also allow comparability between data collected using the GLKN hybrid plot with that collected by the actual FIA program in the area surrounding the parks.

We will primarily be relying on personal data assistants (PDAs) to enter field data at the time measurements are made. However, standard paper field forms printed on rite-in-the-rain® paper will be carried to the site and used if needed. These are included in Appendix A of this report.

Post-Collection Processing of Samples

The nature of this protocol is such that there will be minimal samples collected. One exception to this will be when unknown plant specimens are collected for identification. When this occurs, the seasonal crew will be responsible for getting this to the local botanical expert identified for that park (see SOP 1: Preseason preparations). For more detail on this, see SOP 7: Collection of Unknown Specimens for Identification.

End-of-Season Procedures

The procedures associated with completing the sampling season must be performed in earnest in the weeks immediately following the conclusion of sampling, and continued through the following April. Early post-field season procedures focus on both administrative tasks and data archival procedures. In August, performance reviews must be given to field crew members, and procedures associated with terminating their employment be completed. Throughout the month of September, data archival procedures should be carried out and park species lists and NPSpecies updated with new records.

Review of the protocol should be performed annually, in early October. Following protocol review, there is a three month period (mid-October – mid-January) where data analysis and report writing are the focus. Drafts of annual summary reports are due to the parks for review by January 15 of the year following monitoring (see SOP #15 – Reporting). Every six years, drafts of analysis and synthesis reports will also be due to the parks, on January 31st. The revised final versions of the annual summary reports analysis and synthesis reports are due March 1st and April 1st, respectively. An annual presentation will be made at the annual technical committee meeting, typically scheduled near the end of March. Finally, the month of April may be spent preparing the analysis and synthesis report for submission to a peer reviewed journal. Post field season procedures are spelled out in greater detail in SOP #16 – Post-season procedures.

Data Handling, Analysis, and Reporting

Metadata Procedures

Metadata allows potential data users to evaluate the quality and usefulness of the data based on an understanding of the complete process under which it was collected and maintained. Metadata development begins with project design and planning. The GLKN data manager has established a standard operating procedure for metadata generation and maintenance. In general, a metadata document will be initiated using the NPS Metadata Tools & Editor, Dataset Catalog, or ArcCatalog in the design and planning stage of a project. As the project progresses, this document will be augmented by the project manager to include relevant project details. Full development of metadata for project data will be completed after the field season is completed and the data set is certified by the project manager. Once metadata are complete, the Network data manager will save the document in one or more of four acceptable formats and parse the information into varying levels of information. Metadata are saved on the primary GLKN server along with data and copied to the I&M Program NR-GIS metadata server.

The database design for GLKN data will include a means for recording the protocol version under which each piece of data is collected. The metadata document will, therefore, also contain information about protocol versions used to collect the data.

For metadata associated with geospatial data, we will abide by Executive Order 12906, which mandates that every federal agency document all new geospatial data it collects or produces using the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM; www.fgdc.gov/metadata/constan.html). All GIS data layers will be documented with applicable FGDC and NPS metadata standards. The Network will also generate FGDC-style metadata for non-spatial datasets that meet this standard, absent only the geospatial-specific elements.

Data which are generated and/or managed outside the I&M Program, but used in analyses with GLKN data or distributed in any manner by the NPS, require the same level of documentation as GLKN-generated data. This includes data produced under contract with the NPS. For non-Program data, the project manager will ask the originating entity for metadata. Any contract entered into by the GLKN with data producers will stipulate that FGDC-compliant metadata in HTML, ASCII, or XML format, or in a format specified by the project manager and approved the Network manager. The Network data manager will assist the project manager in metadata acquisition by providing tools, format protocols, and file transfer services.

Overview of Database Design

One goal of the general vegetation monitoring protocol is that GLKN be able to pool the protocol data with that of the Forest Service collected as part of the FIA program. The latter data are collected and made available by the Forest Service approximately one year following collection. While the Network is interested in comparing I&M program data with Forest Service FIA data collected within the parks (Table 5), we are primarily interested in comparisons with FIA data collected regionally, outside of the parks. These comparisons will allow information about the health of forests in Network parks to be placed into context with forests regionally, including

those on other federal land (e.g., national forests), state land (e.g., state parks and forests), and private land.

Table 5. GLKN parks showing the number FIA Phase 2 plots (where tree data are collected) and Phase 3 plots (where down woody material data are collected) in each park.

Park	Phase 2/Phase 3 FIA plots
Apostle Island NL	8/0
Grand Portage NM	0/0
Indiana Dunes NL	3/0
Isle Royale NP	67/1
Mississippi NRRA	2/0
Pictured Rocks NL	28/1
St. Croix NSR	20/1
Sleeping Bear Dunes NL	26/2
Voyageurs NP	33/2

To facilitate analyses using FIA data, the GLKN database structure will be similar to that of the FIA program, and the variable names within the tables will be identical. The GLKN database will consist of nine tables (Survey, County, Plot, Subplot, Condition Class, Tree, Seedling, Boundary, and Subplot Condition Class) that will be linked by specific keys. For a complete description of the GLKN database, please refer to Supplemental Document 1: Great Lakes Network General Vegetation Database Structure and User Guide.

The Great Lakes Network stores and integrates monitoring data from multiple protocols in a Microsoft SQL Server relational database management system (RDBMS) that is used to generate the analyses and reports required by GLKN, and drive an Internet Mapping System (IMS) used for exchange and visualization of GLKN's monitoring data.

Data Entry, Verification and Editing

We will use paper data sheets to record data when in the field. The data will be collected by a team of two with one crew member recording data primarily on overstory trees, shrubs, and coarse woody materials. The second member of the field crew will primarily record data on herbaceous species. The datasheets will be photocopied at the earliest possible date, with one copy stored in the GLKN offices, and a second copy stored offsite.

Once entered, all data will be printed and verified by comparing it with the original field recorded data sheet. Two people will perform this duty with one person reading the values from the original datasheet and the second person checking the values on the printout.

During the initial year of protocol implementation (2007), we attempted to enter data directly into PDAs in the field. This could then be downloaded directly into the database, thus minimizing transcription errors. This turned out to be problematic for a number of reasons. In short, it is not possible to easily check the data before leaving a field site to make sure everything is present and that the data makes sense. We realized too late that there were a number of metrics

missing from various plot data. In addition, most of the sampling time is spent in a backcountry environment for up to four days in a row. Reliance on batteries and chargers is impractical.

Recommendations for Routine Data Summaries and Analyses to Detect Change

After each field season, all data are analyzed to produce annual summaries on the status of terrestrial vegetation in the park(s) sampled that year. These annual summaries provide the Network with current status information relevant to policy and management decisions. A variety of analytical approaches are utilized to assess the status of 1) environmental variables associated with terrestrial vegetation, 2) population (species-level) variables, 3) community structure variables, and 4) community composition variables at each park and across parks in the Great Lakes region. Because the procedures for this are detailed extensively in Standard Operating Procedure 8: Data Analysis, we are not presenting these here.

Recommended reporting schedule and format

Two types of reports will be produced for the General Vegetation Monitoring protocol. Annual summary reports will be produced yearly for the Vital Signs associated with the vegetation protocol that were monitored during the previous year. The primary audience for the annual summary reports will be parks. These summaries will be communications to document our efforts and convey the findings of the previous field season. At a minimum they will provide an introduction that describes why that Vital Sign is being monitored, an outline of the sampling strategy, including the number of sites sampled, parameters measured, and analyses performed, data summaries and a text explanation of the findings, and limited discussion section in which important results are interpreted. The project manager will take the lead in writing the report and will coordinate an internal review. Drafts of annual summary reports will be completed by January 15 for a two week review period by the parks. The final reports will be provided to parks on March 1 of the year following the monitoring.

In addition to annual summary reports, detailed reports in which data are analyzed and synthesized will be produced on a periodic basis. For the general vegetation protocol, analysis and synthesis reports will be written every six years, after each completion of the sampling rotation. They will be written in the format of a scientific journal article (abstract, introduction, methods, results, discussion, literature cited) and will contain in-depth analyses as outlined in this protocol. Further, these comprehensive reports will place the observed results in both a regional and historical context by relating them to other published literature, discuss the significance of the results in terms of environmental change, and provide management recommendations based on the findings.

The project manager (terrestrial ecologist) will take the lead in writing the analysis and synthesis reports, and will coordinate an internal review. The target audience of these reports will be the parks (primarily the natural resource managers), the Network, and both regional and Servicewide I&M. Outside of the park service, the target audience includes the four state departments of natural resources (Indiana, Michigan, Minnesota, and Wisconsin), the Northeastern Area Forest Health Protection unit and the North Central Research Station, both of the of the National Forest Service, and the broader scientific community.

Drafts of analysis and synthesis reports will be completed by January 31 of the year that follows completion of the monitoring cycle. The parks will have a 30 day period for comment and input. In addition, these drafts may also be sent to outside sources for further review. The extent of review will depend on the analytical complexity of the methods and the gravity of inference and recommendations. The final reports will be due on April 1 of the year following completion of the monitoring cycle.

The first analysis and synthesis report will be written following a full rotation of monitoring. At this time, vegetation and the associated Vital Signs will have been monitored in each park for one season, allowing a comparison of vegetation characteristics across parks. In subsequent years, as parks are monitored repeatedly, more in-depth analyses will be conducted for individual parks as well as across parks.

Recommended Methods for Long-Term Trend Analysis

Each park will be visited and surveyed every six years. Once a given park has been sampled a second time, tests for changes in metrics can commence. It will be possible to test for trends with more sensitivity and to evaluate changes in trends once the third sampling event for any given park is complete. In addition to investigating changes in environmental variables and population and community vegetation variables, we also will be assessing the relationships among all of these variables. All long-term change and trend analyses are detailed extensively in Standard operating procedure 8: Data Analysis. Please refer to this for specific details.

Data Archival Procedures

The Access database file in which the vegetation monitoring data are stored will be backed up nightly and a copied backup tape is stored off-site each week.

Personnel Requirements and Training

Roles and Responsibilities

The Project Manager, or Terrestrial Ecologist for this protocol, is a liaison between the permanent Network staff, seasonal Network staff, and the park. The project manager is charged with organization and facilitation of all aspects of the long-term vegetation monitoring protocol. This includes the following:

- hiring seasonal staff
- developing an annual field schedule
- acquiring the appropriate permits (NEPA, camping, collecting, etc.)
- arranging training (first aid, CPR, FIA plot training, etc.)
- refining the budget for the season
- preparing, repairing, and purchasing equipment
- preparing the database for the upcoming season (review species lists, add names of seasonals, etc.)
- contacting local experts in botany, soils, and entomology to establish a working relationship with them prior to the start of the season
- ushering crew members through administrative training (credit card use, etc.) and park specific plot work
- overseeing seasonal staff during field season
- identifying plants accurately and processing unknown plants for later identification
- ensuring plot work meets the desired standards of quality
- ensuring an adequate number of plots get measured each season and at each park
- ensuring effective communication between park staff, the field crew, and other GLKN staff
- reviewing and terminating the seasonal field crew members
- reviewing and revising protocol
- data analysis and report writing
- presenting finding of previous season to the technical committee

The GS-7 crew leader will be responsible for day to day completion of plot establishment and monitoring. The GS-7 will also be responsible for supervising the GS-4/5 seasonals when the project manager is not present. Specific duties include:

- completion of mandatory training including first aid, boat training, and plot establishment
- assisting with navigation to sampling points
- identifying plants accurately and processing unknown plants for later identification
- ensuring plot work meets the desired standards of quality
- collection of plot data and entry into a PDA and/or tablet computer
- transfer of data from the PDA to the tablet computer
- entry of data from paper data sheets to tablet computer and error checking entered data
- completion of timesheets for both the GS-7 and GS-4/5 seasonals
- ensuring equipment is clean and functional prior to each trip
- ensuring all needed equipment is collected and readied prior to each trip

- interact with park staff as needed to organize transportation and equipment needs.

The GS-4/5 seasonals will be responsible for day to day completion of plot establishment and monitoring. Specific duties include:

- completion of mandatory training including first aid, boat training, and plot establishment
- assisting with navigation to sampling points
- identifying plants accurately and processing unknown plants for later identification
- ensuring plot work meets the desired standards of quality
- collection of plot data and entry into a PDA and/or tablet computer
- transfer of data from the PDA to the tablet computer
- entry of data from paper data sheets to tablet computer and error checking entered data
- ensuring equipment is clean and functional prior to each trip
- ensuring all needed equipment is collected and readied prior to each trip

Crew Qualifications

The project manager must have an advanced degree in botany, plant science, or biological science with an emphasis in plants. He/she should also have demonstrated experience identifying the flora of the Great Lakes and surrounding region, acquired through a combination of work experience, education (graduate school research), and/or workshops and other training. The project manager must also have a minimum of one year experience leading a field crew.

In addition to botanical and leadership skills, the project manager must be knowledgeable about multiple aspects of forest health. This includes identification of forest pests and pathogens, and the ability to identify (tree) diseases. The project manager should also be familiar with basic soil collection and classification techniques and be able to infer whether earthworms are present based on soil characteristics. Finally, the project manager must also have experience establishing permanent plots.

The GS-7 level crew leader will oversee the other seasonal employees at the GS-4/5 level, when the project manager is not present. The GS-7 seasonal must have at least a four-year degree in botany, plant science, or biological science and have at least one year of vegetation based work experience equivalent to the GS-5 level. Alternatively, the GS-7 may have an advanced degree with an emphasis in vegetation. The GS-7 must also have at least one season (three months) of supervisory experience of field personnel and have demonstrated experience (work or education) identifying flora of the region(s) where sampling will occur in the year for which they are hired. Finally, they must demonstrate the ability to navigate with map, compass, and GPS.

The GS-4/5 seasonal employees must have a four-year degree or at least 24 semester hours in course work in biology, botany, entomology, soil science, or forestry. Further, at least 9 semester hours must be directly related to the requirements of this position. This person must have demonstrated experience (work or education) identifying both overstory and understory vegetation of the region(s) where sampling will occur in the year for which they are hired.

All people on the crew (project manager and seasonals) must be physically fit and able to work in adverse environments. This includes working in extreme heat and cold, and in the presence of biting/stinging insects and poisonous plants.

Training

The project manager will be expected to attend a Forest Service sponsored FIA Phase 2 and Phase 3 training workshop if these are offered outside of the planned field sampling season. He/she will also be expected to attend a first-aid/CPR course.

The seasonal field crew will arrive around Memorial Day. During this time, they will undergo training in administrative procedures, plot establishment, data collection, data entry, and first aid/CPR.

Administrative training procedures will be performed over the first two days of employment. This will cover issues associated with computer use, credit card use, and time sheets. This training will be provided by the project manager.

The bulk of the three week training time will be devoted to multiple aspects of vegetation monitoring. The seasonal employees will be instructed on how to establish the FIA or hybrid style plots, with emphasis given on the high degree of accuracy required with the distances, angles, and metrics measured. During this time, the crew will also be instructed on use of PDAs and the tablet computer for data collection and entry. The time devoted to vegetation monitoring training will be approximately two weeks. During this time, the crew members will also familiarize themselves with the vegetation of the park in which they are working. Plants that are encountered but cannot be readily identified during this time will be learned so that, when they are encountered in actual plots, they can be quickly identified. This training will be provided by the project manager.

The crew will also participate in any park based first-aid and CPR training. This is usually provided after Memorial Day. Finally, the crew will be instructed on etiquette for interactions with the general public visiting the parks. The project manager will explain how to answer questions about their work, and the Network's work.

Operational Requirements

Annual Workload and Field Schedule

Employment for the seasonal staff will begin three weeks prior to Memorial Day. This will allow time for administrative training and first aid training. Also during this period, the network botanist will be training the seasonal staff on plot establishment, data collection, and the local flora. In general, we will plan to begin actual plot sampling on the Tuesday immediately following Memorial Day. For many northern parks (Apostle Islands, Isle Royale, Pictured Rocks, Voyageurs) however, the phenology may be such that plots cannot be sampled until early to mid-June, depending on temperatures. Where this is the case, we will establish plots that are most easily accessible, and perhaps record data on the overstory species. We will then go back and collect data on the remaining metrics. At one park, Indiana Dunes, we will actually commence plot sampling the week prior to Memorial Day. This will be possible as this is southern most of the network parks. The earlier start data will allow an additional week of field sampling during the season.

In general, sampling will run until the Labor Day weekend. The arrangement results in 14 weeks of plot sampling time (15 in the year in which Indiana Dunes is sampled) and 17 weeks total time. In some years, this may need to be modified, if plants begin to senesce early. If this is the case, plot sampling may be curtailed as early as mid-August.

Facility and Equipment Needs

We are attempting to conduct this protocol in as independent of a manner as possible. The budgets of many parks prevent the park from hiring a seasonal staff that could assist the vegetation monitoring crew with transportation and other logistics. Despite this, transportation remains a key issue in which we will need to rely somewhat on others. At Apostle Islands NL, we are limiting the monitoring there to the mainland and only seven of the 22 islands. Cooperation from park staff to shuttle the network staff between islands is essential. At Isle Royale NP, we have limited sampling sites to the main island, and to Passage Island. We will not be monitoring any of the approximately 400 islands that surround the mainland, due to the logistics of traveling to them. Unlike at the Apostle Islands, however, there is a commercial vessel that we will rely on to transport the field crew to sites around the island. At Saint Croix River, we will primarily access sites via canoe. As this is the case, we will rely on park staff to provide a shuttle back to the network vehicle at the completion of trips. This will occur approximately four - five times over the course of the sampling season. Finally, at Voyageurs NP, we may rely on the park airplane and pilot to fly the crew in to the most remote sites at some point during the sampling season.

In addition to transportation, we will rely on the parks to, wherever possible, provide housing for the field crew. In many instances, this will only be for the seasonals during the four day layover between sampling events, as the crew will be in the backcountry during the sampling period.

At all parks, regardless whether they are remote or not, we will depend on the parks for basic security and safety precautions. The field crew will be equipped with two radios (supplied by the Network) and will organize with the park staff on obtaining a call number prior to beginning sampling. At this point, the field crew will be briefed on proper radio etiquette of the park.

Startup Costs and Budget Considerations

Startup costs for the general vegetation monitoring protocol are primarily for both IT supplies, general field supplies, and camping supplies. Information technology needs include two Trimble Geo XT handheld GPS units, radios, and cameras. All of these items have already been purchased by the network. General field gear includes transect tapes, chaining pins, and diameter tapes, among others. Camping supplies for project startup include four one-person tents, four backpacks for backcountry hiking, and four sleeping pads. Other camping supplies include stoves, filters, and first aid kits. All of this has already been purchased by the network.

The annual operating costs for the general vegetation monitoring protocol are estimated to range between \$54,000 and nearly \$100,000 (Table 6) for the first six years. The majority of these expenses (73 – 82%) are for salary of the GS-5 and GS-7 field crew members. The marked increase in cost between 2008 and 2009 reflects the switch to a permanent crew leader. The salary for the terrestrial ecologist will be included in the annual network budget and is not presented here.

In addition to salary, the annual operating costs include lodging (park campgrounds, shelters, backcountry campsites, and private campgrounds), transportation (car, boat), and meals and incidental expenses. All three of these vary between parks.

Table 6. Estimated annual operating costs for conducting the general vegetation monitoring protocol. Estimates include lodging, transportation, meals and incidental expenses, and salary.

Year	Park (s)	Annual Cost
2007	INDU, GRPO, SACN	\$60,061
2008	VOYA	\$54,186
2009	SLBE, PIRO	\$100,644
2010	ISRO	\$99,914
2011	MISS, APIS	\$100,067

Procedures for Revising the Protocol

The long-term nature of the NPS monitoring program necessitates the need for flexibility to incorporate change. Refined field methods, advances in analysis techniques, and feedback from field crews and project managers can all contribute to improving the monitoring protocol. To systematically identify areas and procedures needing revision, we will review the protocol each year at the end of the field season (see SOP #16, Procedures after the field season). To minimize the changes to the protocol narrative, an attempt will be made to first revise SOPs without making changes in the protocol itself. However, if it is clear that changes will also be needed on the narrative, then it will also be revised. All changes will be reviewed by Network staff, and substantial changes (e.g., revised analysis techniques, significantly altered field methods) may also be sent to outside sources for input. The changes will be recorded in the revision history log of the appropriate SOP and/or narrative, copies of the revised material will be distributed to all relevant parties, and subsequently posted on the Network website. Further, the data manager will be notified of the change(s) so that the metadata of the project database will be updated. For a detailed description of protocol revision procedures, please see SOP #17, Revising the Protocol (Sanders and Elias 2006).

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Appendix A: Standard Operating Procedures

Preparations and Equipment Setup Prior to Field Season

Standard Operating Procedure #1

Version 1.0 (7/1/08)

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NPS – Great Lakes Network

Revision History Log:

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

1.0 Introduction

Preparations for the field season are numerous, and must begin early in the calendar year. Many of these preparations will necessarily overlap with the duties associated with concluding the previous season, such as report writing. The purpose of this SOP is to enumerate preseason duties, so that none are skipped and important deadlines in this regard are not missed. This SOP specifically addresses 1) administration associated with hiring field staff, 2) field work schedules, 3) organization of field season equipment and supplies, and 4) data forms.

1.1 November

- Prepare position descriptions for seasonal employees and send these to the regional office. Get approval so these can be posted in early January.
- Prepare position announcements and contact a human resources specialist for posting these.

1.2 January

- January 8 – 22: Have seasonal position descriptions posted on USAJobs.
- January 2-31: Derive field sites and make plot maps for navigating to them. These maps should contain both topographic and aerial/satellite imagery.

1.3 February

- February 1 – 7: Develop preliminary field schedule. This should identify all potential field sites within the parks where sampling will occur, as well as identify the probable dates when they will be sampled. Development of a preliminary schedule should be coordinated with the entire Network so that sampling and staff demands can be spread out spatially and temporally between and within parks.
- February 7 – 14: Submit preliminary field schedule to parks for approval. At this time, also submit housing and other requests (e.g., collecting and camping permits, boat transportation, research).
- February 14 – 28: Arrange any needed preseason training that is conducted outside of the Network (e.g., boat operation, first aid).

1.4 March

- March 1 – 7: Review and refine budget for the upcoming season. The refined budget should incorporate non-park housing and transportation.
- March 1 – 15: Review equipment list and get equipment organized and made ready. This allows time to make needed repairs (see bullet below) and to order replacement equipment. A list of field equipment needs for one four-person crew is listed in Table 1; if more than four people work on a crew, then equipment needs will change accordingly.
- March 1 – 15: Check forester tapes for proper function and replace worn parts as needed. Check measurements on FIA ropes and hybrid shrub rope to ensure no stretch has occurred; make corrections as needed.
- March 15 – 30: Review field notebooks and datasheets from previous surveys to identify any unique events that may be encountered within specific parks.
- March 15 – 30: Review species lists from previous vegetation sampling efforts in a park and in surrounding areas and compare to reference manuals to identify species not recorded which have a probability of being recorded. Copies of theses combined species

lists should be made and carried into the field as quick references in helping to identify unknown plants.

Table 1. Field equipment list for FIA and Hybrid vegetation sampling

Item	Quantity
Laptop computer for downloading data from PDAs into database	1
List of plant species known or thought possible to exist in park	4
Protocol narrative and SOPs	1
Field guide detailing data collection procedures	4
Site maps showing coordinates	1 set
50m tape	6
logger tapes (30 m auto retractable with nail at the end)	2
1m quadrat frame	2
Chaining pin with rope attached noting 2.82 m distance (shrub circle, hybrid method)	2
Chaining pin with rope attached noting 2.07 m distance (microplot, FIA method)	2
Chaining pin (or expanding pole) noting 7.32 m distance (subplot, FIA method)	2
Calipers for measuring sapling diameters	2
Compasses for navigation and plot layout (adjust/check declination)	4
Clipboards and pencils for recording notes and data	2
Rebar and other materials for permanent marking	several
Trimble GPS unit for navigating to site coordinates and entering plot data	2
Garmin GPS unit as backup for the Trimble	2
Digital camera for photographs of understory, canopy, unknown species, etc.	2
Hammer for pounding in rebar	
Sonar distance measurers	2
Cruiser vest for carrying equipment	4
Hand lens for close-up viewing of vegetation	4
Copies of datasheets on rite-in-the-rain paper	Several
Reference books for plant, insect, and disease identification (see Appendix 1 of this SOP for a bibliography of suggested books and articles)	Several
Field Guide SOP with details of taking measurements	2
Park radio	2
Insect repellent	Several
Insect proof shirts	4
Sunscreen	Several
First Aid kit	2
Plant press	2

1.5 April

- April 1 – 7: Coordinates for the FIA center-point and/or NPS Hybrid-method starting point for each site to be sampled must be loaded onto the Trimble GPS units. Also load regional topographic maps into the Trimbles. These GPS units also should be checked at this time to ensure accuracy, working order, and that the proper settings are loaded (see SOP 4, GPS Use, for details on settings).

- April 1 – 15: Contact local experts in the botany, soils, and entomology of the park(s) in which field work will be conducted. The purpose of this is to establish a line of communication between the field crew and scientists who are knowledgeable about the local area. These experts can then be contacted during the field season if questions arise. Refer to Table 2 for suggested people.

1.6 May

- May: Field crew leader arrives in Ashland. The exact date will vary depending on when actual sampling will begin, which in turn, depends on which park will be sampled first that year. In some years, this may even occur in April. In general, however, the crew leader will arrive in Ashland two weeks prior to the field crew starting at their designated duty station. During their time in Ashland, the crew leader will assist the program manager with final preparations for the upcoming sampling season. This will familiarize the crew leader with procedures. The crew leader may also attend a boat training session on the St. Croix River during this time period. Finally, the program manager and crew leader will establish practice plots so that the crew leader will become familiar with techniques.
- May (late): Field crew arrives at duty station. Again, this is approximate, depending on the park where sampling will commence in a give year. There will be a two to three week training period following their arrival but prior to sampling the first plot. During the first three days of this period, the crew will have two federally mandated training courses: credit card training required for all federal employees issued credit cards and federal information systems security awareness computer training. For both courses the crew members will be required to meet minimum proficiency scores. In addition, the crew members will be required to pass an American Red Cross approved CPR and First Aid training course.

1.7 June

- June (early): Final preparations for getting the field crew ready for establishing plots and collecting data will occur during this time. This will include training in establishing test plots and plant identification, training in use of park radios, and general park etiquette training. This last point will focus on interactions with other park employees, and the general public and will include how to answer questions about the work of the field crew specifically and the Inventory & Monitoring Program in general. Prior to initiating sampling, all field crew members will be required to pass a minimum proficiency test on plant identification.

Table 2. List of local biologists for each Network park. In addition to those noted below, we will also rely on Joe O'Brien (615-649-5266, jobrien@fs.fed.us) for plant pathology and Steve Katovich (651-649-5264, steven_katovich@fs.fed.us) for entomology.

Park	Name	Affiliation	Area of Expertise	Phone	Email
APIS	Jim Meeker	Northland College	botany	715-682-1808	jmeeker@northland.edu
	Andy Goyke	Northland College	entomology	715-682-1550	agoyke@northland.edu
GRPO	Al Harris	Northern Bioscience	botany and entomology	807-344-7213	aharris@northernbioscience.com
INDU	Julie Stumpf	National Park Service	botany	219-926-7561 x 323	julie_stumpf@nps.gov
	Dan Mason	National Park Service	botany	219-926-7561	daniel_mason@nps.gov
ISRO	Janet Marr	Michigan Tech	botany	906-337-5529	jkmarr@mtu.edu
MISS	Eric Epstein	Wisconsin DNR	botany	608-267-5038	eric.epstein@dnr.state.wi.us
PIRO	Janet Marr	Michigan Tech	botany	906-337-5529	jkmarr@mtu.edu
SACN	Eric Epstein	Wisconsin DNR	botany	608-267-5038	eric.epstein@dnr.state.wi.us
	Emmet Judziewicz	U.W. Stevens Point	botany	715-346-4248	ejudziew@uwsp.edu
	Joe O'Brien	U.S. Forest Service	entomology	615-649-5266	jobrien@fs.fed.us
	Todd Lanigan	Wisconsin DNR (Eau Claire)	forest pest specialist	715-839-1632	todd.lanigan@dnr.state.wi.us
	Shane Weber	Wisconsin DNR (Spooner)	forest entomologist	715-635-4156	shane.weber@dnr.state.wi.us
SLBE	Janet Marr	Michigan Tech	botany	906-337-5529	jkmarr@mtu.edu
VOYA	Al Harris	Northern Bioscience	botany and entomology	807-344-7213	aharris@northernbioscience.com

SOP 1 Appendix

Bibliographic List of Suggested Guides for Identifying Plants, Insects, and Diseases

- Allen, T. J., J. P. Brock, and J. Glassberg. 2005. Caterpillars in the Field and Garden: A Field Guide to the Butterfly Caterpillars of North America. Oxford University Press, New York, New York.
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Training Observers

STANDARD OPERATING PROCEDURE #2

Version 1.0 (7/1/08)

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2.0 Introduction

This Standard Operating Procedure explains the training procedures that all observers should follow to learn (1) how to identify wild herbs in various stages of growth, (2) how to accurately sample for trees and shrubs, and (3) how to follow standard sampling protocol and accurately establish sample plots.

2.1 Herb sampling

The most essential component for the collection of credible, high-quality herb data is well-trained and experienced observers. This cannot be overemphasized. The botanists responsible for collecting herb data will require considerable previous experience in the field identification of wild plants in all stages of growth. All crew members will benefit from a brief introduction to the common flora of the park, but in a short time it would be very difficult to train an inexperienced individual thoroughly enough to sample herbs accurately.

Procedures:

1. Before field season, the terrestrial ecologist and field technicians should familiarize themselves with the flora of the park by studying the list of species that are known to occur there and by consulting references for further information. This should also include looking at herbarium specimens of species known to be difficult to identify or distinguish from one another. This step is especially important if the ecologist or technicians have not already done work in the same region as the park.
2. Once at the park, but prior to beginning sampling, the terrestrial ecologist and field technicians should spend time in the field to further familiarize themselves with the plant species present and the current growing conditions.
3. The field technicians must be able to pass a minimum proficiency test for accurately identifying plants: all common species should be recognized in all stages of growth. The technicians should also be familiar with less common species that are known to occur in parks, and should be able to readily identify these by consulting reference materials.
4. Train the technicians on the standard procedure for collecting and documenting unknown species for later identification, ensuring that populations of rare plants are not threatened by collecting and that specimens be well-preserved for future reference. Please refer to standard operating procedure #7: Collection of Unknown Plants for Identification.
5. Train the technicians for specific techniques associated with herbaceous data collection. Ensure that they use their hand to move larger or apparent herbaceous vegetation that might be obscuring smaller or less conspicuous plants. Also ensure that the technicians are feeling certain plants for pubescence and other indentifying traits.
6. If more than one person will be sampling herbs, have them sample several quadrats independently and compare the results. Resolve any differences in technique or taxonomy that arise.

7. Refer to Appendix 1 of SOP # 1 for a list of reference materials.

2.2 Tree and shrub sampling

As with herb sampling, experience in field identification is critical to the accurate sampling of trees and shrubs. There are far fewer species of trees and shrubs than herbs, however, and often they are easier to identify. Thus, it is possible for a less experienced but motivated crew member to learn trees and shrubs well enough for accurate sampling with several days of training before the field season. Those with less experience should not hesitate to ask the terrestrial ecologist for assistance or confirmation should any uncertainty arise during the course of sampling.

Procedures:

1. Before the field season, field technicians should familiarize themselves with the tree and shrub species found in the park by studying the list of species that are known to occur there and by consulting references for further information. This step is especially important for technicians who have not already done field work in the same region as the park.
2. Once at the park, but prior to beginning sampling, crew members should spend time in the field to further familiarize themselves with the tree and shrub species present and the current growing conditions.
3. Field technicians must be able to pass a minimum proficiency test for accurately identifying trees and shrubs: all species should be recognized in all stages of growth. If any questions arise, the technicians should be able to resolve them by consulting reference materials.
4. Train technicians in the proper use of forester tapes to accurately measure trees and breast height. Refer to SOP# 6: Field Methods and Data Collection for specific details of this.
5. Train technicians in the accurate use of the FIA rope and Hybrid shrub rope for counting stems in shrub circles efficiently and accurately.

2.3 General sampling methods and layout

If more than one crew is sampling, all crews will work together to sample one or two sites at the start of the field season. This will ensure that the same methods are followed by all crews, and will allow any unforeseen problems or difficulties to be addressed and the protocol modified if necessary.

Procedures:

1. Train each technician on basic navigation, including GPS and compass use. Given coordinates, each member of the crew should be able to locate a point using the GPS. Each crew member also should be able to read a topographic map and be able to walk a straight line following a bearing on a compass.
2. Following the sampling protocols detailed in later SOPs, sample a site with members from all crews present. The terrestrial ecologist should ensure that every crew member understands

how the plot is located and established, and the purposes of each part of the sampling procedure. While under the observation of other technicians, each technician should participate in all of the sampling activities he/she will normally be responsible for. In addition, technicians should observe sampling activities for which they are not directly responsible, in case their help is needed in the future.

3. During or after sampling, discuss the efficiency and accuracy of the methods used and make minor changes to techniques if necessary. Ensure that all technicians are thoroughly familiar with procedures and address any questions that arise.
4. If there are multiple crews, select another site and let each crew sample it independently. Then compare results, and examine any differences that are apparent.

Safety

STANDARD OPERATING PROCEDURE #3

Version 1.0 (7/1/08)

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3.0 Introduction

Safety of the field crew is the foremost concern during monitoring and travel to and from monitoring sites. The purpose of this SOP is to state the safety policies of the Great Lakes Network as they relate to the general vegetation monitoring protocol.

3.1 First aid

At a minimum, all members of the field crew must have basic first aid and CPR certification. The park where the field crew will be duty stationed will provide training for the certification during the two week time period after the field crew arrives, but before sampling begins. If it is not available during this time, technicians will attend a first aid and CPR course at the earliest possible date thereafter.

3.2 Boat operation

To ensure the safety of all people on the field crew, only those who have undergone boat operator training will be allowed to operate boats. If time and opportunity permit during the two week training period, crew members who have not undergone the training may be allowed to participate in it.

3.3 General vehicle use

Operation of National Park Service cars and trucks is limited to National Park Service employees only. Further, all members of the field crew must possess a valid driver's license and sign the NPS motor vehicle operation waiver stating that they understand the rules of motor vehicle operation and alcoholic consumption. Vehicle operators are expected to abide by state and local laws; this includes all regulations within the park units. Specifically, seat belts must be worn at all times when the vehicle is being operated. Finally, employees should inform their supervisor if, at any point, they do not feel safe in the vehicle, either as a passenger or driver.

3.4 Daily work schedule

Long hours are a fact of field work and field crew members should expect that a fair percentage of work days will be greater than 10 hours. Although attempts will be made to limit the length of the work day to 10 hours, under no conditions will the length of the day exceed 11.5 hours.

It is the responsibility of each crew member to be ready for work each day with his or her own adequate supply of food and water and in appropriate footwear for the terrain and weather. In the event of extreme temperature, wind, rain, or other storms, sampling for the day will be initiated or will be terminated if it has already begun.

Two first aid kits will be supplied to the crew so that both of the two teams will have one. The crew members should familiarize themselves with them so that they know what can be treated in the field.

A job hazard analysis for working in forested environments is included as an appendix of this SOP.

3.5 Alcoholic consumption and drug use

Consumption of alcoholic beverages during the work day is strictly forbidden. Use of alcoholic beverages during off time is permitted. However, consumption occurring on Park Service property (e.g., park housing, back country campsites) must be within compliance of park rules (e.g., no glass containers).

If a field crew member is deemed unfit for work due to excessive alcoholic consumption, he/she may be given the day off without pay, at the discretion of the ecologist or crew leader.

Use of illegal drugs at any time on National Park property, whether work time or off hours, will not be permitted. Violation of this rule will result in disciplinary action and potentially, loss of employment.

3.6 Pre-existing medical conditions

Crew member with pre-existing medical conditions are encouraged, with discretion, to discuss these with their supervisor or other crew members. Knowing about conditions such as diabetes, allergies, and seizures can affect the actions taken by the crew leader or crew members in the event of an emergency.

3.7 Injury reporting

All injuries and illnesses must be reported using the national online safety information management system: www.smis.doi.gov. Once at this site, click on the “Accident Reporting” button. The type of claim filed will depend on the nature of the accident or injury.

Appendix A: Job Hazard Analysis Form

REQUIRED EQUIPMENT & TOOLS FOR JOB	REQUIRED SAFETY EQUIPMENT
Working in Forested and Wetland Environments	Raingear, park radio, leather boots, crew first aid kit, long pants and shirt, gloves.

POTENTIAL HAZARDS	SAFETY CONTROL FACTORS
1) Slipping and falling	a) wear appropriate footwear b) slow down and watch for obstacles
2) Rain / Inclement weather	a) dress appropriately b) bring raingear c) wear sunscreen if appropriate d) drink plenty of water e) look for protection if weather becomes untenable
3) snags and unstable trees	a) communicate with fellow workers b) be wary of all snags and leaning trees c) do not lean up against any tree
4) Insects and Animals	a) wear PPE including insect spray b) look before you step c) carry first aid kit d) make noise to warn animals of approach when hiking e) be informed of appropriate measures to take in case of a bear encounter
5) Allergies	a) inform co-workers maintain on crew allergy list carry and know how to use appropriate medications (epi-pen) if necessary

Using the Global Positioning System

STANDARD OPERATING PROCEDURE #4

Version 1.0 (7/1/08)

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4.0 Introduction

This Standard Operating Procedure (SOP) provides guidance on some of the more common operations associated with global positioning system (GPS) units. This includes guidance for loading predetermined site locations, data dictionaries, and maps, as well as for post collection processing of samples. In addition, it also covers GSP standards to be met by GLKN. Although most GPS units are capable of multiple functions, only those operations relevant to the protocol established to monitor vegetation (Sanders et al. 2007) are discussed. GPS units currently (2007) used by the vegetation monitoring staff are the Trimble GeoXT and Garmin 76CSx.

As of 2007, software pertinent to the use of these GPS units includes:

- TerraSync (Trimble GeoXT) – single table forms software
- GPS Pathfinder Office 4.00 (Trimble GeoXT) – desktop GPS processing software
- ESRI ArcGIS 9.x (Trimble GeoXT or Garmin 76CSx) – desktop GIS software

Due to the rapid development of commercial software and hardware capabilities, it is likely that other GPS units or software will be utilized in the future. Therefore, this SOP is meant to act as a working document that is updated periodically as new hardware and software become available. Although nomenclature may differ depending on what hard-software is utilized, this document should provide sufficient guidance on the general process of data collection using GPS tools until the SOP is revised. Vegetation monitoring staff will obtain unit-specific GPS training prior to deploying in the field. The training will include hands-on use, and will be designed to test all appropriate functions and operations prior to going out into the field. Additionally, this SOP is not intended to be exhaustive or simply a regurgitation of operating manuals, but a document that might be carried into the field or periodically reviewed by field technicians and project leaders. Although some of the information in this SOP is specific to the vegetation monitoring effort by GLKN, much of the text contained herein is applicable to other data collection efforts by GLKN staff. The objective of this document is to summarize GPS use guidelines applicable to the vegetation monitoring efforts at GLKN partner parks.

4.1 Role of GPS in Vegetation Monitoring

GPS units are primarily used in two ways to support vegetation monitoring:

Navigation: Field personnel will be supplied with both topographic and aerial imagery maps for navigation. In addition, permanent plot locations will be loaded into the GPS units prior to commencement of field work. However, because the plot locations are in forested areas with little or no landmarks nearby, field crews will primarily rely on GPS units for navigation.

Recording permanent plot locations: GPS units will be used to record the location of all six transect endpoints (hybrid plot) or all four subplot centers (FIA-style plot).

4.2 Using Mapping-Grade GPS Units

All mapping-grade GPS (sub-meter accuracy) users should become familiar with GLKN GPS collection procedures and relevant manufacturer's user guides and operating manuals before GPS operation. For example, prior to using a Trimble GeoXT GPS unit, the following documents should be reviewed:

- Appendix A of this SOP
- GeoExplorer CE Series: Getting Started Guide
- GPS Mapping for GIS with TerraSync and GeoExplorer CE Series or TerraSync Operation Guide v2.4x
- Basic GPS Data Capture Using TerraSync: A Quick Start Guide

Mapping-grade (sub-meter accuracy) GPS units provide the user with a variety of tools for field data collection. GLKN encourages the use of these units for most projects. These units can be used to acquire spatial data related to points, lines, and polygons along with associated, user defined, tabular attributes. Careful forethought and advanced planning are required to take advantage of these capabilities long before data collection begins.

Data Dictionaries

TerraSync software on mapping-grade GPS units is capable of using data dictionaries. Data dictionaries define the structure and rules to store attribute information about the feature being mapped and are customized for each project. GLKN data management personnel should be directly involved in the creation of data dictionaries. For the vegetation monitoring protocol, we will use data dictionaries to store the coordinates of transect endpoints (hybrid plot) or subplot centers (FIA style plots).

GPS Settings

Positional accuracy of GPS data can be affected by several factors that can be monitored and recorded with mapping-grade GPS units. Table 1 lists these factors, their definitions, and the standard settings for GLKN field work. All spatial data collected shall be analyzed for spatial accuracy and shall meet or exceed the National Map Accuracy Standards (Table 1 in Appendix A, and <http://mapping.usgs.gov/standards>).

Table 1. GPS receiver settings, definitions, and standards for use at GLKN parks.

Setting Name	Definition	GLKN Setting Standard
Almanac	File containing estimated position of satellites, time corrections, and atmospheric delay parameters	Acquired automatically by GPS unit or from online sources within 10 days prior to GPS field work
Altitude reference	Ellipsoid model	Height above Ellipsoid (HAE) (preferred) or Mean Sea Level: if MSL is used, indicate Geoid Model
Antenna height	GPS antenna height above the ground	Variable, usually 1.0 meters for handheld and 1.5 m for backpack
Datum	Geodetic model designed to fit a point on the earth's surface to an ellipsoid	NAD 83 (CONUS) [preferred] WGS 84 [GPS default, as fallback]
Elevation mask	The minimum angle above the horizon at which a GPS receiver will track a satellite	15 degrees
Feature types	Geometry of spatial data	GIS native formats; point, line and polygon are preferred
Logging interval	Time interval between the recording of individual GPS fixes	Points: 1 second
Minimum fixes for point positions	Number of GPS fixes that are used to calculate a single position for a point feature	50 fixes
Mode	2 dimensional for horizontal positions and 3 dimension with an elevation position	3-dimensional (4 satellite minimum)
PDOP mask	Positional Dilution of Precision, a GPS quality estimate based on satellite geometry	6.0 or less
Real-time settings	GPS unit may be capable of performing differential correction of data during collection	Select Integrated WAAS (unless using H-star, e.g., XH unit); setting will be 'auto' or 'on'
Satellite vehicles	Number of satellites used for position fixes	4 minimum
SNR mask	Signal-to-Noise ratio is a measure of the satellite signal relative to background noise	4.0 minimum, 6.0 or greater preferred
Unit of measure	Linear unit of measure	Meter (metric)

GPS signals are received in the WGS84 datum. Processing and transformation of the positional information to other datums can take place internally in the GPS unit or in software, either the GPS data processing software (see below) or in GIS software. GPS data that will receive no post-processing differential correction, unlikely with a mapping grade receiver, can be collected in native WGS84 or NAD83 (CONUS), and ensuring that the datum used is recorded in the metadata. More likely with a mapping grade receiver, the GPS data will be differentially corrected after collection using data from one or more reference base stations. The majority of public base stations in the US are part of the National Geodetic Survey's Continuously Operating Reference Station (CORS) network; and output information in the NAD83 CORS 96 datum. Setting the GPS unit to record data in NAD83 CORS 96 datum will result in the most accurate spatial information when differentially corrected against a CORS base station. A very high precision mapping grade unit may use H-Star technology, which requires post collection

differential correction; using the NAD83 CORS 96 datum and no real-time correction (WAAS) on the GPS unit, and correcting against a group of CORS base stations is necessary to realize the maximum accuracy from an H-Star receiver.

Before beginning data collection, the GLKN data management staff or the GPS user should complete some mission planning tasks. Having printed copies of topographic maps with plot coordinates is essential to maximize field time and efficiency when navigating to sites. Many mapping-grade GPS units have the capability of storing and displaying background maps or GIS layers, which can be very helpful when navigating in the field. For example, topographic maps of the Saint Croix River, which also show landings and tributaries, can be used with GPS units. The GLKN data management staff can support preparation of these background layers and, if necessary, assist in loading them onto the GPS hardware.

GPS units create files to store data during a field session using a prefix and date-time stamp as file names. For example:

RMMDDHHx

R – Unit Prefix

MM – Month

DD – Day

HH – Hour

X – a, b, c, etc., the order files are created within an hour

If multiple GPS units are used for a project, a unique prefix (letter) should be assigned to each unit, which will ensure that downloaded files for each unit contain a unique identifier within the filename. For example, with three GPS units, the unique letters for the units could be N, G, and A. Those letters would serve as a prefix for the file n (e.g., N102715A, G102715A, and A102715A would indicate units N, G, and A, October 27, 15 hour, A first in hour).

Each user should be familiar with the capabilities of the GPS hardware and field computers. If possible, vegetation monitoring staff should receive hands-on instruction from someone familiar with the equipment. At a minimum, the equipment user guides and operator's manuals should be reviewed, and the operator should test the functions s/he intends to use.

It is extremely important that each user become familiar with the battery power and memory capabilities of the GPS units. All units have limited battery and memory resources; these features should be thoroughly tested to gain an understanding of the power and memory limitations of the GPS units before being deployed in the field. It is possible to power or recharge these units from a DC power source, such as a vehicle power outlet.

Data Collection

Data collection should be performed using an approved data dictionary or database for the protocol, if applicable. Moreover, users should be mindful of the following concepts: Mapping-grade GPS units have additional features that aid in data collection. These include:

- *Offset Feature* – Allows user to collect a feature when topography is such that getting next to or over the feature is impossible. For example, if the coordinates at a plot center or transect

endpoint cannot be obtained, coordinates can be collected nearby and a distance and angle to the desired location recorded. The offset feature can then be used to determine the coordinates of the desired location.

Data Processing:

When data collection is complete for the day or round of monitoring, data are downloaded from the GPS unit to a computer. For Trimble GPS units, the proprietary software Pathfinder Office (or the GPS Analyst extension) is used to download, differentially correct, and then export the data to a GIS format. [Note: Trimble Pathfinder Office and GPS Analyst are relatively expensive. However, Trimble also offers a free data transfer utility to download data from the GPS units to a Windows-based PC]. Detailed step-by-step instructions are provided in Appendix B of this SOP. Differential correction is a post-processing procedure to improve upon raw GPS positions using base station data. Base stations consist of a GPS antenna and receiver positioned at a known location specifically to collect data from satellites. The distance between the base station(s) and the remote GPS receiver should be kept to a minimum.

Differential correction should be conducted on all GPS data collected on a mapping grade receiver, even if data were collected using the real-time collection feature. Once the data are differentially corrected, they can be verified and edited. Unintentional features can be deleted and attributes can be reviewed. Please see Appendix B for specific step-by-step instructions on the downloading and differential correction processes.

The last step in processing data is exporting the data set to GIS (such as ArcMap). Depending on the software used for this process, newly created files generated when exporting data are often assigned generic names. For example, if Pathfinder Office is used to export a file named 'VOYA2007.cor' (.cor denotes that the file has already been differentially corrected) that only contains point features, the exported file will be named 'point_ge.shp'. Great care should be taken to not overwrite this file when exporting other data, as the software will continue to use this generic naming convention the next time it is used. In addition, during the export process, the coordinate system to which the data will be exported to should be verified (Table 2).

Managing the incoming GPS data can be a challenge, especially if there are multiple units per project. Common practices used by GLKN include:

- Download all data to a computer or network drive that is regularly backed up.
- Keep GPS data and GIS data separate through electronic file management. Directories and files names should not contain non-alpha-numeric characters and/or spaces (except underscores).
- Keep GPS data in well-organized directories (see Hart and Gafvert (2005), GLKN Data Management Plan, for more details).

Table 2. UTM zones for Great Lakes Network parks.

Park	UTM Zone	Datum
APIS	15	NAD 1983 (Conus)
GRPO	16	NAD 1983 (Conus)
INDU	16	NAD 1983 (Conus)
ISRO	16	NAD 1983 (Conus)
MISS	15	NAD 1983 (Conus)
PIRO	16	NAD 1983 (Conus)
SACN	15	NAD 1983 (Conus)
SLBE	16	NAD 1983 (Conus)
VOYA	15	NAD 1983 (Conus)

Additional data attributes can be included in the data exports. Data attributes recommended by GLKN are listed in Table 3.

Table 3. Recommended fields to be exported in addition to GPS features.

All Features	Point Features	Line Features	Area Features
PDOP	Height	Length (2D)	Area (2D)
Correction status	Position	Length (3D)	Perimeter (2D)
Receiver type			Perimeter (3D)
Date recorded			
Data file name			
Total positions			
Data dictionary name			

At the end of a project, all data and background files should be removed from the GPS unit to free available memory. Data files should not be left on a unit if they have been properly downloaded and verified. In addition, some GPS units require their batteries to be re-charged periodically. Failure to do so can cause the GPS unit batteries to discharge completely, and may cause some files and software to be deleted.

Additional information can be found at <http://www.nps.gov/gis/gps/gps4gis/>, which describes the steps outlined here in greater detail.

4.3 Using Recreational-Grade GPS Units

Recreational-grade GPS units can be used to acquire location information when there are problems with the mapping grade GPS units working correctly. Recreational GPS units do not have data dictionaries for storing attribute information with the point location. However, using a recreational-grade unit to record transect endpoints and subplot centers at each site is a reliable alternative when mapping-grade units cannot be used.

As with mapping-grade GPS units, personnel that employ recreational-grade GPS units should become familiar with GLKN GPS collection procedures and relevant manufacturer's user guides and operating manuals before GPS operation. For example, prior to using a Garmin 76CSx (recreational-grade) GPS unit, the following documents should be reviewed:

- Appendix A of this SOP
- GPSMAP 76CSx Quick Start Guide
- GPSMAP 76CSx Owner's Manual and Reference Guide
- Garmin MapSource™ User's Manual and Reference Guide

Planning

If a recreational-grade GPS meets the criteria of the project, the unit chosen must have the capability of downloading collected data to a personal computer. Downloading data is usually accomplished with a parallel or USB cable connection.

The monitoring sites must be loaded onto the GPS unit before departure to the field in the event that the recreational-grade GPS units will be used for navigation. Some recreational grade GPS units have the ability to store and display topographic maps, which can aid in navigation. These should also be loaded beforehand.

Much of the data collected by GPS will eventually reside in a relational database. Each GPS feature collected should contain a unique identifier that relates the feature to an associated record in a database. For vegetation monitoring, the records associated with each GPS feature will be vegetation parameters. Since recreational GPS units have only one text field for input, careful consideration should be given to the use of this field and the design of unique identifiers. GLKN data management and GIS staff can assist in creating unique IDs on a project by project basis.

Data Collection

Location data are captured by recreational-grade GPS units as *waypoints*. When taking a waypoint, enter the site ID or site designation in the text field provided. This ID should be consistent with the naming convention used in the data dictionaries. For example, transect endpoint 5 of plot 7045 will be labeled as “7045-5”; the center of subplot 2 at plot 4058 will be “4058-2”.

Data Processing

Data should be downloaded from GPS units once a day or after each field session. The DNR Garmin freeware product: (<http://www.dnr.state.mn.us/mis/gis/tools/arcview/index.html>) can be used to download data from Garmin GPS units. Data should be downloaded both as a text file and a shapefile. Each file name should include the download date. Points should be checked for reasonable spatial accuracy and errors. Subsequent downloads should be error-checked in the same manner. When data collection is finished, all files should be compiled into one spatial file, and along with the raw downloads, should be saved to the appropriate location on Great Lakes Network servers.

4.4 Metadata

Regardless of the type of GPS unit used to collect data, all resulting GIS datasets need to have information documenting how the GPS data were collected. NPS requires that FGDC (Federal Geographic Data Committee, www.fgdc.gov/index.html) compliant metadata be written for all geospatial layers created (Executive Order 12906). Until final FGDC metadata is written, the data collection and management process is incomplete. Tracking GPS projects depends on the

complexity of the project, how many participants, length of project etc. Documentation can be a simple 'readme' text file, or a detailed daily log.

The Great Lakes Network recommends formal metadata be written by the data collectors, as they are the ones familiar with the project and resulting data. However, Network data management and GIS staff are usually the ones documenting someone else's work. Chapter 7 of the GLKN Data Management Plan (Hart and Gafvert 2005) includes a detailed discussion of metadata procedures. At a minimum, the following details should be documented to facilitate final FGDC metadata:

- Name of project
- Name(s) of data collectors
- EHE/EPE or maximum PDOP (using 4 satellites)
- Coordinate system (projection, datum, and zone)
- Type (or types) of GPS units used
- The range of field collection dates
- Name of base station(s) used for differential correction
- Name and version of software used for downloading
- Any major editing performed on the raw data (e.g., moving of points)
- All versions of data dictionaries used

4.5 QA/QC

Long-term monitoring is only useful if users have confidence in the data. Efforts to detect trends and patterns in ecosystem processes require high-quality, well-documented data that minimize error and bias. Data of inconsistent or poor quality can result in loss of sensitivity and lead to incorrect interpretations and conclusions.

NPS Director's Order #11B: Ensuring Quality of Information Disseminated by the National Park Service (www.nps.gov/policy/DOrders/11B-final.htm) specifies that information produced by the NPS must be of the highest quality and based on reliable data sources that are accurate, timely, and representative of the most current information available. Therefore, GLKN will establish and document procedures for quality assurance (QA) and quality control (QC) to identify and reduce the frequency and significance of errors at all stages in the data life cycle. Under these procedures, the progression from raw data to verified data to validated data implies increasing confidence in the quality of those data. Quality assurance and quality control procedures will document internal and external review processes and include guidance for addressing problems with data quality.

Examples of general of QA/QC practices include:

- Standardized field data collection forms
- Use of field computers and automated data loggers
- Proper calibration and maintenance of equipment
- Training of field crew and data technicians
- Database features such as built-in pick lists and range limits to reduce data entry errors

- Automated error-checking routines

Many of the standard operating procedures associated with the protocol for monitoring vegetation include a discussion of QA/QC as it relates to the protocol. Examples of QA/QC practices pertaining to use of GPS include:

- Ensure that GPS-related software is periodically updated as it becomes available and has been tested.
- For each plot, compare location positions for different visits, including the position recorded during establishment of the monitoring station. This will allow for an assessment of position accuracy over time.
- Check to see if the accuracy of the GPS unit meets or exceeds the National Map Accuracy Standards shown in Table 1 of Appendix A.
- Ensure that the appropriate coordinate system is used when collecting and exporting data.
- Use mapping software (e.g., Pathfinder Office or ArcGIS 9.x) to view features (or waypoints) overlaid on a geo-referenced air photo or topographical map to check for accuracy.
- If applicable, check the accuracy of the attribute(s) recorded on a GPS unit by using mapping software (see bullet above) and look-up tables or in spreadsheets generated after post-processing is complete.

A final report on data quality, including data collected by GPS, will be incorporated into the documentation for this project. Such documentation will include a listing of the specific methods used to assess data quality and an assessment of overall data quality prepared by the project manager. This is a necessary part of the data quality elements of the metadata file.

4.6 Literature Cited

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Appendix A

This appendix discusses the role of GPS in GLKN data management and provides an explanation of the types of GPS units that are available. The text is taken directly from the GLKN GPS Field Collection Guide, which can be found in its entirety in Appendix K of the Great Lakes Inventory and Monitoring Data Management Plan (Hart and Gafvert 2005).

Introduction

Over the past decade new tools have been developed to help researchers collect and manipulate data while in the field. Global Positioning System (GPS) is one such tool. GPS is currently a constellation of 28 US Department of Defense satellites (as of 2006) orbiting 11,000 miles above the Earth, making a complete orbit approximately every 12 hours, and transmitting signals to Earth at precisely the same time. The position and time information transmitted by these satellites is used by a GPS receiver to triangulate a location coordinate on the earth using three or more satellites.

Role of GPS in GLKN Data Management

Data collected using GPS-enabled equipment represents all or part of the acquisition stage of an information resources lifecycle that includes several other stages (see Section 5.4 in GLKN Data Management Plan). The process and methodology used for acquisition, planning, data collecting, and post-processing incorporate several aspects of data management, including quality assurance, data storage and organization, and data stewardship. To promote data quality and simplify data management, the Great Lakes Network expects to use electronic data logging equipment for some data acquisition. However, parallel or complementary use of hand written data sheets and field notes will remain important for data collection activities.

Types of GPS units

At the most basic level GPS equipment can just consist of a GPS antenna and the associated signal processing circuitry. The antenna can be a standalone device, be incorporated in to a handheld unit, or be integrated into a larger electronic device, such as a personal data assistant (PDA), data logger, or portable computer. As technology evolves, the Great Lakes Network will continually try to use equipment which maximizes spatial accuracy; reduces hardware weight and user fatigue; and reduces database development, data manipulation, and transformation.

There are three major types of GPS units that are based on the level of accuracy to which spatial data can be collected. Survey-grade GPS units are used for surveying tasks that require very high accuracy (1 cm or less). Mapping-grade units can map features from sub-meter to less than 5m accuracy, employing differential correction. Recreational-grade GPS units are sold primarily for outdoor sports and recreational activities. Accuracy using recreational GPS units ranges from 5 to 30m. Most natural resource-related data collection requirements correspond to either the recreational-grade or mapping-grade.

Figure 1 shows some of the major differences between these two types. Deciding which type of unit to use is an essential part of project planning, and depends on the end product needed. Mapping-grade GPS units are recommended for most GLKN field work; however, for some projects recreational-grade units can meet a project's accuracy requirements and reduce the cost

of field operations. The choice of GPS unit should be made by the project manager after consulting with the GLKN data management and GIS staff.

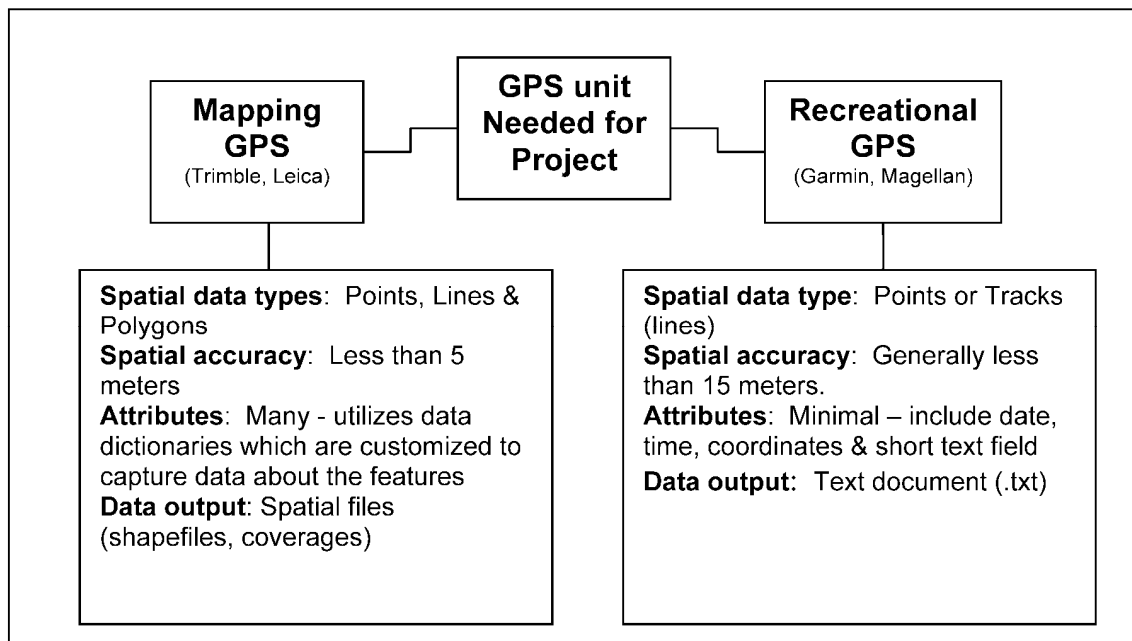


Figure 1. Differences between different grades of GPS units.

All resulting GIS data layers need to meet or exceed the National Map Accuracy Standards for a 1:24,000 product (NPS GIS Data Standards, 2002 http://www.nps.gov/gis/data_info/standards.html). Table 1 provides the allowable horizontal accuracy for some common scales.

Table 1. Map scales and allowable error.

Scale	Allowable Error
1:40,000	33.8 meters (111 feet)
1:31,680	16.1 meters (53 feet)
1:24,000	12.2 meters (40 feet)
1:20,000	10.1 meters (33 feet)
1:12,000	6.1 meters (20 feet)
1:9,600	4.9 meters (16 feet)
1:4,800	2.4 meters (8 feet)
1:2,400	1.2 meters (4 feet)
1:1,200	0.6 meters (2 feet)

Definitions

Accuracy - The degree of conformance between the estimated or measured position, time, and/or velocity of a GPS receiver and its true time, position, and/or velocity as compared with a constant standard.

Almanac -Data transmitted by a GPS satellite, which include orbit information on all the satellites, clock correction, and atmospheric delay parameters. The almanac is used to facilitate rapid satellite vehicle (SV) acquisition. The orbit information is a subset of the ephemeris data with reduced precision.

Attribute – Tabular information about a specific feature.

Base Station - GPS files collected continuously from community base stations, local base stations, or Continually Operating Reference Stations (CORS). Gathering base files will require an internet connection and software that dials into a server that houses the base station data collected at the same time of the rover. Data stored on these servers will not be available in real-time - hence this step is conducted after field collection. Trimble users would use the Differential Correction utility supplied in Pathfinder Office.

Differential Correction - The merging of rover file data with base map data to correct position errors due to atmospheric interference. Autonomous data (rover) are collected in the field while base data are stored at the stationary base station. The two datasets are loaded into a post-processing software package where corrections are applied. This process will reduce errors in the field collected data (the rover) by correlating and correcting for known errors recorded in the base file that has the same time tag. As distance between the rover and base file increase, there is degradation in post-processed accuracy. In general, a degradation of one part per million (1ppm) occurs as the distance between the base station and rover increases. For example, one millimeter of degradation occurs for every kilometer between base and rover.

Datum (*geodetic datum*) – A mathematical model that is designed to fit a point on the earth's surface to an ellipsoid. Commonly used datums are North American Datum (NAD) 1927, and NAD 1983, modeled to represent the North American continent.

Feature - A feature is the spatial location of a physical object, or some event or phenomenon. Features are often referred to as graphic data in a GIS. Examples include a tree (point), road (line), or land parcel (polygon).

FGDC - The Federal Geographic Data Committee is a 19 member interagency committee composed of representatives from the Executive Office of the President, Cabinet-level and independent agencies who develop policies, standards, and procedures for organizations to cooperatively produce and share geographic data. (www.fgdc.gov/index.html)

Global Positioning Systems (GPS) – a constellation of a minimum of twenty-four satellite vehicles orbiting the earth approximately every twelve hours at an approximate pacing of sixty degrees, between 11,000 – 12,000 miles above the surface of the Earth

Lines – geographic term related to the scale that describe how a feature is drawn. Lines are linear measures of a feature (such as a line representing a trail)

Mapping Grade – GPS receivers capable of attaining five meters of accuracy or better using differential correction.

Metadata - Data about the data. Usually comes in the form of a text or html document with information on the dataset's quality, current projection, attributes, distribution and citation. In the National Park Service, this generally implies a file compliant to the FGDC Content Standard for Digital Geospatial Metadata.

Multipath – error which occurs when a GPS signal sent from a satellite vehicle is bounced or redirected by an object, prior to reaching a GPS receiver. Multipath will cause the time it takes a GPS signal sent by a satellite vehicle to reach a GPS receiver to be inflated. This will cause inaccuracies in positions collected.

Points – geographic term related to the scale that describe how a feature is drawn. Points are single dimensional features (such as a point representing a spring).

Polygons - geographic term related to the scale that describe how a feature is drawn. Polygons have area associated with the feature (such as a circle representing a parking lot).

Projection - A method of representing the earth's three-dimensional surface as a flat two dimensional surface. This normally involves a mathematical model that transforms the locations of features on the earth's surface to locations on a two-dimensional surface.

Post Processing – utilizing base station data, GPS software, and data acquired by a GPS receiver in the field to gain an accurate fixed position.

Triangulation - The process of determining the distance between points on the earth's surface by dividing up a large area into a series of connected triangles, measuring a base line between two points, and then locating a third point by computing both the size of the angles made by lines from this point to each end of the base line and the lengths of these lines.

Waypoint – a named 3 dimensional position on the earth's surface, that is, having both a latitude and longitude. Waypoints are assigned to a fixed location in the field so it can be navigated to consistently and accurately through time.

Appendix B

This appendix discusses the step-by-step process for downloading and differentially correcting GPS data collected by the vegetation monitoring program.

Overview

This Standard Operating Procedure (SOP) is an addendum to the GLKN GPS Field Data Collection Guide, which covers more general GPS use. This document covers equipment and procedures specific to collecting location information with sub-meter accuracy. The collection of ground control information in development of ortho-photography from aerial imagery is used as an example, but the same principles will apply when other data collection requirements specify very high accuracy.

This SOP is specific to the Trimble GeoXT unit; subsequent upgrades or new versions will require updating this document. Trimble XT Series GPS units are capable of acquiring sub-meter accuracy when used with an external antenna, (Zephyr antenna), and when the raw data collected in the field is properly post-processed using differential correction of H-Star data.

The current GPS hardware for GLKN consists of a Trimble ProXT GPS Receiver, with a Bluetooth wireless connection to a PDA running Windows Mobile OS, and a Zephyr dual frequency antenna.

Post-processing (differential correction) should be performed as soon as possible after data collection. The CORS base station data is usually available within a 2 hour lag time, though occasionally there are periods of time when data is not available, either due to malfunction of equipment, inadequate satellite coverage, or high ionospheric disturbance. These factors are not within the control of the field personnel collecting the data, but post-processing will uncover these problems. Any affected locations should be revisited to obtain high accuracy information.

CORS stations maintain complete records for only 30 days, after which the data collection interval is reduced from 1, 5, or 30 second, depending on the station, to 30 minute intervals. This is done in order to save hard drive space. Differential correction files that are downloaded should be archived with the data, so that high temporal resolution base station files are available, in the event that post-processing needs to be redone on a dataset at a later time.

Field Operations

The steps below for field data collection are specific to the hardware configuration currently used by GLKN. The following settings will provide the best accuracy with the ProXT unit, and the Network will also provide a standard data dictionary (.ddf file), and Terrasync configuration file (.tcf file), in order to ensure those settings are programmed into the unit.

In TerraSync Setup, select Logging Settings

Verify: Log Velocity Data No

Measure and input precise antenna height

Allow Position Update Confirm

Confirm End Feature No

Filename Prefix J or S, depending on unit

Between Feature Logging Style Off

In TerraSync Setup, select Coordinate System

Verify: System UTM

Zone 16 North (for GRPO, INDU, ISRO, PIRO, SLBE)

15 North (for APIS, MISS, SACN, VOYA)

Datum NAD 1983 (Conus) CORS96

Altitude Reference Height Above Ellipsoid

Altitude and Coordinate Units Meters

Display USNG Off

In TerraSync Setup, select Real-time Settings

Use Uncorrected GPS

Post-processing the Data

The Network is currently using Pathfinder Office (v.4.00) for completing differential correction on the field data files. Alternatively, ArcGIS GPS Analyst may be used, and is an extension to ArcGIS, available from Trimble. Both software packages effectively accomplish the same task using a nearly identical interface.

Data files should be downloaded from the PDA shortly after returning from the field. This is done using the 'Data Transfer' option under Utilities within Pathfinder, and the files are downloaded as a bundled .ssf file. The PDA must be connected to the computer, and ActiveSync is used to establish the communication. In Pathfinder Office, select the file, and go through the differential correction utility.

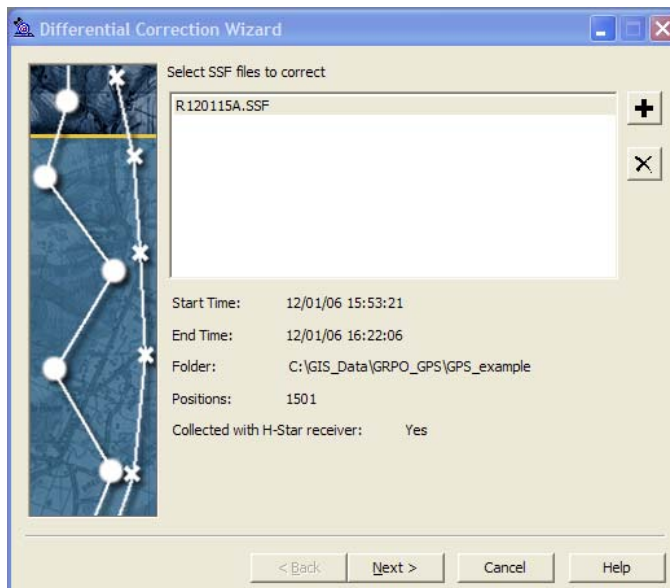


Figure 2. Differential correction wizard using Pathfinder Office. Note that the last line verifies that H-Star quality data was collected in the field.

Select Automatic Standard Carrier and Code Processing radio button in the next dialog box, then proceed through verifying processing parameters when clicking 'Next' again.

Selections in the next dialog box should be as indicated in the screen capture below:

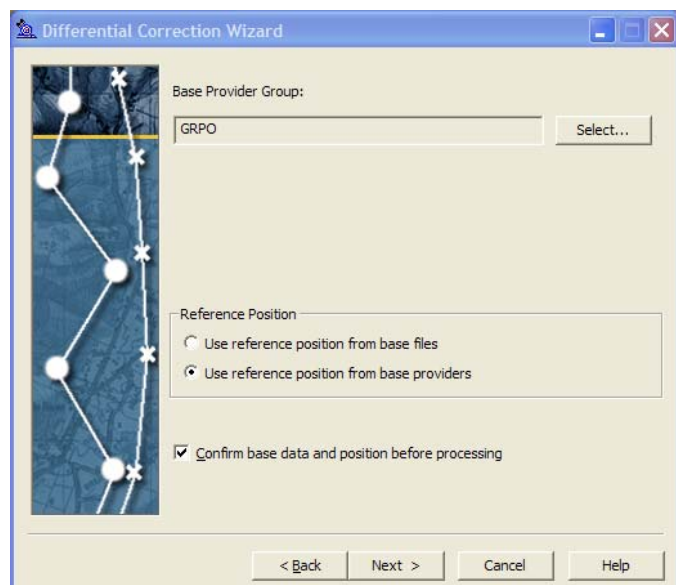


Figure 3. Select Use reference position from base providers

Using reference position from base providers ensures that all data will be in WGS 84 reference frame (or datum). Trimble maintains a database in which all station locations are based on WGS84 (or ITRF). Selecting as above accesses that database rather than using the data directly from base files. Also click on 'Confirm data and position before processing' radio button. This will check for any discrepancies between the base provider file in the Trimble software with the actual base station location information.

There are three relevant files in gathering information on each CORS station, and are accessible from the NGS website (<http://www.ngs.noaa.gov/CORS/>). These are the *data sheet*, *log file* and *RINEX2* file. It is advisable to manually verify the location of the base station by downloading the *data sheet* from NGS.

The following example is for Wisconsin Point 1 (WIS 1)

RN1701

RN1701 DESIGNATION - ENTRY
 RN1701 PID - RN1701
 RN1701 STATE/COUNTY- WI/DOUGLAS
 RN1701 USGS QUAD - SUPERIOR (1994)

RN1701
 RN1701 *CURRENT SURVEY CONTROL
 RN1701

RN1701*	NAD 83(1997) -	46 42 16.09557(N)	092 01 01.14242(W)	ADJUSTED
RN1701*	NAVD 88 -	184.850 (meters)	606.46 (feet)	ADJUSTED

This example indicates that the coordinate data provided is in NAD83, not WGS84. In this case, using location data directly from this CORS station will mix NAD83 data with the other WGS84 station data. This would introduce significant error into the 'corrected' positions. Selecting

Reference Position from Base Providers, (see Figure 3), will ensure that the correction from this station is done using WGS84.

The *log file* provides additional information, for example, the Point of Contact agency information. In the case of Wisconsin Point 1, the U.S. Coast Guard is the agency, and this agency typically outputs correction data in NAD83 rather than WGS84.

11. On-Site, Point of Contact Agency Information

```

Agency : U.S. Coast Guard
Preferred Abbreviation : (A10)
Mailing Address : (multiple lines)
Primary Contact
  Contact Name : Supervisor, Shore Support (DGPS) C2CEN
  Telephone (primary) : 757-686-4064
  Telephone (secondary) :
  Fax :
  E-mail :
Secondary Contact
  Contact Name :
  Telephone (primary) :
  Telephone (secondary) :
  Fax :
  E-mail :

```

The *RINEX2* file has information on observation frequency (1 sec, 5 sec, 30 sec), and whether single or dual frequency (L1 & L2) data is collected. Dual frequency data collection is required in order to post process HStar data.

```

4-character ID : wis1 (# = 49871S001)
Receiver type : ASHTECH Z-XII3 (# = 05486) (fw = RD00)
Antenna type : ASH700829.3 SNOW (# = 11940)

Time of start of window : 2007 Jan 1 00:00:00.000
Time of end of window : 2007 Jan 1 23:59:30.151
Time line window length : 23.99 hour(s), ticked every 3.0 hour(s)
  antenna WGS 84 (xyz) : -154015.0664 -4379030.8537 4619413.5969 (m)
  antenna WGS 84 (geo) : N 46 deg 42' 16.77" W 92 deg 00' 51.56"
  antenna WGS 84 (geo) : 46.704659 deg 267.985678 deg
    WGS 84 height : 140.5613 m
|qc - header| position : 82 m
Observation interval : 30.0000 seconds
Total satellites w/ obs : 31
NAVSTAR GPS SVs w/o OBS : 32
NAVSTAR GPS SVs w/o NAV :
Rx tracking capability : 12 SVs
Poss. # of obs epochs : 2880
Epochs w/ observations : 2880
Possible obs > 0.0 deg: 32366
Possible obs > 5.0 deg: 28409
Complete obs > 5.0 deg: 24439
Deleted obs > 5.0 deg: 35
Moving average MP1 : 0.580744 m
Moving average MP2 : 0.614103 m
Points in MP moving avg : 50

```

```

No. of Rx clock offsets : 151
Total Rx clock drift    : +151.000000 ms
Rate of Rx clock drift  : +6.294 ms/hr
Avg time between resets : 9.533 minute(s)
Freq no. and timecode   : 2 9857 ffffff
Report gap > than       : 10.00 minute(s)
epochs w/ msec clk slip : 0
other msec mp events    : 1 (: 41) {expect ~= 1:50}
IOD signifying a slip   : >400.0 cm/minute
IOD slips < 5.0 deg*    : 0
IOD slips > 5.0 deg     : 15
IOD or MP slips < 5.0*  : 0
IOD or MP slips > 5.0   : 16
* or unknown elevation
first epoch  last epoch  hrs  dt  #expt  #have  %  mp1  mp2
o/slps
SUM 07  1  1 00:00 07  1  1 23:59 23.99 30 28409 24439 86 0.58 0.61
1527

```

Processing parameters are:

```

Receiver tracking capability      : 12 SVs
Maximum ionospheric rate (L1)    : 400.00 cm/min
Report data gap greater than     : 10.00 min
Expected rms level of P1 multipath : 50.00 cm
Expected rms level of P2 multipath : 65.00 cm
Multipath slip sigma threshold   : 4.00 cm
% increase in MP rms for C/A | A/S : 100.00 %
Points in MP moving averages     : 50
Minimum signal to noise for L1   : 0
Minimum signal to noise for L2   : 0
Elevation mask (cutoff)          : 5.00 degrees
Elevation comparison threshold   : 25.00 degrees
Orbit path spline fit sample time : 10 min
SVs w/ code data for position try : 5
Width of ASCII summary plot      : 72
Data indicators on summary plot   : yes
Do ionospheric observable        : yes
Do ionospheric derivative        : yes
Do high-pass ionosphere observable : no
Do multipath observables         : yes
Do 1-ms receiver clock slips     : yes
Tolerance for 1-ms clock slips   : 1.00e-02 ms
Do receiver LLI slips            : yes
Do plot file(s)                  : no

```

After viewing information on the stations, select the best group of available stations:

The example shown below is for GRPO. All CORS (Continuously Operating Reference Stations) must be dual frequency carriers in order to process H-Star data.

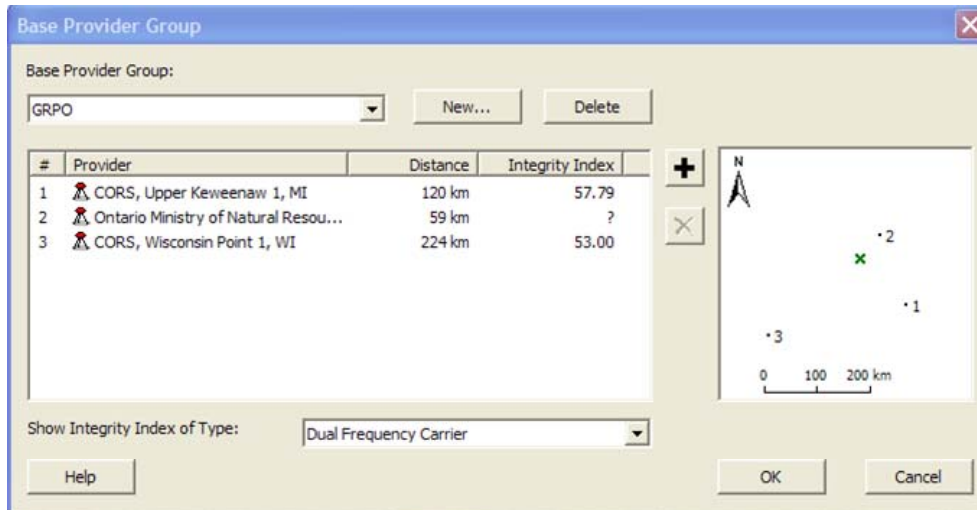


Figure 3. Selecting the available base stations

Select stations based on the following criteria:

Closest distance to GPS data collected

Must be Dual Frequency Carrier if using H-Star data

High 'Integrity Index'

Data collection frequency preferably 1 second or 5 second rather than 30 second

Once differential correction is complete, export the data using the Export utility in Pathfinder Office. Set the output coordinate system to UTM NAD83, zone 15 or 16, CORS 96 (see Table 1, below). If the user does not have Pathfinder office, there is a free data transfer utility from Trimble that will provide for bundling the raw export files from the PDA into an ssf file, which can then be sent to the GLKN Data Manager or GIS Specialist to complete the post-processing. (Go to: <http://www.trimble.com/datatransfer.shtml>)

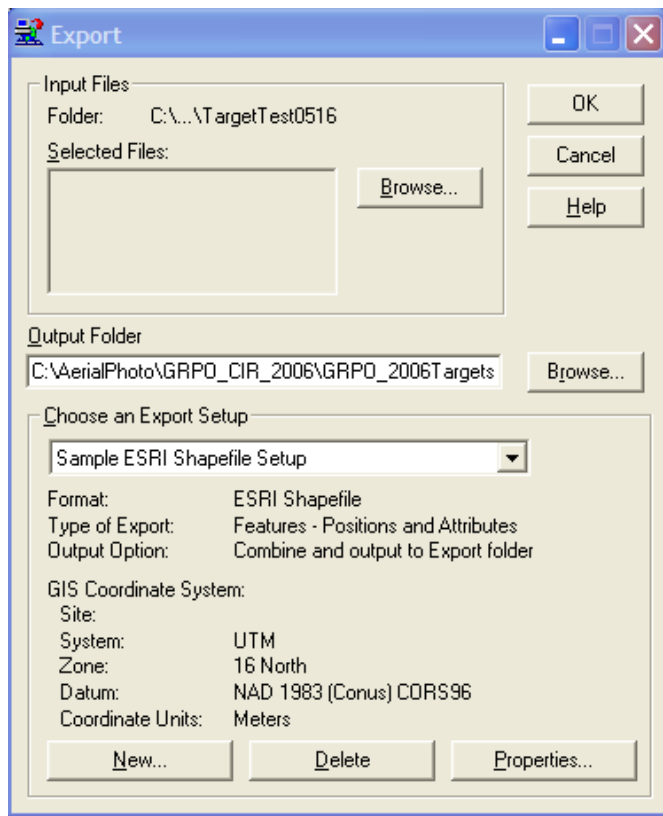


Figure 4. Export to shapefile utility in Pathfinder Office

Additionally, check that all pertinent data attributes are selected for export within the shapefile. This is done from the Properties tab on the Export page.

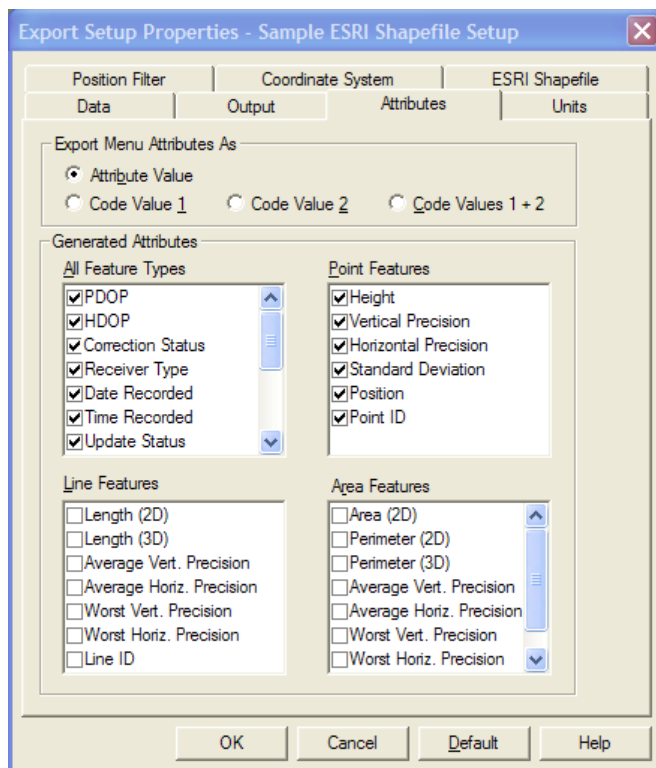


Figure 5. Ensure that all boxes above are checked when exporting corrected GPS files

Park	UTM Zone	Datum
APIS	15	NAD83 (CORS 96)
GRPO	16	NAD83 (CORS 96)
INDU	16	NAD83 (CORS 96)
ISRO	16	NAD83 (CORS 96)
MISS	15	NAD83 (CORS 96)
PIRO	16	NAD83 (CORS 96)
SACN	15	NAD83 (CORS 96)
SLBE	16	NAD83 (CORS 96)
VOYA	15	NAD83 (CORS 96)

Table 1. UTM Zones for the nine GLKN parks

Output from Pathfinder Office is in shapefile format with default name, but no projection information is created. The next step is to rename the file using standard naming conventions outlined in the GLKN Data Management Plan, open in ArcGIS, and use ArcToolbox to define the correct projection. Finally, archive the output files from Pathfinder Office.

Plot Establishment

STANDARD OPERATING PROCEDURE #5

Version 1.0 (7/1/08)

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Revision History Log:

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

5.0 Introduction

Potential sampling sites will be selected prior to fieldwork and will be limited to areas where at least 10% cover by tree species occurs (or can occur). These potential sites will be generated by a computer following a generalized random-tessellation stratified design (GRTS, Stevens and Olsen 2004). This design ensures that the points are both spatially balanced throughout the sampling frame while also randomly chosen.

Prior to field work, all potential sites will be viewed using geographic information systems by overlaying the location on aerial photography or satellite imagery. This will eliminate many sites beforehand that are not in appropriate habitat (e.g., those potential sites on beaver ponds, parking lots, or other non-forested habitats). The remaining sites will be presented to the park's natural resource manager for final comments.

All potential sites that are not eliminated by the process described above will be visited for plot establishment and data collection. While at the site, the sampling crew will perform a final check with additional criteria as outlined below.

5.1 Criteria for Accepting or Rejecting Sampling Sites in the Field

Once a site is located in the field, it must be checked to ensure that the plot falls within acceptable sampling criteria.

1) Within each transect or subplot, the ground must be at least 30% vegetated or potentially vegetated. For example, in many northern Network parks, there are large expanses of exposed bedrock. If any one transect or subplot is covered by >30% bedrock, the site must either be moved (see below) or abandoned as this cover type will never be vegetation. In contrast, areas that have recently been burned or experienced a blowdown will become vegetated over time. These areas will be monitored. In addition, the plot must not have an obstacle (stream, trail) that runs the length of a transect. If this is the case the plot must be moved to avoid this situation. A transect may cross, however, one of these obstacles.

2) There must not be any obstacles that present a safety hazard to the crew. This includes, but is not limited to, steep cliffs within the transects or subplots and hornet/wasps nests directly where plot marking will be placed.

3) The plot must be located within fully owned National Park Service lands. This latter point is especially relevant at Saint Croix NSR, where a large number of irregularly shaped, privately held inholdings are interlaced with the federally owned land on which monitoring will be conducted.

If the three criteria outlined above are not met, a plot may be moved. Movement of a plot must only be to the closest location meeting the criteria outlined above (Figure 1). No plot will be moved greater than 100 meters from the original location. If the plot cannot be moved within 100 m and meet the desired criteria, the plot will not be established and the site will not be monitored.

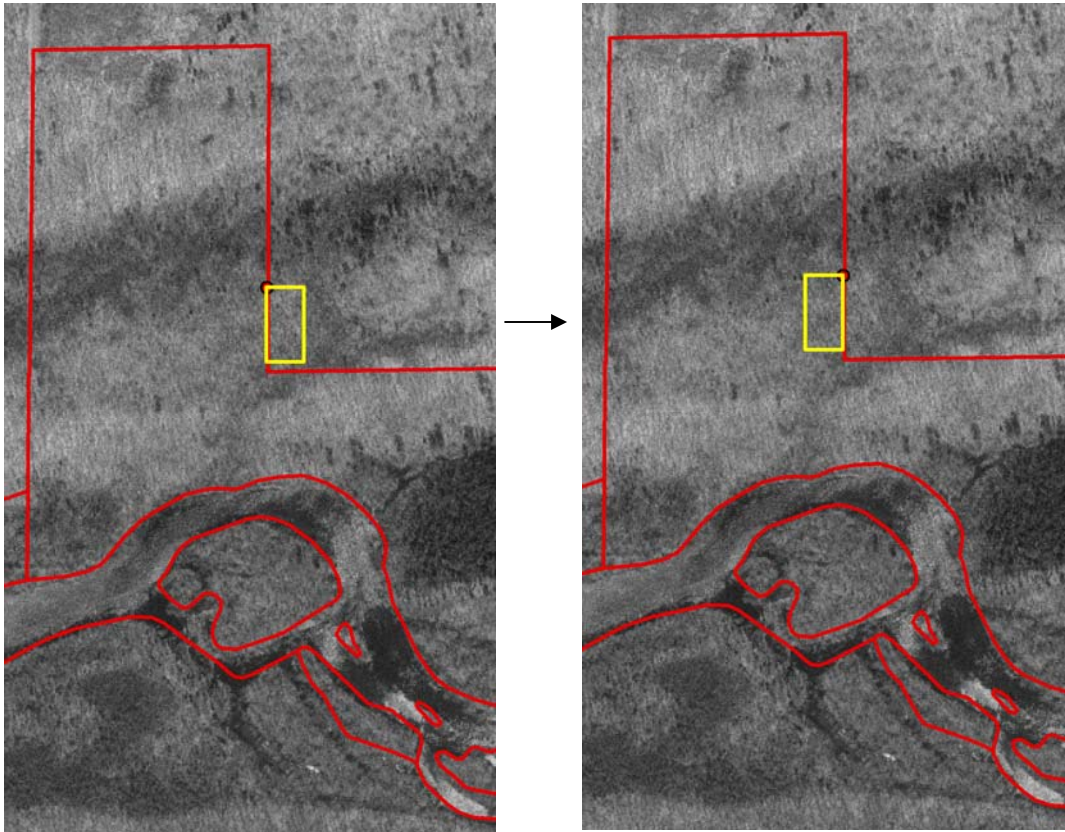


Figure 1. The red lines in the image on the left show the irregular shape of parcels of federally owned land at Saint Croix NSR. The original plot coordinates are denoted by the red dot, with the yellow rectangle in the image on the left denoting the original plot location. This plot will be moved 49 m due west to fit it entirely into the federally owned parcel.

5.2 Plot Establishment

Sampling at Great Lakes Network parks will use one of two plot types: either the hybrid style plot or the FIA style plot (see protocol narrative). All plots at any given park, however, will be of the same type. Additionally, we will be using true north as the reference from which all bearings will be taken. At all parks and years where magnetic north differs from true north by 2° or more, we will account for declination.

5.2.1. Hybrid Plot Establishment

Hybrid plots (Johnson et al. 2006) consist of three parallel 50 m transects, spaced 50 meters apart (Figure 2). The GPS coordinates of the site will be the northwest corner of the plot, corresponding to point 1 on transect 1.

Transect 1 will be laid out using a compass along with both a tape measure and electronic sonar distance measurers. Sonar measurers allow one to easily get a straight path through shrubs and brush. Pin flags will be placed along this path. A tape measure will then be pulled out along the path of the pin flags. This tape measure is needed to accurately place the location of the

herbaceous quadrats (Figure 2, and SOP 6). Specific instructions on this process are presented below.

Typically Person 1 will walk out a distance at approximately 90° , while Person 2 (at Point 1) then directs this person exactly to the correct angle (90°) using a compass. The distance that Person 1 walks will depend on the degree of brushyness. In more open plots, Person 1 may walk as far as about 25 meters, while in brushy plots, Person 1 may walk out less than 10 meters. A pin flag will be placed in the ground at the correct angle (90°) and the horizontal distance will be recorded. Person 2 will then pull the tape to the pin flag, ensuring that it is completely straight, and that it is as close to the ground as possible. Person 2 will then walk out again and this process is repeated until the entire 50 meters is laid out and Point 2 is established. Point 3 is established by following this same procedure from Point 1, with two exceptions. The angle followed for establishing Point 3 is 180° , instead of 90° . In addition, there will be no tape measure laid out. Pin flags will still be placed between Points 1 and 3 to aid in orientation when working in the plot. Following the establishment of Point 3, Transect 2 and Point 4 will be established in the same manner as Transect 1 and Point 2. Point 5 will be established in the same manner as Point 3. Finally, Transect 3 and Point 6 will be established in the same manner as Transect 1 and Point 2. It is important to note that all transect will be based on horizontal distances. GPS coordinates of all six points will be collected.

At the completion of sampling, all pin flags will be pulled up.

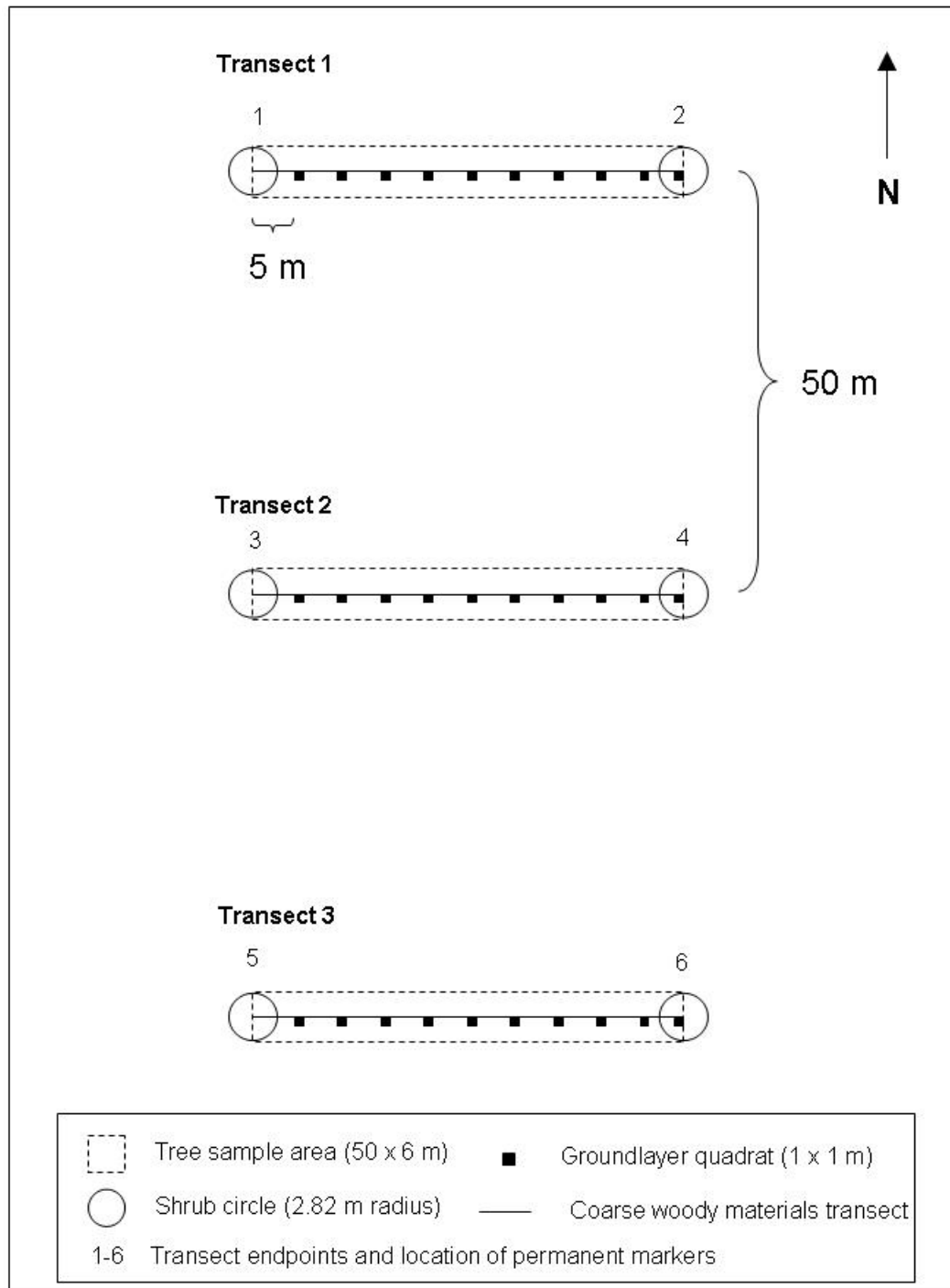


Figure 2. Diagram of the hybrid sampling plot.

5.2.2 FIA Plot Establishment

The standard FIA Phase 2/3 plot is composed of four 7.32 m (24.0 ft) radius subplots (Figure 3) in which the species and diameter at breast height (DBH) of all trees are recorded. Within each subplot (Figure 4) are three transects at 30°, and 150°, and 270°, along which quadrats are placed to record groundlayer data. The plot layout used by GLKN differs from the standard FIA phase 3 plot in that groundlayer data will be collected at three quadrats along each transect, rather than one quadrat. In addition, GLKN will not be limiting sapling data measurements (trees ≥ 2.6 cm DBH and < 12.7 cm DBH) to the microplot as FIA does, because sapling data will be collected over the entire subplot.

The GPS coordinates of the plot will be the center of subplot 1. The center of each additional subplot will be located by using a compass and either a tape measure or sonar distance measurers. To mark the three transects of each subplot, a compass and tape measure will be used. The tape will be laid down so that the herbaceous quadrats can be placed in the correct location and coarse woody debris data can be collected. The end of each transect will be demarcated with rebar sunk into the ground.

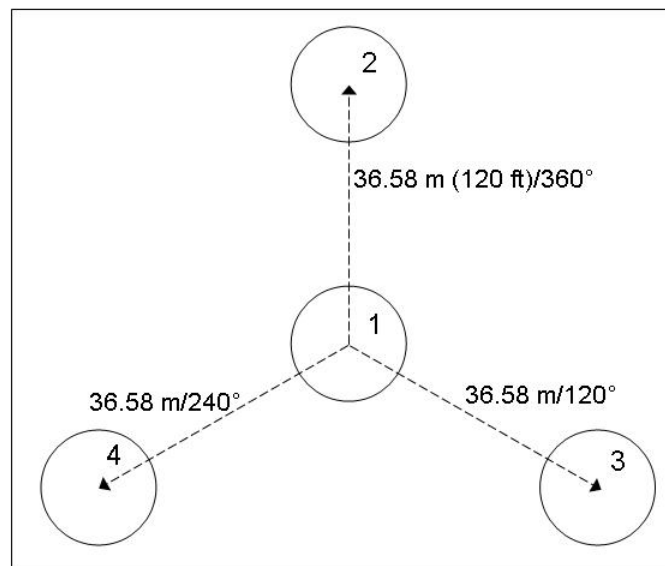


Figure 3. overview diagram of FIA Phase 2/3 plot showing four subplots.

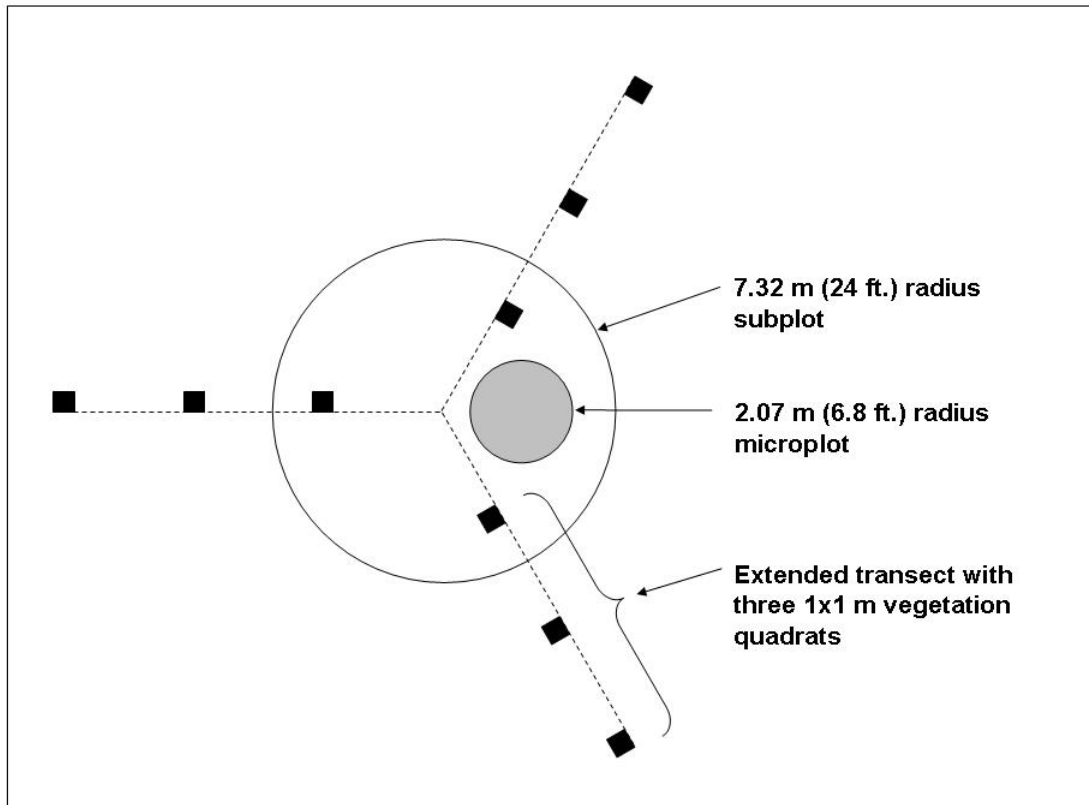


Figure 4. Detail of an FIA style subplot. The Forest Service FIA program records groundlayer data only at the most internal 1×1 m quadrat along each transect; the Great Lakes I&M Network will record groundlayer data at all three 1×1 m quadrats along each transect. Additionally, the FIA program records sampling data only within the microplot; the Great Lakes I&M Network will not limit sapling data to this area, but will record it over the entire subplot.

5.3 Permanently Marking Plots

For hybrid plots, each of the six points at the end of the transects will be marked; where the FIA style plot is used, the center of each subplot will be marked. The degree of permanent marking will vary by park. Within parks with designated wilderness areas, marking will be minimal, while permanent marking at other parks will be slightly more visible. No plots will be marked in such a manner as to be evident from roads, trails, or other heavily used public use areas.

In wilderness areas, a 30 cm (1 ft) piece of rebar will be sunk nearly flush with the ground at marking points. In the event that there is bedrock or some other obstruction preventing it being placed adequately into the ground, we will first attempt to hammer the rebar in at an angle so that the top of the piece is in the correct position. In the event that this is not possible, the rebar will be placed a certain distance away from the actual point center and we will record the distance and angle from the rebar to the actual target location.

At some parks, a greater degree of permanent marking will be permitted, which will increase the ability to relocate transects and quadrats, and ensure consistency with regard to which trees are within transects. Here we will sink a 60 cm (2 ft) piece of rebar 30 cm into the ground so that 30 cm remain above it. The top of this piece will be fitted with a yellow plastic cap over the rebar,

to aid visibility. Since rebar can come out of the ground by frost heaving as well as other means, and because it can be difficult to relocate a point if there is only one piece of marking, we will identify three reference trees surrounding the rebar. The distance and angle of these trees to the rebar will be recorded. Specifically, the angle will be recorded by standing in front of the tree and facing the rebar, or by backsighting to the tree when straddling the rebar. At parks where it is permitted, we will also place unique identification tags at the base of these trees.

At all permanent marking locations, the location will be recorded using a mapping grade (sub-meter accuracy) Trimble GPS. Initial attempts will be made to record this location with the Trimble unit set to a precision of delusion of position (PDOP) ≤ 6 . However, if readings cannot be obtained, the PDOP will be adjusted upward as needed.

5.4 Plot Reestablishment During Subsequent Site Visits

Plots and points will be relocated using a combination of GPS, a metal detector, and reference stakes. Because sites will be visited only once every six years, permanent markers and the reference points will be checked during each visit and reestablished as needed.

5.4.1 Reestablishing Points

Where reference stakes are used, an attempt will be made to relocate the rebar designating the start point and three reference stakes. Once located, the distances and angles from the reference points to the start point will be checked. The distances should be within 5 cm and 2° from the values recorded during the original establishment of the plot. If this criteria is not met, it will be left to the discretion of the field crew leader to reposition the markers. For example, if the distance and angle from two markers to the start point has not changed, but the third one has changed, the crew leader will reposition the third marker based on the original placement values from the start point. In contrast, if the distances and angles from all three marker points are off, the crew leader may reposition the start point from the three reference points.

Where reference stakes are not used, we will attempt to relocate the rebar using a metal detector and GPS. If it cannot be relocated, we will attempt to locate adjacent points, from which we will extrapolate the lost point.

5.4.2 Recording Locational Data

Following reestablishment of permanent points, the GPS coordinates will again be recorded during each site visit. Because of limitations on the locational accuracy of current GPS units, it is probable that these coordinates will differ from the coordinates recorded at the time of plot establishment. Nonetheless, it is hoped that both the continued improvement of GPS units and repeated visitation to sites will refine the actual site coordinates.

5.5 Literature Cited

Johnson, S. E., E. L. Mudrak, and D. M. Waller. 2006. A comparison of sampling methodologies for long-term forest vegetation monitoring in the Great Lakes Network National Parks, National Park Service, Great Lakes Inventory and Monitoring Network Report: GLKN/2006/03.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* **99**:262-278.

Field Methods and Data Collection

STANDARD OPERATING PROCEDURE #6

Version 1.0 (7/1/08)

Suzanne Sanders

NPS-Great Lakes Network

Revision History Log:

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

6.0 Introduction

This standard operating procedure defines the criteria for collection of data in the field. It is intended to ensure consistency between observers and sampling events. In addition, this SOP clarifies potentially ambiguous scenarios, eliminating uncertainty with measurements and data collection. It is intended to be a reference source, taken into the field and consulted as needed.

6.1 Whole plot data

- **Plot identification** – Record the predetermined plot identifier and date.
- **GPS points** – When using the Hybrid plot, record the GPS locations of the six transect ends. When using the FIA plot, record the GPS locations of each of the four subplot centers. For both plot types, record locations to the hundredth of a meter (centimeter), using UTM coordinates with the North American Datum of 1983 (NAD83).
- **Kotar/NVCS forest type** – Record the forest type either by using the Kotar Classification guidelines or the choices within the National Vegetation Classification System. This will be used in post-stratification analyses.
- **Photopoints** – For the Hybrid plot, photos should be taken at each of the six transect ends, facing directly into the plot. Therefore, at points 1, 3, and 5, the photos should be taken facing due east (90°) while at points 2, 4, and 6, the photos should be taken facing due west (270°). For the FIA plot, one photo will be taken at each subplot center. At subplot 1 center, the photo will be taken directly overhead. At the other subplot centers, the photo will be taken facing directly toward subplot 1. Therefore, at subplot 2, the photo will be taken at 180°, at subplot 3, the photo will be taken at 300°, and at subplot 4, 60°. Record the photo identification number from the camera for each of the points.

6.2 Tree data

Trees ≥ 2.5 cm (1 in) in diameter are sampled within the belt transects (Hybrid plot) or subplots (FIA plot). 'Tally trees' are defined as all live and standing dead trees in the transects the first time a plot is established, and all trees that grow into the transects thereafter. Details of measuring standing dead trees are presented below. Trees are alive if they have any living parts (leaves, buds, cambium) **at or above the point of diameter measurement**. Trees that have been temporarily defoliated are still alive. Once tallied, dead trees over 2.5 cm (1 inch) in diameter are tracked until they no longer qualify as standing dead. **Working around dead trees is a safety hazard - crews should exercise extreme caution!** Trees that are deemed unsafe to measure should be estimated.

Standing dead:

To qualify as a standing dead tally tree, dead trees must be at least 2.5 cm (1 in) in diameter, have a bole which has an unbroken height of at least 1.37 m (4.5 ft), and lean less than 45 degrees from vertical as measured from the base of the tree to 1.37 m. See Figures 1-3 for examples.

Note: The angle on bent or curved trees is determined by drawing an imaginary straight line from the top of the tree to the base.

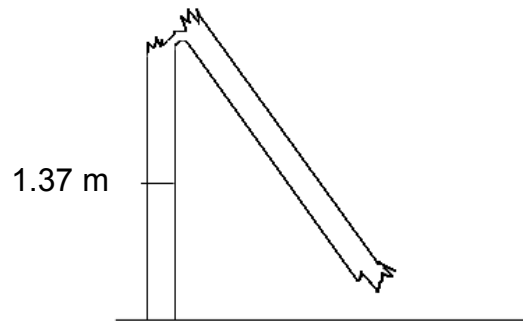


Figure 1. This tree would be tallied because it is at least 1.37 m in unbroken actual length and at least 2.5 cm at 1.37 m.

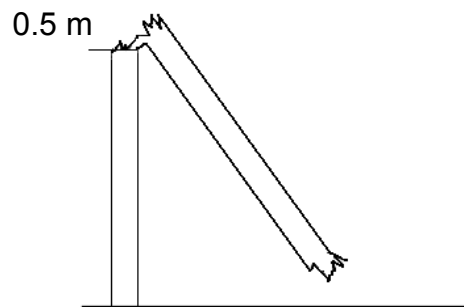


Figure 2. This tree would not be tallied because it does not have an unbroken length of 1.37 m.

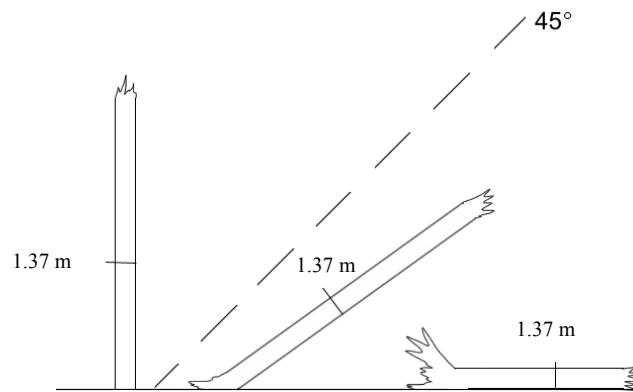


Figure 3. Other examples of dead trees. The tree on the left would be tallied since is at least 2.5 cm at 1.37 m and has at least 1.37 m in unbroken actual length. The two trees on the right would not since they are leaning at an angle $> 45^\circ$ from vertical.

- **Species** – Record the 6 digit code (Table 1) of each tree ≥ 2.5 cm diameter breast height (DBH, 1.37 m) in each of the three 6 m wide belt transects (Hybrid plot) or each of the four 7.32 m radius subplots (FIA plot).
- **Diameter** – Unless one of the following special situations is encountered, measure DBH at 1.37 m above the ground line on the uphill side of the tree. Round each measurement down to the nearest tenth centimeter. For example, a reading of 12.78 cm is recorded as 12.7 cm. In many situations, irregularities in the bole (e.g., forking trees, bulges) will impede the circumference measurement. Refer to the special instructions, below, for taking measurements in these instances.
- **Live/dead** – Record whether the tree is living or dead.
- **Damage** – If any damage is evident, record both the damage agent and the damage severity. Examine the bark as well as any branches, leaves/needles, and buds that are accessible and/or observable from the ground. Table 2 lists the damage agents that will be recorded as part of this protocol, and shows both general agents (boldface) and specific agents (normal font). Five specific damage agents, denoted with a “*” in Table 2, are designated as core agents in the FIA program; as such, for consistency, the presence of these agents will be assessed first. For detailed information on identification, life cycles, and ecology of these diseases, please refer to Appendix A: Pest and Pathogen Field Guide.

To quantify the degree of damage, use the criteria shown in the “severity rating” column of Table 3, below. Consider the following information about locations affected by damage when collecting damage data:

- **Roots** – Above ground up to 30 cm (12 in) on bole.
- **Bole** – Main stem(s) starting at 30 cm (12 in), including forks up to a 10-cm (4 in) top. (A fork is at least 1/3 diameter of the main stem, and occurs at an angle $< 45^\circ$ in relation to the main stem.
- **Branch** – All other woody material. Primary branch(s) occur at an angle $> 45^\circ$ in relation to bole.
- **Foliage** – All leaves, buds and shoots.

Table 1. Identification codes and specific gravity values for tree species in Great Lakes Network parks. Specific gravity values are from Woodall and Williams 2005.

Species code	Species	Specific gravity	Species code	Species	Specific gravity
ABIBAL	<i>Abies balsamea</i>	0.34	LARLAR	<i>Larix laricina</i>	0.49
ACESPX	<i>Acer</i> spp.	0.49	LIRTUL	<i>Liriodendron tulipifera</i>	0.40
ACENEG	<i>Acer negundo</i>	0.44	MACPOM	<i>Maclura pomifera</i>	0.76
ACENIG	<i>Acer nigrum</i>	0.52	MALSPX	<i>Malus</i> spp.	0.61
ACEPEN	<i>Acer pennsylvanicum</i>	0.44	MORSPX	<i>Morus</i> spp.	0.59
ACERUB	<i>Acer rubrum</i>	0.49	MORALB	<i>Morus alba</i>	0.59
ACESA1	<i>Acer saccharinum</i>	0.44	MORRUB	<i>Morus rubra</i>	0.59
ACESA2	<i>Acer saccharum</i>	0.56	NYSSYL	<i>Nyssa sylvatica</i>	0.46
ACESPI	<i>Acer spicatum</i>	0.44	OSTVIR	<i>Ostrya virginiana</i>	0.63
AESSPX	<i>Aesculus</i> spp.	0.33	PICSPX	<i>Picea</i> spp.	0.38
AESFLA	<i>Aesculus flava</i>	0.33	PICGLA	<i>Picea glauca</i>	0.37
AESGLA	<i>Aesculus glabra</i>	0.33	PICMAR	<i>Picea mariana</i>	0.37
AILALT	<i>Ailanthus altissima</i>	0.37	PINBAN	<i>Pinus banksiana</i>	0.40
AMESPX	<i>Amelanchier</i> spp.	0.33	PINRES	<i>Pinus resinosa</i>	0.41
AMEARB	<i>Amelanchier arborea</i>	0.33	PINSTR	<i>Pinus strobus</i>	0.34
AMEHUM	<i>Amelanchier humilis</i>	0.33	PINSYL	<i>Pinus sylvestris</i>	0.41
AMEINT	<i>Amelanchier interior</i>	0.33	PLAOCC	<i>Platanus occidentalis</i>	0.46
AMELAE	<i>Amelanchier laevis</i>	0.33	POPSPX	<i>Populus</i> spp.	0.37
ASITRI	<i>Asimina triloba</i>	0.47	POPBAL	<i>Populus balsamifera</i>	0.31
BETSPX	<i>Betula</i> spp.	0.48	POPDEL	<i>Populus deltoides</i>	0.37
BETALL	<i>Betula alleghaniensis</i>	0.55	POPGRA	<i>Populus grandidentata</i>	0.36
BETLEN	<i>Betula lenta</i>	0.60	POPTRE	<i>Populus tremuloides</i>	0.37
BETNIG	<i>Betula nigra</i>	0.56	PRUSPX	<i>Prunus</i> spp.	0.47
BETPAP	<i>Betula papyrifera</i>	0.48	PRUPEN	<i>Prunus pensylvanica</i>	0.36
CARCAR	<i>Carpinus caroliniana</i>	0.58	PRUSER	<i>Prunus serotina</i>	0.47
CARSPX	<i>Carya</i> spp.	0.62	PRUVIR	<i>Prunus virginiana</i>	0.36
CARCOR	<i>Carya cordiformis</i>	0.60	QUESPX	<i>Quercus</i> sp.	0.58
CARGLA	<i>Carya glabra</i>	0.66	QUEALB	<i>Quercus alba</i>	0.60
CARLAC	<i>Carya lacinosa</i>	0.62	QUEBIC	<i>Quercus bicolor</i>	0.64
CAROVA	<i>Carya ovata</i>	0.64	QUEMAC	<i>Quercus macrocarpa</i>	0.58
CARTOM	<i>Carya tomentosa</i>	0.64	QUERUB	<i>Quercus rubra</i>	0.56
CASDEN	<i>Castanea dentata</i>	0.40	QUEVEL	<i>Quercus velutina</i>	0.56
CELOCC	<i>Celtis occidentalis</i>	0.49	ROBPSE	<i>Robinia pseudoacacia</i>	0.66
CERCAN	<i>Cercis canadensis</i>	0.58	SALSPX	<i>Salix</i> sp.	0.36
CORSPX	<i>Cornus</i> spp.	0.64	SASALB	<i>Sassafras albidum</i>	0.42
CORFLA	<i>Cornus florida</i>	0.64	SORAME	<i>Sorbus americana</i>	0.42
CRASPX	<i>Crataegus</i> spp.	0.62	SORDEC	<i>Sorbus decora</i>	0.42
FAGGRA	<i>Fagus grandifolia</i>	0.56	THUOCC	<i>Thuja occidentalis</i>	0.29
FRASPX	<i>Fraxinus</i> spp.	0.54	TILAME	<i>Tilia americana</i>	0.32
FRAAME	<i>Fraxinus americana</i>	0.55	TSUCAN	<i>Tsuga canadensis</i>	0.38
FRANIG	<i>Fraxinus nigra</i>	0.45	ULMSPX	<i>Ulmus</i> sp.	0.50
FRAPEN	<i>Fraxinus pennsylvanica</i>	0.53	ULMAME	<i>Ulmus americana</i>	0.46
FRAQUA	<i>Fraxinus quadrangulata</i>	0.53	ULMPUM	<i>Ulmus pumila</i>	0.46
GLETRI	<i>Gleditsia triacanthos</i>	0.60	ULMRUB	<i>Ulmus rubra</i>	0.48
ILEOPA	<i>Ilex opaca</i>	0.50	UNKHAR	unknown hardwood	0.51
JUGSPX	<i>Juglans</i> spp.	0.51	UNKSOF	unknown softwood	0.38
JUGCIN	<i>Juglans cinerea</i>	0.36	UNKXXX	unknown	0.46
JUGNIG	<i>Juglans nigra</i>	0.51			

Special DBH situations:

1. **Forked tree:** In order to qualify as a fork, the stem in question must be at least 1/3 the diameter of the main stem and must branch out from the main stem at an angle of 45 degrees or less. Forks originate at the point on the bole where the piths intersect. Forked trees are handled differently depending on whether the fork originates below 30 cm, between 30 cm and 1.37 m, or above 1.37 m.

Note: Fork does not have to be live to be considered as a Fork.

- **Trees forked below 30 cm.** Trees forked in this region are treated as distinctly separate trees (Figure 4). Distances are measured individually to the center of each stem where it splits from the stump (Figures 4 - 6). DBH is measured for each stem at 1.37 m above the ground. When stems originate from pith intersections below 30 cm, it is possible for some stems to be within the limiting distance of the belt transect or subplot, and others to be beyond the limiting distance. If stems originating from forks that occur below 30 cm fork again between 30 cm and 1.37 m (Figure 7-E), the rules in the next paragraph apply.
- **Trees forked between 30 cm and 1.37 m.** Trees forked in this region are also counted as separate trees (Figures 5, 7 D-F). The DBH of each fork is measured at a point 1.07 cm (3.5 feet) above the pith intersection. When forks originate from pith intersections between 30 cm and 1.37 m, the limiting distance is the same for all forks—they are either all on, or all off the plot—and is determined by the central stump.

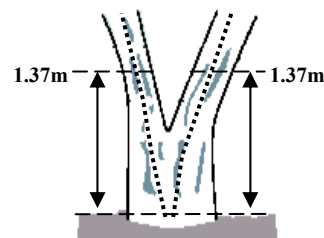


Figure 4.
Forked below

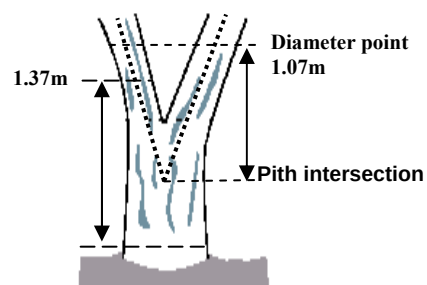


Figure 5. Forked
between 30cm –

- Multiple forks are possible if they all originate from approximately the same point on the main stem. In such cases, measure DBH on all stems at 1.07 m above the common pith intersection (Figure 7-F).

Once a stem is tallied as a fork that originated from a pith intersection between 30 cm and 1.37 m, do not recognize any additional forks that may occur on that stem. Measure the diameter of such stems just below the base of stem separation as shown in Figure 7-E (i.e., do not move the point of diameter the entire 1.07 m above the first fork).

- **Trees forked at or above 1.37 m.** Trees forked in this region count as one single tree (Figure 6). If a fork occurs at or immediately above 1.37 m measure diameter below the fork just beneath any swelling that would inflate DBH.

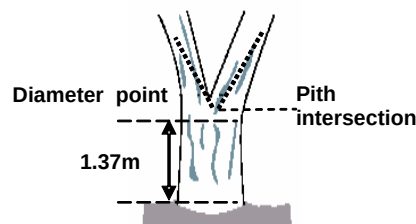
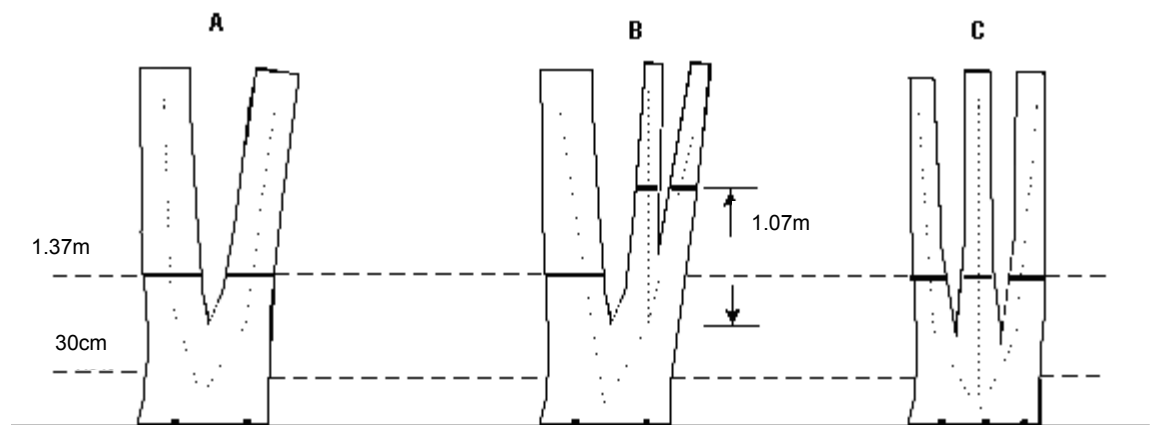
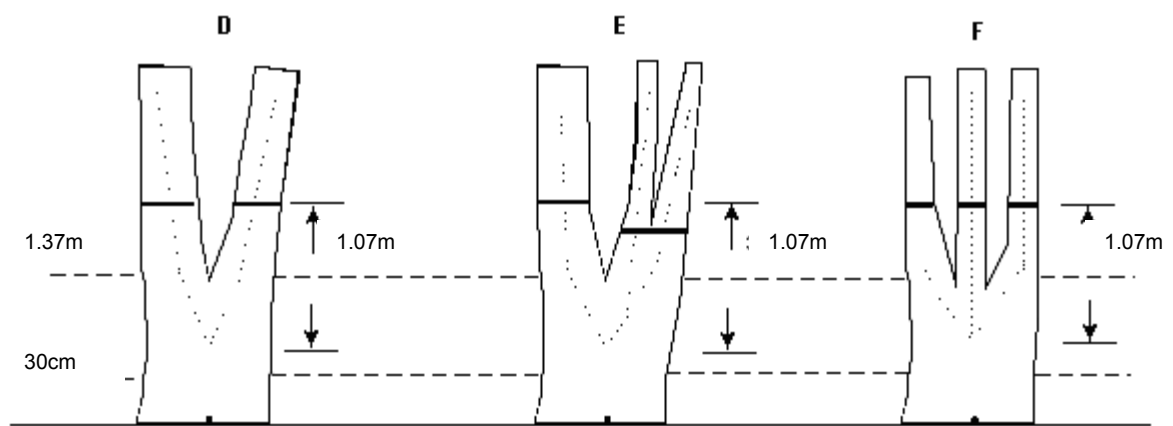


Figure 6. One tree.



1. Trees fork below 30cm



2. Trees fork above 30cm

Figure 7. Summary of where to measure DBH, distance, and azimuth on forked trees.

2. Stump Sprouts: Stump sprouts originate between ground level and 1.37 m on the boles of trees that have died or been cut. Stump sprouts are handled the same as forked trees, with the exception that stump sprouts are not required to be 1/3 the diameter of the dead bole. Stump sprouts originating below 30 cm are measured at 1.37 m from ground line. Stump sprouts originating between 30 cm and 1.37 m are measured at 1.07 m above their point of occurrence. As with forks, rules for measuring distance depend on whether the sprouts originate above or below 30 cm. For multi-stemmed woodland species, treat all new sprouts as part of the same new tree.

3. Tree with butt-swell or bottleneck: Measure these trees 46 cm above the end of the swell or bottleneck if the swell or bottleneck extends 91 cm or more above the ground (Figure 8).

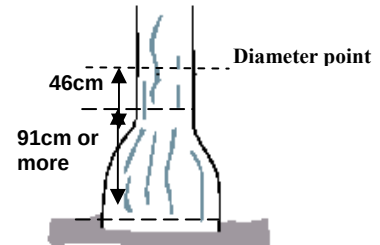


Figure 8. Bottleneck tree.

4. Tree with irregularities at DBH: On trees with swellings (Figure 9), bumps, depressions, and branches (Figure 10) at DBH, diameter will be measured immediately above the irregularity at the place it ceases to affect normal stem form.

NC Note: If a normal diameter can not be obtained at or above 1.37 m, it is valid to measure the diameter below 1.37 cm.

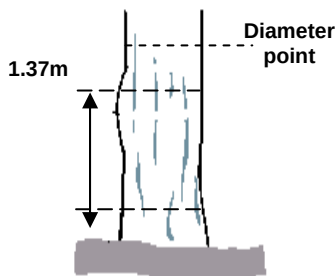


Figure 9. Tree with swelling.

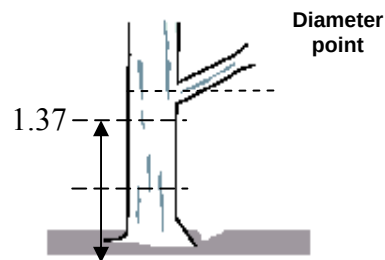


Figure 10. Tree with branch.

5. Tree on slope: Measure diameter at 1.37 m from the ground along the bole on the uphill side of the tree (Figure 11).

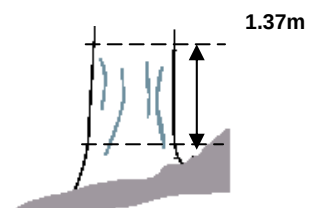


Figure 11. Tree on a slope.

6. Leaning tree: Measure diameter at 1.37 m from the ground along the bole. The 1.37 m distance is measured along the underside face of the bole (Figure 12).

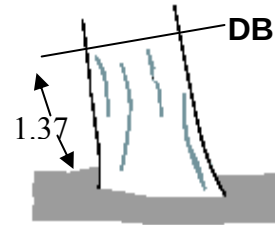


Figure 12. Leaning tree.

7. Independent trees that grow together: If two or more independent stems have grown together at or above the point of DBH, continue to treat them as separate trees. Estimate the diameter of each.

8. Missing wood or bark: Do not reconstruct the DBH of a tree that is missing wood or bark or at the point of measurement. Record the diameter, to the nearest 0.1 cm, of the wood and bark that is still attached to the tree (Figure 13). If a tree has a localized abnormality (gouge, depression, etc.) at the point of point of DBH, apply the procedure described for trees with irregularities at DBH (Figure 9 and 10).

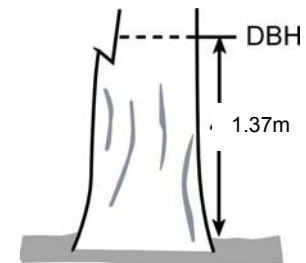


Figure 13. Tree with part of stem missing.

9. Live windthrown tree: Measure from the top of the root collar along the length to 1.37 m (Figure 14).

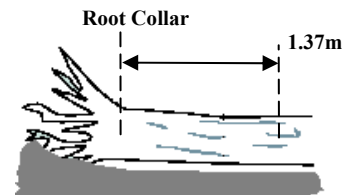


Figure 14. Tree on the ground.

10. Down live tree with tree-form branches growing vertical from main bole. When a down live tree, touching the ground, has vertical (less than 45 degrees from vertical) tree-like branches coming off the main bole, first determine whether or not the pith of the main bole (averaged along the first log of the tree) is above or below the duff layer.

- If the pith of the main bole is above the duff layer, use the same forking rules specified for a forked tree, and take all measurements accordingly (Figure 15).
- If the pith intersection of the main down bole and vertical tree-like branch occurs below 1.37 m from the stump along the main bole, treat that branch as a separate tree, and measure DBH 1.07 m above the pith intersection for both the main bole and the tree-like branch.

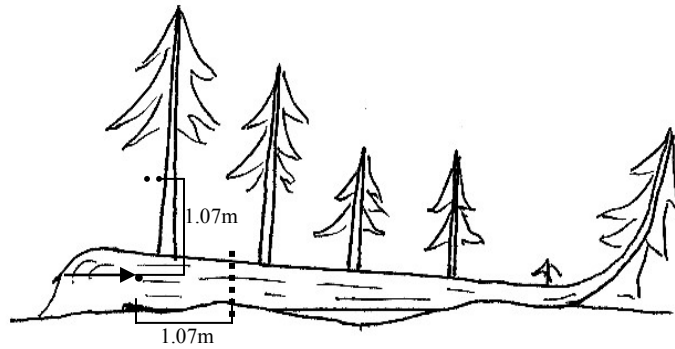


Figure 15. Down tree above duff.

- If the intersection between the main down bole and the tree-like branch occurs beyond the 1.37 cm point from the stump along the main bole, treat that branch as part of the main down bole.
- If the pith of main tree bole is below the duff layer, ignore the main bole, and treat each tree-like branch as a separate tree; take DBH from the ground, not necessarily from the top of the down bole (Figure 16). However, if the top of the main tree bole curves out of the ground towards a vertical angle, treat that portion of that top as an individual tree originating where the pith leaves the duff layer.

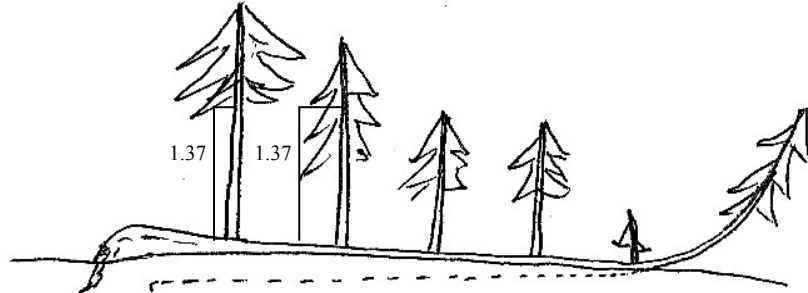


Figure 16. Down tree below duff.

12. Tree with curved bole (pistol butt tree): Measure along the bole on the uphill side (upper surface) of the tree (Figure 17).

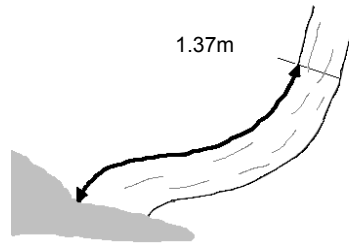


Figure 17. Tree with curved bole (pistol butt tree).

Table 2. Damage agents to be scouted as part of the General Vegetation Monitoring Protocol. General agents are shown in boldface; specific agents in standard font. Asterisks indicate core damage agents as designated in the FIA program.

11000 – Bark beetles	*21001 – Armillaria root disease (<i>Armillaria</i> spp.)
11010 – eastern larch beetle (<i>Dendroctonus simplex</i>)	*21010 – annosus root disease (<i>Heterobasidion annosum</i>)
*11012 – red turpentine beetle (<i>Dendroctonus valens</i>)	21028 – sudden oak death (<i>Phytophthora ramorum</i>)
11029 – pine engraver (<i>Ips pini</i>)	
12000 – Defoliators	22000 – stem decays/cankers
12031 – scarlet oak sawfly (<i>Caliroa quercuscoccineae</i>)	22041 – beech bark disease (<i>Neonectria faginata</i> and <i>N. ditissima</i>)
12037 – large aspen tortrix (<i>Choristoneura conflictana</i>)	
12038 – spruce budworm (<i>Choristoneura fumiferana</i>)	24000 – Decline complexes/dieback/wilts
12039 – jackpine budworm (<i>Choristoneura pinus</i>)	24022 – Dutch elm disease (<i>Ophiostoma ulmi</i> and <i>O. novo-ulmi</i>)
12041 – larch casebearer (<i>Coleophora laricella</i>)	24004 – ash decline/yellows (multiple)
12058 – yellownecked caterpillar (<i>Datana ministra</i>)	
12057 – walnut caterpillar (<i>Datana integerrima</i>)	25000 – Foliage disease
12058 – yellownecked caterpillar (<i>Datana ministra</i>)	25025 – anthracnose (<i>Gnomonia</i> spp.)
12061 – introduced pine sawfly (<i>Diprion similis</i>)	25057 – siricococcus tip blight (<i>Sirococcus conigenus</i>)
12082 – fall webworm (<i>Hyphantria cunea</i>)	25058 – diplodia shoot blight (<i>Diplodia pinea</i>)
12088 – aspen blotch miner (<i>Lithocolletis tremuloidiella</i>)	
12089 – gypsy moth (<i>Lymantria dispar</i>)	26000 – Stem rust
12093 – eastern tent caterpillar (<i>Malacosoma americanum</i>)	26001 – white pine blister rust (<i>Cronartium ribicola</i>)
12096 – forest tent caterpillar (<i>Malacosoma disstria</i>)	
12136 – yellowheaded spruce sawfly (<i>Pikonema alaskensis</i>)	30000 – Fire
12141 – elm leaf beetle (<i>Pyrrhalta luteola</i>)	
12153 – basswood thrips (<i>Thrips calcaratus</i>)	41000 – Wild animals
14000 – Sucking insects	
*14003 – balsam wooly adelgid (<i>Adelges piceae</i>)	50000 – Abiotic damage
*14014 – hemlock wooly adelgid (<i>Adelges tsugae</i>)	50001 – air pollutants
14015 – pine spittlebug (<i>Aphrophora parabell</i>)	50003 – drought
14016 – Saratoga spittlebug (<i>Aphrophora saratogensis</i>)	50004 – flooding/high water
	50005 – frost
	50008 – lightening
	50009 – nutrient imbalances
	50011 – snow/ice
	50013 – wind/tornado
15000 – Boring insects	
15005 – two-lined chestnut borer (<i>Agrilus bilineatus</i>)	70000 – Human activities
15022 – Zimmerman pine moth (<i>Dioryctria zimmermani</i>)	
15082 – Asian long-horned beetle (<i>Anoplophora glabripennis</i>)	90000 – Unknown
15087 – emerald ash borer (<i>Agrilus planipennis</i>)	90001 – broken top
15088 – hemlock borer (<i>Melanophila fulvoguttata</i>)	90002 – dead top
15089 – Sirex woodwasp (<i>Sirex noctilio</i>)	90051 – canker/gall
15090 – red oak borer (<i>Enaphalodes rufulus</i>)	90052 – open wound
	90053 – resinosis
	90054 – broken
	90055 – damaged or discolored foliage

Table 3. Severity ratings to describe tree damage.

Agent	Location Affected	Severity Ratings
Bark beetles 11000	Bole, Branches	001 - Successful current attack 002 - Previous year's successful attack 003 - Top kill
Defoliators 12000	Foliage	Percent of foliage affected
Sucking insects 14000	Bole, Branches, Foliage	Percent of the circumference of a running 3'-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Wood borers 15000	Bole, Branches	001 - Successful current attack 002 - Previous year's successful attack 003 - Top kill
Root/butt diseases 21000	Roots	001 – Live host tree within 30 ft of an infected tree 002 – Live host tree with signs of root disease but no crown symptoms 003 - Live host tree with signs of root disease also with crown symptoms
Cankers (non-rust) 22000	Bole, Branches	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected.
Decline complexes 24000	Any	None
Foliage diseases 25000	Foliage	Percent of foliage affected
Stem rusts 26000	Bole, Branches	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected.
Fire 30000	Bole, Branches, Foliage	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Wild animals 41000	Bole, Branches	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected.
Abiotic 50000	Bole, Branches, Foliage	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Human activities 70000	Bole, Branches, Foliage	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Unknown/other 90000	Any	None

6.3 Coarse woody materials

Data on coarse woody material will be collected along each of the three parallel 50 m horizontal distance transects (Hybrid method) or the three 7.32 m horizontal distance radii of each subplot (FIA method) using the line intercept method. Tally rules follow, below. For all pieces of coarse woody material tallied, the parameters recorded are: species, diameter at line intercept, small end diameter, large end diameter, length, and decay class.

- **Species** – Record the 6 digit code (Table 1) of each piece of coarse woody material (≥ 0.91 m [3 ft] long and ≥ 7.6 cm [3 in] diameter) along the transect.
- **Diameter at line intercept** – Record the diameter, in centimeters, at the point of intercept. This diameter should be taken perpendicular to the length of the log, regardless of the orientation of the piece to the transect line. Record to the tenths of centimeters, rounding down, rather than to the nearest tenth.
- **Small end diameter** – Record the diameter, in centimeters, at the piece's small end. This diameter will occur either at (1) the actual end of the piece, if the end has a diameter ≥ 7.6 cm, or (2) at the point where the piece tapers down to 7.6 cm in diameter. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume. Record to the tenths of centimeters, rounding down, rather than to the nearest tenth.
- **Large end diameter** – Record the diameter, in centimeters, at the piece's large end. The large end will occur either at a broken end, a fracture, or at the root collar. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume. Record to the tenths of centimeters, rounding down, rather than to the nearest tenth.
- **Length** – Record the length of the piece that lies between the piece's recorded diameter at small end and diameter at large end. For curved logs, measure along the curve. Record in meters and centimeters. For example, a log that is three meters and 54 centimeters would be recorded as 3.54.
- **Decay class** – Record the decay class of the piece using the rules outlined in Table 4. Because decay conditions may vary along a piece, record the decay class that predominates.

Table 1. Distinguishing characteristics of the five decay classes (From Woodall and Williams, 2005).

Decay class	Structural integrity	Texture of rotten portions	Color of wood	Invading roots	Branches and twigs
1	sound, freshly fallen, intact logs	intact, no rot; conks of stem decay absent	original color	absent	if branches are present, fine twigs are still attached and have tight bark
2	sound	mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	original color	absent	if branches are present, many fine twigs are gone and remaining fine twigs have peeling bark
3	heartwood sound; piece supports its own weight	hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	reddish brown or original color	sapwood only	branch stubs will not pull out
4	heartwood rotten; piece does not support its own weight, but maintains its shape	soft, small blocky pieces; a metal pin can be pushed into heartwood	reddish or light brown	throughout	branch stubs pull out
5	none, piece no longer maintains its shape, it spreads out on the ground	soft; powdery when dry	red-brown to dark brown	throughout	branch stubs and pitch pockets have usually rotted down

Tally Rules for Coarse Woody Debris Sampling

1. Tally only those trees whose central longitudinal axes intersect the transect line (Figure 18).

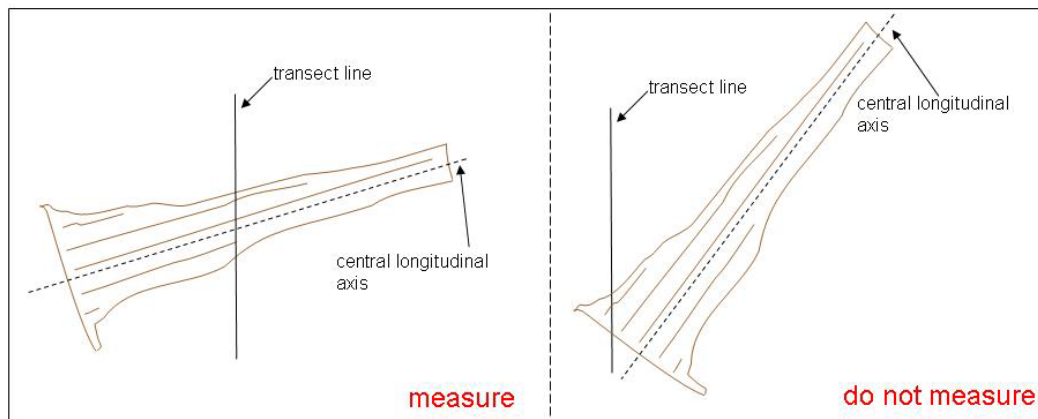


Figure 18. Do not tally any CWD piece whose central longitudinal axis does not cross the transect line.

2. Tally dead trees and stumps that are leaning $\geq 45^\circ$ from vertical. Do not tally live trees or standing dead trees and stumps that are still upright and leaning $< 45^\circ$ from vertical. See section 6.2, above.

3. The minimum length of any tally piece is 0.91 m (3 ft).

4. The decay class of the piece determines whether or not the piece is tallied.

For decay classes 1 to 4: tally a piece if it is ≥ 7.6 cm in diameter at the point of intersection with the transect. The piece must be ≥ 0.91 m (3 ft) in length and ≥ 7.6 cm (3 in) in diameter along that length. If the intersect diameter is close to 3.0 inches, measure the diameter to the nearest 0.1 cm to determine if the piece qualifies.

For decay class 5: tally a piece if it is ≥ 12.7 cm (5.0 in) in diameter at the point of intersection with the transect. The piece must be ≥ 0.91 m (3 ft) in length and ≥ 12.7 cm (3 in) in diameter along that length. Only pieces that still have some shape and log form are tallied – humps of decomposed wood that are becoming part of the duff layer are not tallied.

5. Tally pieces created by natural causes or by human activities such as cutting only if not systematically machine-piled.

6. Tally a piece only if the point of intersection occurs above the ground. If one end of a piece is buried in the litter, duff, or mineral soil, the piece ends at the point where it is no longer visible. Measure the diameter and length at this point.

7. If the central longitudinal axis of a piece is intersected more than once on a transect line or if it is intersected by two transect lines, tally the piece each time it is intersected (uncommon situation, see Figure 19).

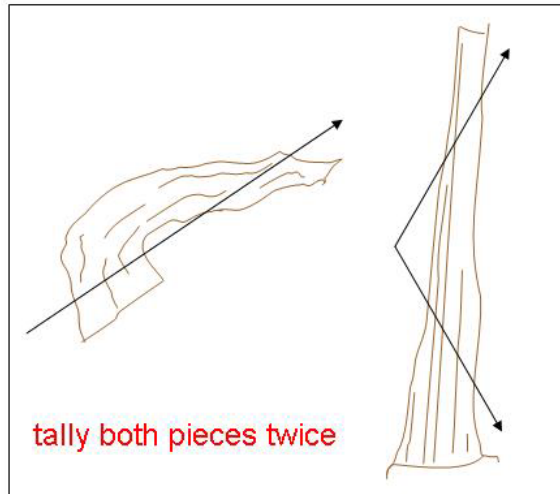


Figure 19. If the central longitudinal axis crosses a transect twice, then tally the piece twice.

8. Tally a piece only once if the subplot center falls directly on the central longitudinal axis of the piece. Tally the piece on the 30° transect.

9. If a piece is fractured across its diameter or length, and would pull apart at the fracture if pulled from either end or sides, treat it as two separate pieces. If judged that it would not pull apart, tally as one piece. Tally only the piece intersected by the transect line.

10. Do not tally a piece if it intersects the transect on the root side of the root collar. Do not tally roots.

11. When the transect crosses a forked down tree bole or large branch connected to a down tree, tally each qualifying piece separately. To be tallied, each individual piece must meet the minimum diameter and length requirements.

12. In the case of forked trees, consider the “main bole” to be the piece with the largest diameter at the fork. Variables for this fork, such as ‘decay class’ and ‘total length’ should pertain to the entire main bole. For smaller forks or branches connected to the main bole (even if the main bole is not a tally piece), variables pertain only to that portion of the piece up to the point where it attaches to the main bole (see Figure 20).

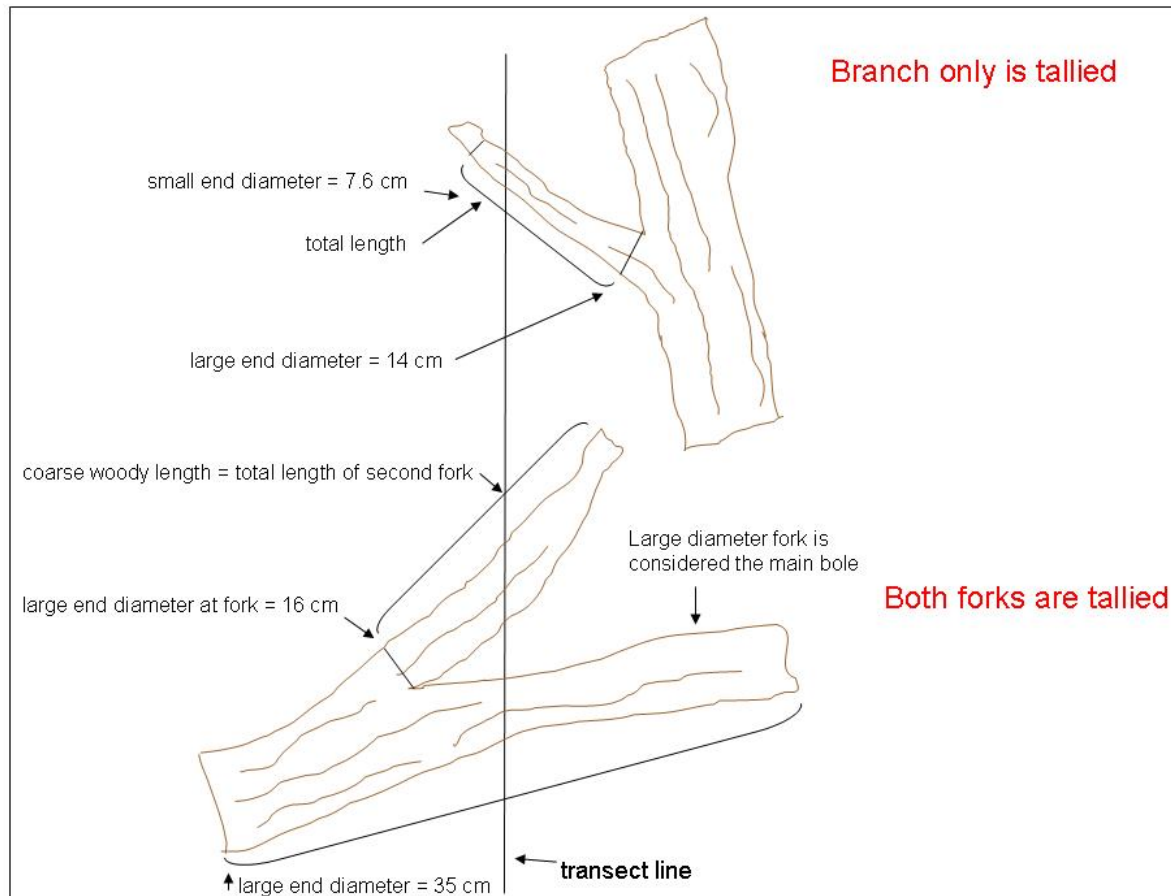


Figure 20. CWD tally rules for forked trees.

6.4 Tree walkthrough

Once trees in all of the transects have been tallied, perform a 20 minute time delimited walkthrough of the entire plot (50 meters $\times$ 100 meters) to determine the complete list of tree species that are present in each plot. It is possible that there are species that will be recorded here, but not in the transects. Record each species only once. When it is determined that all species have been identified, estimate the percentage of cover by canopy species (as likely seen from above) for the entire plot. Make sure to include the percentage of gap in the canopy. Since percentage of cover is estimated based on the aerial view only, the collective value for all species plus the gap should equal 100%. Similarly, since there are species being recorded that are only in the subcanopy, these species will have percent cover values of 0%

6.5 Shrubs and saplings

Record all shrub species present in each of the 2.82 m radius shrub circles. For each species present, also record the percentage cover. Since each shrub circle is 25 m², a 1m² area will be 4% cover.

Record the species of qualifying tree seedlings in each 1 $\times$ 1 groundlayer quadrat. Qualifying tree seedlings must be at least 15 cm (for conifers) and 30 cm (for hardwoods) and exhibit signs of second year growth, such as bud scars. Seedlings must also be less than 2.5 cm diameter at breast height. In addition, record the count of each species present.

6.6 Groundlayer

Herbs, tree saplings, shrubs, and browse are all assessed in the thirty 1 × 1 groundlayer quadrats. For herbaceous plants, record each species that is rooted in each groundlayer quadrat.

Record the species of qualifying tree saplings in each 1 × 1 groundlayer quadrat. Qualifying tree saplings must be at least 15 cm (for conifers) and 30 cm (for hardwoods) and exhibit signs of second year growth, such as bud scars. Seedlings must also be less than 2.5 cm diameter at breast height. In addition, record the count of each species present.

Record the number of apparent individuals for each species of qualifying shrubs in each 1 × 1 groundlayer quadrat. Qualifying shrubs must exhibit signs of second year growth, such as bud scars.

6.7 All species walkthrough

Following the completion of all thirty groundlayer quadrats, perform a 20 minute time delimited walkthrough of the entire plot (50 meters × 100 meters) to determine the complete list of herb species that are present in each plot. It is possible that there are species that will be recorded here, but not in the transects. Record each species only once.

6.8 Browse

Indirect browse:

Indirect measures of browse by assessing indicator species height will be made in each groundlayer quadrat. For each park, three preidentified herbaceous species will be examined in each quadrat by counting the total number of each, noting how many of these are unbrowsed and non-reproductive, how many are unbrowsed and reproductive, and how many are browsed. The maximum height for each species will be recorded (to the tenth of a centimeter) and it will be noted whether this height is a leaf, reproductive structure, or stem that has been clipped.

Direct browse:

Direct measures of browse will be made by looking at the three closest shrubs or saplings from the northwest corner of each herbaceous quadrant, that are between 0.20 m and 1.8 m in height. It will be noted whether these have been browsed. If there are fewer than three shrubs or saplings within a 2 meter radius from the herbaceous quadrat, direct browse will be assessed on those that are present. It is possible that there will be no shrubs or saplings within a two meter radius; in these instances, no direct browse will be assessed for those quadrats.

6.9 Acknowledgments

We are indebted to the U.S. Forest Service, North Central Region both for providing text files of the FIA field guide and allowing us to incorporate it into the GLKN field guide.

Procedures for Dealing with Unknown Species

STANDARD OPERATING PROCEDURE #7

Version 1.0 (7/1/08)

Sarah Johnson
University of Wisconsin – Madison

Suzanne Sanders
NPS – Great Lakes Network

Revision History Log:

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

7.0 Introduction

Occasions will likely arise when the field crew is unable to identify species onsite. This standard operating procedure presents criteria for collecting and preserving specimens when these situations arise.

Before collection of any plants or insects from the field, attempts should first be made to identify it onsite using reference books. When this is not possible, the guidelines below should be followed.

7.1. Collection of herbaceous plants

No plants are to be collected from within the units where data are collected (i.e., the belt transects, subplots, groundlayer quadrats, and shrub circles). To collect herbaceous plants, an attempt must first be made to locate individuals of the questioned species outside of the outer boundary of the plot. There must be at least five individuals (hereafter, this also refers to ramets if the unknown species is, or appears to be, clonal) present for one to be removed. If ten individuals are present, two may be collected. No more than two individuals of a given species should be collected at any given plot. If no individuals can be located outside of the outer plot boundary, one or two may be collected from within the boundary, provided they are not within the six meter wide belt transects. The same criteria for collecting outlined above applies.

Prior to removal of the individual plant, we will photograph it attempting to show characteristics that will facilitate identification at a later time. This includes taking multiple close-up photographs of the flowers, fruits, and leaves, as well as whole plant pictures in which the plant size is placed in context with that of other plants.

Caution should be exercised when selecting which plant(s) to collect. While it may be tempting to collect the largest plant(s) meeting the criteria above, this practice should be avoided. Larger plants may be contributing proportionately greater to species recruitment than smaller plants. Collection of plants should tend toward smaller individuals, provided there is sufficient material present for identification.

An attempt should be made to remove the root as well as the aboveground portion of the plant. Soil should be knocked free from the roots to the extent possible without damaging them. The specimen should be placed in a plastic bag that is subsequently labeled with a permanent marker. The specimen should be pressed as soon as possible after collection. Until it is pressed, the specimen should be kept in as cool and dark of a place as possible, and not be allowed to be crushed.

If there are no plants of the given species outside of the area where data are collected, or if there are less than five individuals present, the voucher specimens will not be removed from the area. In these instances, we will rely entirely on the photographs and notes collected at the site.

7.2 Collection of woody plants

In the event that woody plant species cannot be identified in the field after consulting reference manuals, portions of these plants may be cut and removed from the field for later identification. When collecting plants, an attempt must first be made to locate individuals of the same species

outside of the outer boundary of the plot. To collect a stem containing reproductive structures, assure that at least five reproductive stems must be present in total. This can include one plant with five reproductive stems, five plants, each with one reproductive stem, or some combination of the two. If at least 10 reproductive stems are present, then two may be collected for later identification. If leaves are not present on the reproductive stem, or if the judgment is made that additional stems with leaves may aid identification, up to two stems containing leaves may be collected, provided there are at least 10 present near the plot.

As detailed above in the herbaceous section, collection of smaller specimens, rather than larger ones, should be a priority. The specimen should be pressed within 12 hours after collection. If the specimen cannot be pressed immediately after collection, it should be placed in a plastic bag.

If there are no individuals present outside of the outer plot area, an attempt should then be made to sample within the plot area but in trees rooted outside of the six meter wide transects. The same rules stated above, on the number of stems required for collection, apply here. No collecting of stem material should be made within the belt transects.

If there are not woody individuals of the questionable species outside of the sampling units, we will take photographs to show as much detail of the species as possible.

Reproductive material (i.e., viable seeds, non-viable seed husks, decaying acorns) may be collected at the discretion of the field crew, however caution must be exercised so that only a small portion is collected.

7.3 Collection of insects and insect sign

An attempt will be made to identify any species of insect (native or exotic) that is adversely affecting tree health. If the insect species (or the ensuing disease) cannot readily be made in the field, specimens may be collected for later identification. This can include individuals in either the adult or larval stages, or eggs. All samples will be collected in vials but will not be preserved.

In addition to direct collection of insects, pieces of insect sign may also be collected. This can include leaves or stems fed on by the insects, as well as other identifying material (pieces of tent, silk, cocoons, chrysalides, etc.).

Photographs will be taken to aid in identification and to show the extent of an infestation as needed.

7.4 Collection of fungal and lichen material

An attempt will be made to identify any species of fungus or lichen that is adversely affecting tree health. If the fungus (or the ensuing disease) cannot readily be made in the field, specimens may be collected in vials for later identification. Photographs may also be taken to detail the disease.

7.5. Identification

We will take voucher specimens, collected material, and photographs to subject matter experts for the park in which we are working. Selected experts have been identified *a priori* and are listed in Table 1, although consultations will not be limited to those listed in this table.

Table 1. List of local biologists for each Network park. In addition to those noted below, we will also rely on Joe O'Brien (615-649-5266, jobrien@fs.fed.us) for plant pathology and Steve Katovich (651-649-5264, steven_katovich@fs.fed.us) for entomology.

Park	Name	Affiliation	Area of Expertise	Phone	Email
APIS	Jim Meeker	Northland College	botany	715-682-1808	jmeeker@northland.edu
	Andy Goyke	Northland College	entomology	715-682-1550	agoyke@northland.edu
GRPO	Al Harris	Northern Bioscience	botany and entomology	807-344-7213	aharris@northernbioscience.com
INDU	Julie Stumpf	National Park Service	botany	219-926-7561 x 323	julie_stumpf@nps.gov
	Dan Mason	National Park Service	botany	219-926-7561	daniel_mason@nps.gov
ISRO	Janet Marr	Michigan Tech	botany	906-337-5529	jkmarr@mtu.edu
MISS	Eric Epstein	Wisconsin DNR	botany	608-267-5038	eric.epstein@dnr.state.wi.us
PIRO	Janet Marr	Michigan Tech	botany	906-337-5529	jkmarr@mtu.edu
SACN	Eric Epstein	Wisconsin DNR	botany	608-267-5038	eric.epstein@dnr.state.wi.us
	Emmet Judziewicz	U.W. Stevens Point	botany	715-346-4248	ejudziew@uwsp.edu
	Todd Lanigan	Wisconsin DNR (Eau Claire)	forest pest specialist	715-839-1632	todd.lanigan@dnr.state.wi.us
	Shane Weber	Wisconsin DNR (Spooner)	forest entomologist	715-635-4156	shane.weber@dnr.state.wi.us
SLBE	Janet Marr	Michigan Tech	botany	906-337-5529	jkmarr@mtu.edu
VOYA	Al Harris	Northern Bioscience	botany and entomology	807-344-7213	aharris@northernbioscience.com

Pests and Pathogens

STANDARD OPERATING PROCEDURE #8

Version 1.0 (7/1/08)

Suzanne Sanders

NPS – Great Lakes Network

Revision History Log:

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

8.0 Introduction

Pests and pathogens can have tremendous impacts on trees, shrubs, and herbaceous plants (Johnson and Lyon 1991; Sinclair and Lyon 2005). It is important to document and quantify outbreaks and invasions of key taxa of insects, fungi, nematodes, and other pests so that associations may be drawn between pest presence and/or abundance and long-term vegetation dynamics. This standard operating procedure (SOP) outlines the process for doing this.

This Terrestrial Pest and Pathogen indicator of forest health will be monitored within the context of the General Vegetation Monitoring Protocol (Sanders et al. 2006); therefore there is no separate monitoring protocol. Instructions for both field methods and analysis techniques are contained or referenced within this SOP.

Because the Network will be monitoring terrestrial vegetation at each park only once every six years, pests and pathogens will also be documented at this interval. We concede that it is ideal to monitor annually, and to quantify pest and pathogen abundance directly. Because time demands and personnel costs are prohibitive, however, we will monitor for pests and pathogens while at terrestrial vegetation plots. Further, we will qualify and quantify pest and pathogen activity by the type and degree of damage to vegetation, rather than by assessing abundance of the disease agents directly. This is detailed below.

The NPS-GLKN pest and pathogen sampling design and analyses are designed to answer the following specific questions:

- Which targeted pests and pathogens are present in terrestrial vegetation monitoring plots? We will search for selected pests and pathogens (Box 1) on trees that are included in the vegetation monitoring plots.
- Within given habitat types, what are the pest and pathogen species collectively present?
- To what extent are pests and pathogens damaging trees? We will calculate the percentage of trees infested, and note the severity of damage on the infested part(s).

The answers to these questions provide direct information about the health of forests in Great Lakes Network Parks. Further, this information can be combined with information on community structure, succession, and other indices forest growth and will allow us to draw inferences on overall forest health.

8.1 Field Methods

As part of the General Vegetation Monitoring Protocol, all trees for which DBH and species are recorded will be assessed for damage. This will occur by examining the bark as well as any branches, leaves/needles, and buds that are accessible and/or observable from the ground. Box 1 lists the damage agents that will be recorded as part of this protocol, and shows both general agents (boldface) and specific agents (normal font). Five specific damage agents, denoted with a “*” in Box 1, are designated as core agents in the FIA program; as such, for consistency, the presence of these agents will be assessed first. All damage agents will be recorded under the fields, DAMAGE_AGENT_1 (for the more severe damage if more than one core agent is present) and DAMAGE_AGENT_2 (for the agent causing the less severe damage if more than one is present). For detailed information on identification, life cycles, and ecology of these diseases, please refer to Appendix A: Pest and Pathogen Field Guide.

To quantify the degree of damage, use the criteria shown in the “severity rating” column of Table 1, below. This will be recorded under the fields DAMAGE_SEVERITY_AGENT_1 – 2 (corresponding to the DAMAGE_AGENT, above). Consider the following information about locations affected by damage when collecting damage data:

- Roots – Above ground up to 12 inches on bole.
- Bole – Main stem(s) starting at 12 inches, including forks up to a 4-inch top. (A fork is at least 1/3 diameter of the main stem, and occurs at an angle $<45^\circ$ in relation to the main stem.
- Branch – All other woody material. Primary branch(s) occur at an angle $>45^\circ$ in relation to bole.
- Foliage – All leaves, buds and shoots.

Box 1. Damage agents to be scouted as part of the General Vegetation Monitoring Protocol. General agents are shown in boldface; specific agents in standard font. Asterisks indicate core damage agents as designated in the FIA program.

11000 – Bark beetles

- 11010 – eastern larch beetle (*Dendroctonus simplex*)
- *11012 – red turpentine beetle (*Dendroctonus valens*)
- 11029 – pine engraver (*Ips pini*)
- 11047 – hickory bark beetle (*Scolytus quadrispinosus*)

12000 – Defoliators

- 12031 – scarlet oak sawfly (*Caliroa quercuscoccineae*)
- 12037 – large aspen tortrix (*Choristoneura conflictana*)
- 12038 – spruce budworm (*Choristoneura fumiferana*)
- 12039 – jackpine budworm (*Choristoneura pinus*)
- 12041 – larch casebearer (*Coleophora laricella*)
- 12057 – walnut caterpillar (*Datana integerrima*)
- 12058 – yellownecked caterpillar (*Datana ministra*)
- 12061 – introduced pine sawfly (*Diprion similis*)
- 12082 – fall webworm (*Hyphantria cunea*)
- 12088 – aspen blotch miner (*Lithocolletis tremuloidiella*)
- 12089 – gypsy moth (*Lymantria dispar*)
- 12093 – eastern tent caterpillar (*Malacosoma americanum*)
- 12096 – forest tent caterpillar (*Malacosoma disstria*)
- 12136 – yellowheaded spruce sawfly (*Pikonema alaskensis*)
- 12141 – elm leaf beetle (*Pyrrhalta luteola*)
- 12153 – basswood thrips (*Thrips calcaratus*)

14000 – Sucking insects

- *14003 – balsam wooly adelgid (*Adelges piceae*)
- *14014 – hemlock wooly adelgid (*Adelges tsugae*)
- 14015 – pine spittlebug (*Aphrophora parabella*)
- 14016 – Saratoga spittlebug (*Aphrophora saratogensis*)

15000 – Boring insects

- 15005 – two-lined chestnut borer (*Agrilus bilineatus*)
- 15022 – Zimmerman pine moth (*Dioryctria zimmermani*)
- 15082 – Asian long-horned beetle (*Anoplophora glabripennis*)
- 15087 – emerald ash borer (*Agrilus planipennis*)
- 15088 – hemlock borer (*Melanophila fulvoguttata*)
- 15089 – Sirex woodwasp (*Sirex noctilio*)
- 15090 – red oak borer (*Enaphalodes rufulus*)

Box 1, continued.

21000 – root/butt diseases

- *21001 – Armillaria root disease (*Armillaria* spp.)
- *21010 – annosus root disease (*Heterobasidion annosum*)
- 21028 – sudden oak death (*Phytophthora ramorum*)

22000 – stem decays/cankers

- 22041 – beech bark disease (*Neonectria faginata* and *N. ditissima*)

24000 – Decline complexes/dieback/wilts

- 24022 – Dutch elm disease (*Ophiostoma ulmi* and *O. novo-ulmi*)
- 24004 – ash decline/yellows (multiple)

25000 – Foliage disease

- 25025 – anthracnose (*Gnomonia* spp.)
- 25057 – siricoccus tip blight (*Sirococcus conigenus*)
- 25058 – diplodia shoot blight (*Diplodia pinea*)

26000 – Stem rust

- 26001 – white pine blister rust (*Cronartium ribicola*)

30000 – Fire

41000 – Wild animals

50000 – Abiotic damage

- 50001 – air pollutants
- 50003 – drought
- 50004 – flooding/high water
- 50005 – frost
- 50008 – lightening
- 50009 – nutrient imbalances
- 50011 – snow/ice
- 50013 – wind/tornado

70000 – Human activities

90000 – Unknown

- 90001 – broken top
- 90002 – dead top
- 90051 – canker/gall
- 90052 – open wound
- 90053 – resinosis
- 90054 – broken
- 90055 – damaged or discolored foliage

Table 1. Severity ratings to describe tree damage.

Agent	Location Affected	Severity Ratings
Bark beetles 11000	Bole, Branches	001 - Successful current attack 002 - Previous year's successful attack 003 - Top kill
Defoliators 12000	Foliage	Percent of foliage affected
Sucking insects 14000	Bole, Branches, Foliage	Percent of the circumference of a running 3'-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Wood borers 15000	Bole, Branches	001 - Successful current attack 002 - Previous year's successful attack 003 - Top kill
Root/butt diseases 21000	Roots	001 – Live host tree within 30 ft of an infected tree 002 – Live host tree with signs of root disease but no crown symptoms 003 - Live host tree with signs of root disease also with crown symptoms
Cankers (non-rust) 22000	Bole, Branches	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected.
Decline complexes 24000	Any	None
Foliage diseases 25000	Foliage	Percent of foliage affected
Stem rusts 26000	Bole, Branches	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected.
Fire 30000	Bole, Branches, Foliage	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Wild animals 41000	Bole, Branches	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected.
Abiotic 50000	Bole, Branches, Foliage	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Human activities 70000	Bole, Branches, Foliage	Percent of the circumference of a running 3-ft section of bole; percent of branches (crown volume) affected; percent of foliage affected.
Unknown/other 90000	Any	None

8.2 Analyses

Data will be summarized for each park and presented in tables and figures to show the current status after each year that a park is sampled. Hypothetical examples are shown below and include a summary table showing all pests and pathogens located in a given park for the season (Table 2) and a graph showing the percentage of trees infested by given species in multiple forest types (Figure 1).

Table 2. All targeted species located at St. Croix NSR, including the number and percentage of plots (out of 28) on which the pest was located. (Hypothetical Table)

Pest/Pathogen	Number of Plots Present	Percentage of Plots Present
forest tent caterpillar	18	64
jackpine budworm	15	54
large aspen tortrix	13	13
sirococcus shoot blight	12	43
two-lined chestnut borer	6	21
spruce budworm	9	32
annosum root rot	5	18

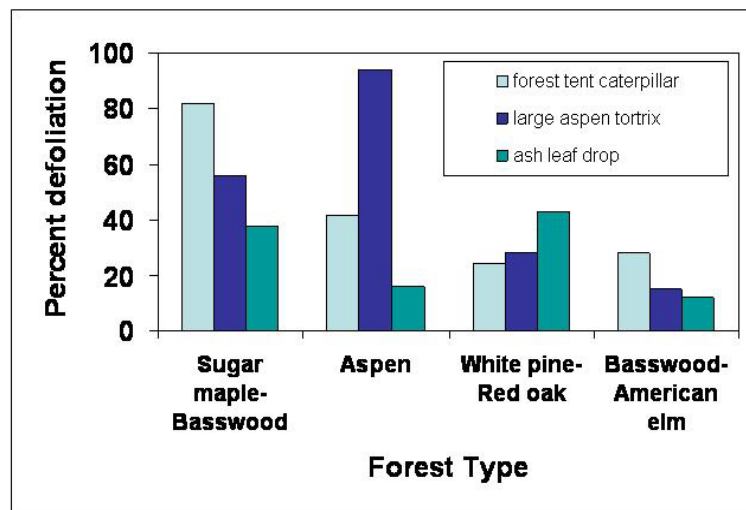


Figure 1. Mean percentage of defoliation on trees by three leaf defoliating insects in four habitat types at St. Croix NSR. (Hypothetical Figure)

Analyses testing for either a change or trend may be performed after two or three visits to a park, respectively. These analyses, if performed, must be done so and interpreted with caution. Insect and disease outbreaks are frequently cyclic, often occurring in < 5 year intervals. Results indicating differences after five or 10 years will not necessarily be a consequence of linear change during that period.

Rather than test for change in tree damage, for example, over a given time interval, we will likely use pest and pathogen damage as a covariate in other analyses. For example, we may be

interested in determining whether pest/pathogen damage explains differences in species diversity between the two time periods.

8.3 Acknowledgements

We are grateful to Joe O'Brien, Steven Katovich, and Manfred Mielke of the U.S. Forest Service for providing reviews of earlier drafts of this SOP. We are also grateful to the U.S. Forest Service FIA program for providing us with information on the Damage Indicator and allowing us to incorporate portions of those guidelines into this SOP.

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Succession

STANDARD OPERATING PROCEDURE #9

Version 1.0 (7/1/08)

Suzanne Sanders

NPS – Great Lakes Network

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9.0 Introduction

The successional states present in Great Lakes Network national parks range from newly fallow fields (Sleeping Bear Dunes NL) to old growth (Apostle Islands and limited amounts at Voyageurs NP and Isle Royale NP). Most, however, are in various stages of primary or secondary succession, following historical logging events prior to park designations.

The successional trajectories followed by individual stands depend not only on site conditions such as soils and hydrography (Leak 1986), but also on past land use (Dale et al. 1990). Some historical practices, such as logging, can affect succession by accelerating the successional pathway (Abrams and Scott 1989) as well as by altering the trajectory (Bourgeois et al. 2004). Although more subtle, current and future events may also influence the course of succession. For example, longer fire intervals are allowing more shade tolerant species such as balsam fir (*Abies balsamea*) and paper birch (*Betula papyrifera*) to become important forest components (Frelich and Reich 1995), while early and mid-successional species such as red pine (*Pinus resinosa*) can become less common (Scheller, et al. 2005). Other current impacts on forest succession include competition from invasive tree species (Titus and Tsuyuzaki 2003), injury from insects and pathogens (Malmström and Raffa 2000), and differential species response to elevated CO₂ (Catovsky and Bazzaz 1999).

This standard operating procedure (SOP) is linked to the Great Lakes Network General Vegetation Monitoring Protocol (Sanders et al. 2007), which specifies a six year sampling rotation where each Network park is visited once during this interval. This SOP provides guidance on analyzing and interpreting tree and sapling data from the General Vegetation Monitoring Protocol so that successional trajectories in Great Lakes Network national parks may be understood. Specifically, we hope to answer two key questions about succession in Network parks:

- Is forest structure changing? We'll measure basal area and density of all tree species ≥ 2.5 cm (1 in) in monitoring plots and test for change between time periods.
- Are the structural characteristics of Great Lakes Network forests moving toward those of stable, uneven-aged old-growth forests? We will compare the observed, surviving fraction in multiple size classes with the initial, baseline surviving fraction in these classes.

9.1 Field Methods

As part of the general vegetation monitoring protocol (Sanders et al. 2007), we will record the species, diameter at breast height (DBH), and height of all trees (DBH ≥ 12.7 cm (5 in)) and saplings (DBH 2.5 cm (1 in) - <12.7 cm (5 in)) in either the four 7.32 m radius subplots (FIA method, Figure 1) or the three 6 $\times$ 50 m belt transects (hybrid method, Figure 2) that comprise each plot. We will also record DBH and species (when possible) of standing dead trees.

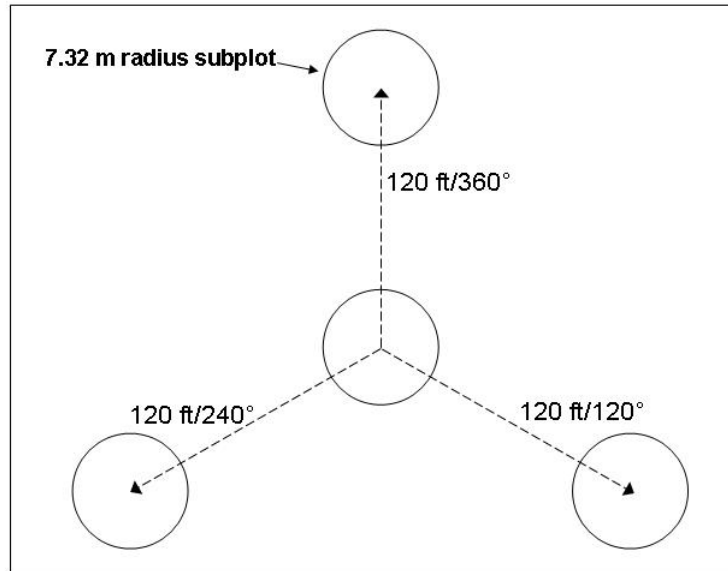


Figure 1. Diagram of FIA style monitoring plot showing four 7.32 m radius subplots.

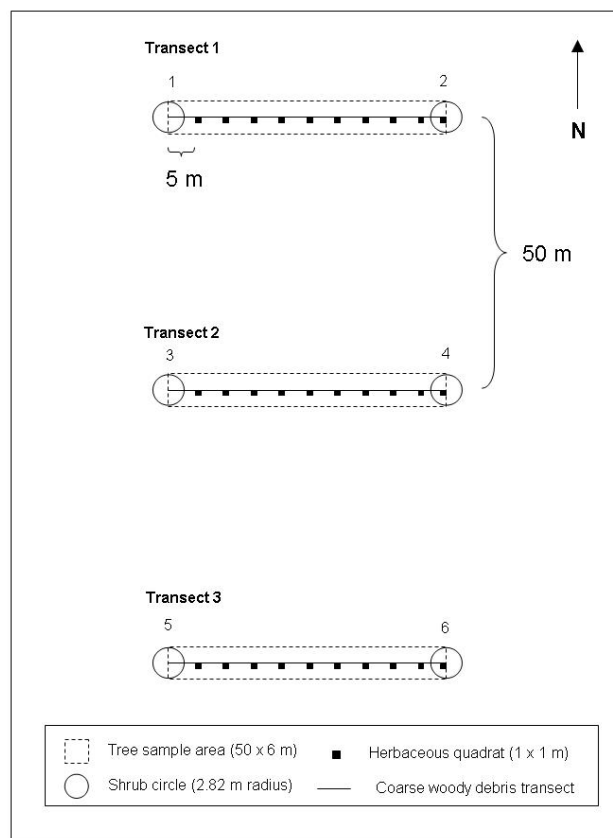


Figure 2. Hybrid plot, with 6 × 50 m belt transects demarcated by the dashed lines.

9.2. Analysis Methods

Summary analyses

Following the initial visit to each park, we will summarize the characteristics (density, basal area, down woody materials) at both the stand and individual species level (for key species only, Table 1). Summary graphs will be also presented, and will include density – diameter distribution graphs for different habitat types, showing the size distribution of multiple species during the previous season (Figure 3).

From the diameter distributions recorded at the first park visit, we will calculate the baseline (initial) surviving fraction between DBH size classes. This is simply the ratio of stems in a larger size class to that in the next smaller class. Where initial size structure is being maintained, a constant ratio in the number of trees present in successive size classes will emerge (Meyer and Stevenson 1943) and the resulting graphs exhibit the characteristic reverse-J shape (Figure 4). This is typically the case in uneven-aged, and old growth forests where recruitment is balanced by mortality (Leak 1996). In younger forests, more common throughout GLKN parks, the diameter distribution shapes vary. Characteristic shapes can include a flattened bell shape (Ward and Smith 2000), indicating an even-aged forest from either massive disturbance or a previous timber harvest. Severe browse can be evidenced by marked by smaller surviving fractions in the lowest size classes.

In addition to summary tables and graphs and diameter distribution graphs, additional summary information will be presented, as warranted, to display key traits about the initial forest structure.

Table 1. Hypothetical table layout showing the site characteristics of all trees collectively and key individual species (balsam fir, white pine, red pine) at during year of plot establishment.

Site	Fuel load ^a tons acre ⁻¹	Basal area m ² ha ⁻¹				Stand density stems ha ⁻¹			
		All	balsam fir	white pine	red pine	all	balsam fir	white pine	red pine
2001									
2002									
2003									
2004									
.....									
2020									
Mean									

^a Includes coarse and fine woody materials; this is presented in English units to facilitate comparisons with other projects.

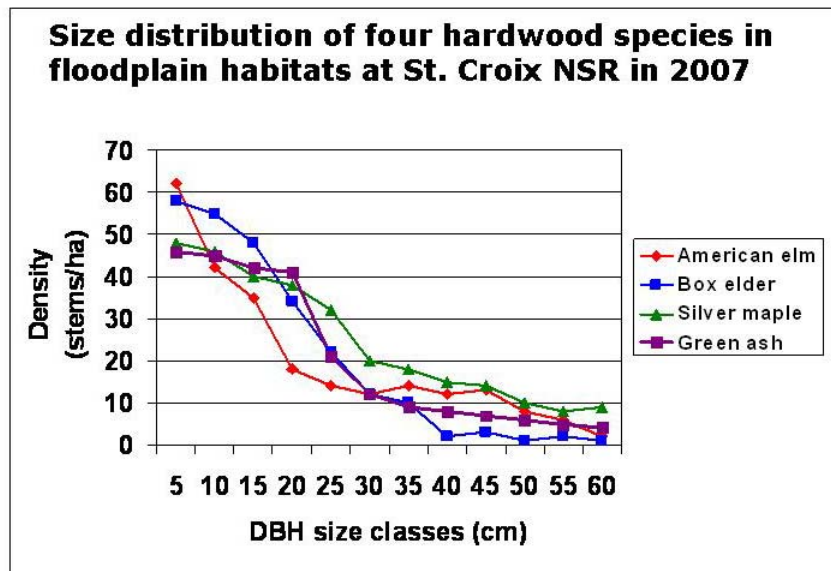


Figure 3. Hypothetical graph showing density-diameter relationships of four floodplain species in one season at SACN.

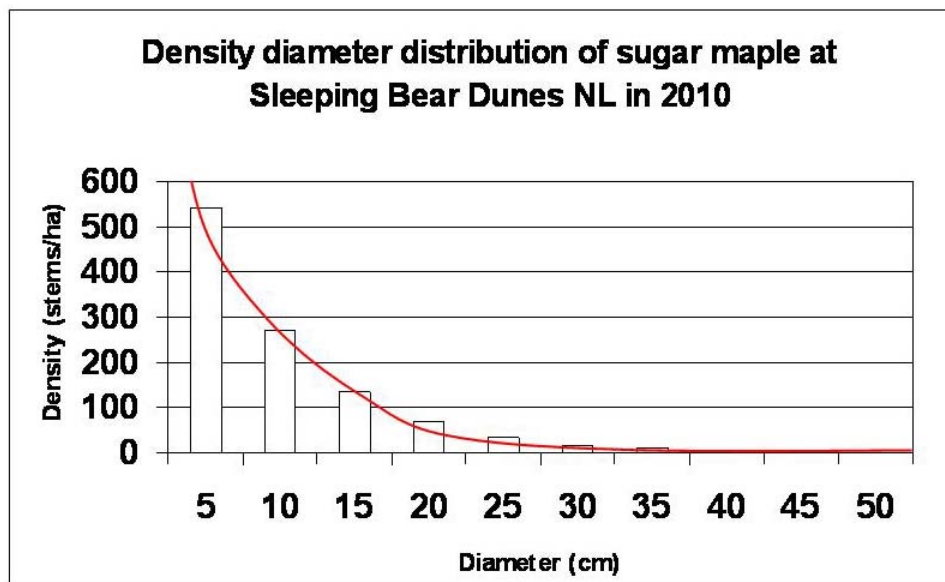


Figure 4. Hypothetical graph showing the reverse-J distribution (red line) of sugar maple densities at Sleeping Bear Dunes NL.

Trend analyses

After the second and all sequential visits to a park, we will again present density-diameter distributions and calculate the surviving fraction between size classes and draw inferences about whether the site characteristics are moving toward those of stable, uneven-aged forests. We will also look at overall change in stand (plot) basal area and stem count between visits (or over time).

In addition to calculating data on surviving fractions of all species collectively, we will also present graphs and tables showing changes in size and frequency of individual species. For example, for a given habitat, we may present density – diameter distribution graphs of a given species during multiple sampling years (Figure 5). This can be used to detect and/or highlight density changes in a particular size class. Depending on the shape of these graphs, they can be used to infer the drivers of this change. For example, in Figure 4, below, changes in the density of the two lowest size classes may indicate high sapling browse intensity.

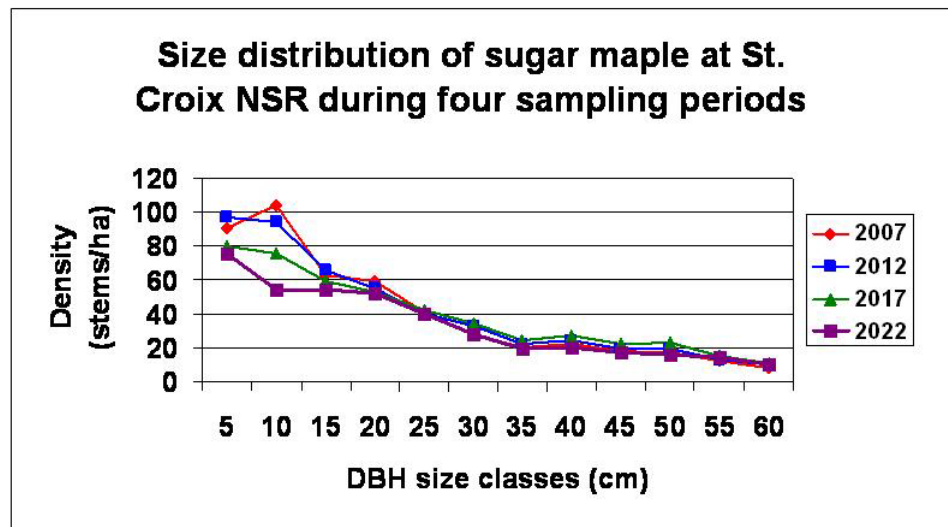


Figure 5. Hypothetical graphs showing the distribution of sugar maple size classes over four sampling periods.

Finally, additional graphs, tables, and analyses will be presented, as warranted, to convey the successional states of Great Lakes Network forests.

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Coarse Woody Materials

STANDARD OPERATING PROCEDURE #10

Version 1.0 (7/1/08)

Suzanne Sanders, NPS-Great Lakes Network

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10.0 Introduction

This standard operating procedure (SOP) is intended to provide guidance for monitoring coarse woody materials in habitat types within the nine Great Lakes Network national parks.(CWM). This indicator of forest health will be monitored within the context of the General Vegetation Monitoring program (Sanders et al. 2008); therefore there is no stand-alone monitoring protocol. Field methods and analysis techniques are contained in this SOP, while specific details of field data collection are provided in SOP #6: Field methods and data collection.

The NPS-GLKN woody materials sampling is designed to answer the following specific questions:

- What is the CWM volume (m^3/ha) in specific habitat types?
- What is the CWM biomass (kg/ha) in specific habitat types?
- What is the density (pieces/ha) of CWM in specific habitat types?
- What is the magnitude and direction of change in CWM volume, biomass, and density in each habitat between two or more sampling events?

CWM sampling provides information about the health of forests in Great Lakes Network Parks. Further, this information can be combined with that of community structure, succession, and other indices of forest growth that allows us to develop holistic forest health inferences.

10.1 Field Methods

As part of the General Vegetation Monitoring Protocol, the Great Lakes Network will be using one of two monitoring plot designs, depending on the park where monitoring occurs (Sanders et al. 2007). At some parks, we will be using the “hybrid plot” design (Johnson et al. 2006). This plot design was developed to meet the needs of the Great Lakes Network by combining assets of other long-term monitoring sampling protocols used in the region. At other parks, we will be using a plot design similar to one used by the Forest Inventory and Analysis (FIA) program of the USDA Forest Service (USDA 2005). Regardless of the employed plot design, our measurement variable definitions will mirror that of the FIA program. For example, criteria for discerning between CWM decay classes will be identical between the two programs. This will enable comparisons of CWM data collected within the network parks with that from forested areas surrounding the parks.

The hybrid plot is composed of three parallel 50 m horizontal distance transects, each oriented east-west (Figure 1). Data on CWM (≥ 0.91 m [3 ft] long and ≥ 7.6 cm [3 in] diameter) will be collected along each of these transects using the line intercept method (Brown 1974, de Vries 1986; Woodall and Williams 2005). For most CWD pieces, the parameters recorded are transect intersection diameter, small end diameter, large end diameter, length, species, and decay class (Table 1). For pieces in decay class 5, the small- and large-end diameters are not recorded. In addition, the length must be ≥ 1.52 m (5 ft) and the diameter at the line intercept must be ≥ 13.0 cm and the piece must be ≥ 13 high from the ground surface.

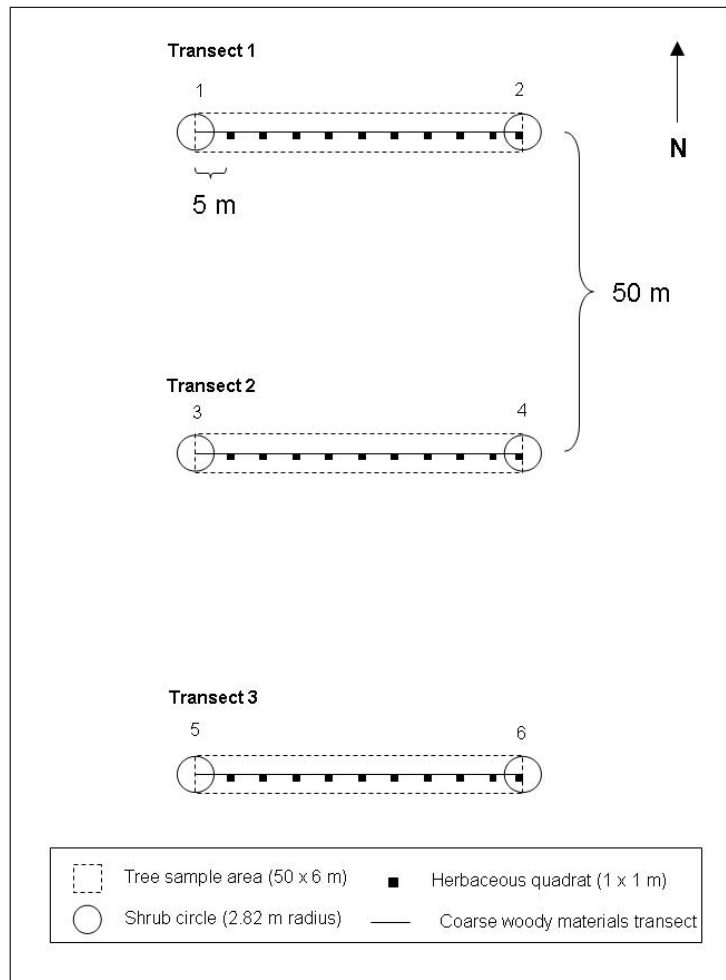


Figure 1. The hybrid plot, showing the three parallel transects along which data on coarse woody materials will be collected.

Table 1. Distinguishing characteristics of the five decay classes. From U.S. Department of Agriculture, 2006.

Decay class	Structural integrity	Texture of rotten portions	Color of wood	Invading roots	Branches and twigs
1	sound, freshly fallen, intact logs	intact, no rot; conks of stem decay absent	original color	absent	if branches are present, fine twigs are still attached and have tight bark
2	sound	mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	original color	absent	if branches are present, many fine twigs are gone and remaining fine twigs have peeling bark
3	heartwood sound; piece supports its own weight	hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	reddish brown or original color	sapwood only	branch stubs will not pull out
4	heartwood rotten; piece does not support its own weight, but maintains its shape	soft, small blocky pieces; a metal pin can be pushed into heartwood	reddish or light brown	throughout	branch stubs pull out
5	none, piece no longer maintains its shape, it spreads out on the ground	soft; powdery when dry	red-brown to dark brown	throughout	branch stubs and pitch pockets have usually rotted down

The FIA plot (Figure 2) is composed of four 7.32 m (24 ft) horizontal distance radius subplots, with each subplot having three transects spanning the radius at 30°, 150°, and 270° (Figure 1). Coarse woody material is sampled along the entire length of all three transects in the same manner described for the hybrid plot, above.

For both plot types, refer to SOP 6, Field methods and data collection, for specific tally rules on data collection.

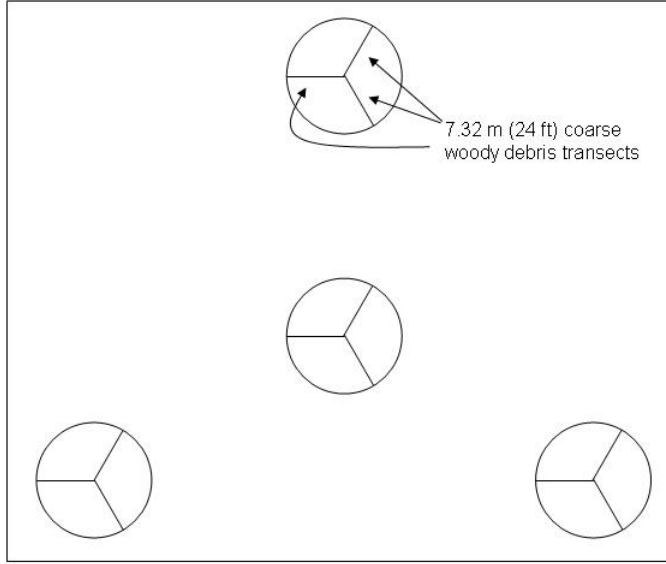


Figure 2. FIA style plot showing the three CWM transects within each of the four subplots.

10.2 Estimation Methods

Volume estimation for CWM based on a single transect of horizontal distance length L (m) is calculated by (Woodall and Williams 2005):

$$\bar{y} = \frac{f\pi}{2L} \sum_{i=1}^n (y_i / l_i) \quad (11.1)$$

where $\bar{y}$ is the volume in m^3/ha , $f = 10,000 \text{ m}^2/\text{ha}$, y_i is the volume of piece i (m^3), and l_i is the length of piece i (m).

The volume of individual pieces of CWM will be calculated following Smalian's formula (Husch et al. 1972):

$$V_m = \frac{(\pi/8)(D_s^2 + D_L^2)l}{10,000} \quad (11.2)$$

where D_s is the small end diameter (cm) and D_L is the large-end diameter (cm) and l is the length of the piece (m).

Where the small- and large-end diameters are not recorded and the only diameter is at the line intercept location, the volume of the individual piece will be estimated using Huber's formula (Husch et al. 1972):

$$V_m = \frac{(\pi/4)(D_T^2)l}{10,000} \quad (11.3)$$

where D_T is the transect diameter (cm). Refer to Appendix A for an example calculation of CWM volume.

While volume of CWM per unit area is important for many applications, estimates of CWM biomass are critical to carbon and fuel monitoring efforts. Because the biomass of any individual CWM piece is partially dependent on its species and stage of decay, CWM biomass estimates must incorporate species and decay class specific density constants. Hence, biomass per unit area is calculated by:

$$\text{kg/ha} = (\text{cubic meters per hectare}) \times 1000 \text{ kg/m}^3 \times \text{SpG} \times \text{DCR} \quad (11.4)$$

where SpG is the specific gravity for a given species (Table 2) and DCR is the decay reduction factor for a given decay class (Table 3, Woodall and Williams 2005).

In addition to volume and biomass, the density of CWM pieces is also of interest to the Network. Estimation of the number of CWM pieces per hectare based on a single transect of length L is calculated by (Woodall and Williams 2005):

$$\bar{y} = \frac{f\pi}{2L} \sum_{i=1}^n (1/l_i) \quad (11.5)$$

where $\bar{y}$ is the number of pieces per hectare, $f = 10,000 \text{ m}^2/\text{ha}$, and l_i is the length of piece i (m). An example calculation of this is shown in Appendix A.

Table 2. Identification codes and specific gravity values for tree species in Great Lakes Network parks. Specific gravity values are from Woodall and Williams 2005.

Species code	Species	Specific gravity	Species code	Species	Specific gravity
ABIBAL	<i>Abies balsamea</i>	0.34	LARLAR	<i>Larix laricina</i>	0.49
ACESPX	<i>Acer</i> spp.	0.49	LIRTUL	<i>Liriodendron tulipifera</i>	0.40
ACENEG	<i>Acer negundo</i>	0.44	MACPOM	<i>Maclura pomifera</i>	0.76
ACENIG	<i>Acer nigrum</i>	0.52	MALSPX	<i>Malus</i> spp.	0.61
ACEPEN	<i>Acer pennsylvanicum</i>	0.44	MORSPX	<i>Morus</i> spp.	0.59
ACERUB	<i>Acer rubrum</i>	0.49	MORALB	<i>Morus alba</i>	0.59
ACESA1	<i>Acer saccharinum</i>	0.44	MORRUB	<i>Morus rubra</i>	0.59
ACESA2	<i>Acer saccharum</i>	0.56	NYSSYL	<i>Nyssa sylvatica</i>	0.46
ACESPI	<i>Acer spicatum</i>	0.44	OSTVIR	<i>Ostrya virginiana</i>	0.63
AESSPX	<i>Aesculus</i> spp.	0.33	PICSPX	<i>Picea</i> spp.	0.38
AESFLA	<i>Aesculus flava</i>	0.33	PICGLA	<i>Picea glauca</i>	0.37
AESGLA	<i>Aesculus glabra</i>	0.33	PICMAR	<i>Picea mariana</i>	0.37
AILALT	<i>Ailanthus altissima</i>	0.37	PINBAN	<i>Pinus banksiana</i>	0.40
AMESPX	<i>Amelanchier</i> spp.	0.33	PINRES	<i>Pinus resinosa</i>	0.41
AMEARB	<i>Amelanchier arborea</i>	0.33	PINSTR	<i>Pinus strobus</i>	0.34
AMEHUM	<i>Amelanchier humilis</i>	0.33	PINSYL	<i>Pinus sylvestris</i>	0.41
AMEINT	<i>Amelanchier interior</i>	0.33	PLAOCC	<i>Platanus occidentalis</i>	0.46
AMELAE	<i>Amelanchier laevis</i>	0.33	POPSPX	<i>Populus</i> spp.	0.37
ASITRI	<i>Asimina triloba</i>	0.47	POPBAL	<i>Populus balsamifera</i>	0.31
BETSPX	<i>Betula</i> spp.	0.48	POPDEL	<i>Populus deltoides</i>	0.37
BETALL	<i>Betula alleghaniensis</i>	0.55	POPGRA	<i>Populus grandidentata</i>	0.36
BETLEN	<i>Betula lenta</i>	0.60	POPTRE	<i>Populus tremuloides</i>	0.37
BETNIG	<i>Betula nigra</i>	0.56	PRUSPX	<i>Prunus</i> spp.	0.47
BETPAP	<i>Betula papyrifera</i>	0.48	PRUPEN	<i>Prunus pensylvanica</i>	0.36
CARCAR	<i>Carpinus caroliniana</i>	0.58	PRUSER	<i>Prunus serotina</i>	0.47
CARSPX	<i>Carya</i> spp.	0.62	PRUVIR	<i>Prunus virginiana</i>	0.36
CARCOR	<i>Carya cordiformis</i>	0.60	QUESPX	<i>Quercus</i> sp.	0.58
CARGLA	<i>Carya glabra</i>	0.66	QUEALB	<i>Quercus alba</i>	0.60
CARLAC	<i>Carya laciniosa</i>	0.62	QUEBIC	<i>Quercus bicolor</i>	0.64
CAROVA	<i>Carya ovata</i>	0.64	QUEMAC	<i>Quercus macrocarpa</i>	0.58
CARTOM	<i>Carya tomentosa</i>	0.64	QUERUB	<i>Quercus rubra</i>	0.56
CASDEN	<i>Castanea dentata</i>	0.40	QUEVEL	<i>Quercus velutina</i>	0.56
CELOCC	<i>Celtis occidentalis</i>	0.49	ROBPSE	<i>Robinia pseudoacacia</i>	0.66
CERCAN	<i>Cercis canadensis</i>	0.58	SALSPX	<i>Salix</i> sp.	0.36
CORSPX	<i>Cornus</i> spp.	0.64	SASALB	<i>Sassafras albidum</i>	0.42
CORFLA	<i>Cornus florida</i>	0.64	SORAME	<i>Sorbus americana</i>	0.42
CRASPX	<i>Crataegus</i> spp.	0.62	SORDEC	<i>Sorbus decora</i>	0.42
FAGGRA	<i>Fagus grandifolia</i>	0.56	THUOCC	<i>Thuja occidentalis</i>	0.29
FRASPX	<i>Fraxinus</i> spp.	0.54	TILAME	<i>Tilia americana</i>	0.32
FRAAME	<i>Fraxinus americana</i>	0.55	TSUCAN	<i>Tsuga canadensis</i>	0.38
FRANIG	<i>Fraxinus nigra</i>	0.45	ULMSPX	<i>Ulmus</i> sp.	0.50
FRAPEN	<i>Fraxinus pennsylvanica</i>	0.53	ULMAME	<i>Ulmus americana</i>	0.46
FRAQUA	<i>Fraxinus quadrangulata</i>	0.53	ULMPUM	<i>Ulmus pumila</i>	0.46
GLETRI	<i>Gleditsia triacanthos</i>	0.60	ULMRUB	<i>Ulmus rubra</i>	0.48
ILEOPA	<i>Ilex opaca</i>	0.50	UNKHAR	unknown hardwood	0.51
JUGSPX	<i>Juglans</i> spp.	0.51	UNKSOF	unknown softwood	0.38
JUGCIN	<i>Juglans cinerea</i>	0.36	UNKXXX	unknown	0.46
JUGNIG	<i>Juglans nigra</i>	0.51			

Table 3. Decay reduction factors for calculating biomass (from Waddell, 2002).

Decay class	Species group	
	Hardwoods	Softwoods
1	1.00	1.00
2	0.84	0.78
3	0.71	0.45
4 and 5	0.45	0.42

10.3 Data Summaries and Analyses

Summarized data will be presented in figures and tables annually for each park preceding field sampling (e.g., biomass of coarse woody material in different habitats and regions, as well as proportion of plots in different biomass categories).

To test for change between successive sampling events and among multiple sampling events, we will use repeated measures analysis of variance (ANOVA) (see SOP 14: Data summary and analysis). Prior to all analyses, assumptions (e.g., normality and sphericity) will be tested and modifications made if needed. Time and either habitat or region will be the main effects and CWM biomass will be the dependent variable.

Results of the CWM inventory will be compared qualitatively with those describing plant community structure. This will allow inferences to be drawn relating fuel loads, community structure, successional states, and forest health.

10.4 Acknowledgements

The Great Lakes Network is grateful to Christopher Woodall of the U.S. Forest Service for providing reviews and comments on this SOP.

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Appendix A: Example Calculations

Below, we present sample calculations for estimating both CWM volume per hectare and pieces per hectare. The table below represents three pieces located along a 50 m transect for this example:

Piece ID	Species	Length (m)	Diameter (cm)	Decay class
1	Acer saccharum	6	8	4
2	Quercus rubra	14	20	3
3	Pinus strobus	8	12	1

Coarse woody material volume per hectare:

Volume estimation for coarse woody debris based on a single transect of length L is calculated by (Woodall and Williams 2005):

$$\bar{y} = \frac{f\pi}{2L} \sum_{i=1}^n (y_i / l_i) \quad (11.1)$$

where $\bar{y}$ is the volume in m^3/ha , $f = 10,000 \text{ m}^2/ha$, y_i is the volume of piece i (in meters), and l_i is the length of piece i (in meters).

Where only transect diameter is measured at the line intercept location, the volume of the individual piece will be estimated using Huber's formula (Husch et al. 1972):

$$V_m = \frac{(\pi/4)(D^2)l}{10,000} \quad (11.3)$$

where D^2 is the diameter (in cm) at the intercept point.

Thus, volume for each of the three pieces is calculated as:

$$\text{Piece 1: } V_m = (3.14/4) (8 \text{ cm})^2 (6\text{m}) / 10,000 = (0.785)(64 \text{ cm}^2)(6\text{m})/10,000 = 0.030144 \text{ m}^3$$

$$\text{Piece 2: } V_m = (3.14/4) (20 \text{ cm})^2 (14\text{m}) / 10,000 = (0.785)(400 \text{ cm}^2)(14\text{m})/10,000 = 0.4396 \text{ m}^3$$

$$\text{Piece 3: } V_m = (3.14/4) (12 \text{ cm})^2 (8\text{m}) / 10,000 = (0.785)(144 \text{ cm}^2)(8\text{m})/10,000 = 0.090432 \text{ m}^3$$

Volume for the transect is calculated as:

$$\bar{y} = \frac{(10,000 \text{ m}^2 / ha)(3.14)}{2(50\text{m})} \sum_{i=1}^n \frac{0.0301 \text{ m}^3}{6\text{m}} + \frac{0.4396 \text{ m}^3}{14\text{m}} + \frac{0.0904 \text{ m}^3}{8\text{m}}$$

$$\bar{y} = \frac{31400 \text{ m}^2 / ha}{100\text{m}} \times [0.0050 \text{ m}^2 + .0314 \text{ m}^2 + 0.0113 \text{ m}^2] = 314 \text{ m} / ha \times 0.3301 \text{ m}^2 = 103.71 \text{ m}^3 / ha$$

Coarse woody material biomass per hectare:

Biomass estimation for coarse woody debris based on a single transect of length L is calculated by (Woodall and Williams 2005):

$$\text{kg/ha} = (\text{cubic meters per hectare}) \times 1000 \text{ kg/m}^3 \times \text{SpG} \times \text{DCR} \quad (11.4)$$

where SpG is the specific gravity for a species and DCR is the decay reduction factor.

Because SpG and DCR vary, this calculation should be used for each tree:

$$\text{Piece 1: } \text{kg/ha} = \frac{(10,000 \text{ m}^2 / \text{ha})(3.14)}{2(50 \text{ m})} \times \frac{0.030144 \text{ m}^2}{50 \text{ m}} \times 1000 \text{ kg/m}^3 \times 0.44 \times 0.45 = 37.48 \text{ kg/ha}$$

Piece 2:

$$\text{kg/ha} = \frac{(10,000 \text{ m}^2 / \text{ha})(3.14)}{2(50 \text{ m})} \times \frac{0.4396 \text{ m}^2}{50 \text{ m}} \times 1000 \text{ kg/m}^3 \times 0.56 \times 0.71 = 1097.65 \text{ kg/ha}$$

Piece 3:

$$\text{kg/ha} = \frac{(10,000 \text{ m}^2 / \text{ha})(3.14)}{2(50 \text{ m})} \times \frac{0.0904 \text{ m}^2}{50 \text{ m}} \times 1000 \text{ kg/m}^3 \times 0.34 \times 1.00 = 193.02 \text{ kg/ha}$$

then summed over all trees in the transect:

$$\text{total kg/ha} = 37.48 \text{ kg/ha} + 1097.65 \text{ kg/ha} + 193.02 \text{ kg/ha} = 1328.15 \text{ kg/ha}$$

Coarse woody material pieces per hectare:

Estimation of the number of coarse woody debris pieces per hectare based on a single transect of length L is calculated by (Woodall and Williams 2005):

$$\bar{y} = \frac{f\pi}{2L} \sum_{i=1}^n (1/l_i) \quad (11.5)$$

where $\bar{y}$ is the number of pieces per hectare, $f = 10,000 \text{ m}^2/\text{ha}$, and l_i is the length of piece i (in meters).

Thus, the number of pieces per hectare is calculated as:

$$\bar{y} = \frac{(10,000 \text{ m}^2 / \text{ha})\pi}{2(50 \text{ m})} \times [(1/6 \text{ m}) + (1/14 \text{ m}) + (1/8 \text{ m})]$$

$$\bar{y} = 314m/ha \times [(0.16/m) + (0.071/m) + (0.125/m)]$$

$$\bar{y} = 314m/ha \times 0.356/m = 111.78/ha$$

Data Management

STANDARD OPERATING PROCEDURE #11

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11.0 Introduction

Data collected under the vegetation monitoring protocol (Sanders et al. 2008) must be entered, quality-checked, documented, managed, and made available to others for a variety of purposes, such as management decision-making, research, and education. The Great Lakes Inventory & Monitoring Network (GLKN) adopted and amended a database from the U.S. Forest Service Forest Inventory and Analysis (FIA) program, providing the Network with a tailored venue for data storage and management, while also permitting compatibility with the FIA program.

This standard operating procedure outlines data stewardship responsibilities and provides specific instructions and references for entering, quality checking, and managing vegetation data.

11.1 Data Stewardship Roles and Responsibilities

The purpose of data stewardship is to share the responsibility for managing data and information resources that are organized, useful, compliant, available, and safe. The demand for detailed, high quality data and information about vegetation requires a group of people working together to ensure that data are collected using appropriate methods, and that resulting datasets, reports, maps, and other derived products are well managed.

The Great Lakes Network (GLKN) terrestrial ecologist serves as project manager for vegetation monitoring. The project manager will supervise data collection, provide project oversight, direct on-the-ground data collections, and provide cohesive links among data collection, synthesis, interpretation, and reporting.

While the project manager must act as the steward for vegetation monitoring data for the Network, other project and GLKN personnel are also accountable for specific data management tasks. Table 1 lists stewardship responsibilities of personnel involved in the management of vegetation data. To ensure that all project data are managed properly, individuals must understand their responsibilities, communicate with one another, and assist one another as needed.

Table 1. Data stewardship responsibilities of water quality monitoring personnel.

Personnel Role	Data management responsibilities related to vegetation monitoring
Project Crew Member	Crew members collect and manage data with direction and guidance from the crew leader and/or project manager. Data collection includes obtaining GPS coordinates, and recording measurements and observations. Crew members are responsible for quality control by following data collection and recording instructions and by promptly verifying recorded data. Crew members may also perform data entry and verification.
Project Crew Leader	The crew leader normally performs the same duties as the other crew members and ensures adherence to data collection and processing protocols, including data verification and documentation. The crew leader also works with the project manager on vegetation data management in the office.
Project Manager (Network Terrestrial Ecologist)	The project manager is responsible for all project operations and results, and may also participate in field operations. The project manager ensures that data management activities are conducted according to established procedures and is responsible for data validation: approving the data content, quality, and documentation, as well as making decisions about data sensitivity and distribution. The project manager is responsible for evaluating project data at specified intervals, analyzing data for trends, and following reporting requirements.
Network Data Manager	The network data manager ensures that vegetation monitoring data are organized, useful, compliant, available, and safe. The network data manager oversees activities related to training, user support, quality assurance, documentation, backups, archiving, and data maintenance and distribution.
Network Data Specialist	The network data specialist is the project manager's primary contact for database assistance, including development of tables and queries and reporting needs. The network data specialist is also the initial contact for backups, archiving, and data maintenance and distribution.
Network Quantitative Ecologist	The network quantitative ecologist assists the project manager with analyses, primarily for reporting on status and trends of the vegetation vital signs.

11.2. Database Design

The monitoring database is a complex MS Access database made of two components, a front-end database and the back-end database. The front-end contains a user interface portion along with various queries, forms, reports and visual basic code for underlying function of the database as a whole and use with the user interface. The user interface consists of various forms to help the user enter and validate data, along with the ability to query, through forms, the data for various QAQC and final reports. The back-end database consists of numerous lookup and data storage tables, which are linked to the front-end database.

The Great Lakes Network will maintain one master copy of the vegetation at the Ashland office on a central server. This is the only copy that can be used to export data to other locations. Additional copies of the database will be used by GLKN personnel stationed at parks, but they can only be used as a conduit for data entry. For analysis, the data from the master copy at the Network, that has passed all QA/QC procedures, must be used.

11.3 Data Management Procedures

11.3.1 Data Collection

Data values are measured and obtained according the GLKN General Vegetation Monitoring Protocol and recorded on field forms (see SOP #6, Field Methods and Data Collection). Crew

members are responsible for legible, accurate entries on field forms. As a first step to verify data, crew members will check and double-check the recorded values prior to leaving a plot; these checks will ensure both legibility and that data on all desired parameters has been recorded.

Digital images of sample sites are acquired during site establishment (SOP #6) and at every visit thereafter. Crew members are responsible for proper settings and use of digital camera equipment and should refer to the user manual for details specific to the camera.

GPS coordinates are stored as waypoints if using a recreational GPS unit, or as features if using a mapping-grade unit with a data dictionary. When possible, the GPS data will be differentially corrected to improve the accuracy of location coordinates. See SOP #3 for more information on using a GPS unit.

11.3.2 Data Entry, Verification, and Documentation

Prior to leaving a field site, sampling crews will review the field data collection forms and verify the completeness, accuracy, and legibility of each form. As soon as is possible following sampling, the crew leader will make a photocopy of each field form and ensure each copy is legible. Upon receiving the copies, the project manager will proofread the datasheets, making sure that they have been filled out completely. All data sheets should have been reviewed for completeness while in the field, however some deficiencies in data recording may not be identified until all data sheets have been reviewed as a group. Originals will be kept at the Great Lakes Network Office and photocopies will be stored offsite.

Project staff enters plot data into the vegetation monitoring database as soon as possible following each site visit.

Data verification starts with the QA/QC steps that are detailed in SOP #18. As data are entered into the database, either by keyboard or using an import routine, a suite of QA/QC procedures exist that compare the entered data with expected formats and accepted data value ranges or domains. For many of the variables, the MS Access database will not accept out-of-bounds data, and correction is mandatory. Standard MSAccess queries have also been developed to parse out incorrectly entered data.

A user's identification is assigned to each aspect of data handling, from collection through the final steps of QA/QC. On data sheets, the identity of the data collector(s) is recorded. Once entered, standard reports of data will be generated in MSAccess and printed out. Two people will perform a final QA/QC check by reading the original datasheets and checking these values on the reports.

Executive Order 12906, mandates federal agencies to "...document all new geospatial data it collects or produces, either directly or indirectly..." using the Federal Geographic Data Committee Content Standard for Digital Geospatial Metadata. Vegetation monitoring meets the definition of geospatial data and, thus, GLKN is responsible for documenting all public datasets using metadata that meets that standard. Consult the GLKN Data Management plan (Hart and Gafvert 2005) for additional details about metadata procedures and requirements.

11.3.3 Data Validation

Prior to distributing the data for any type of use, the project manager validates the master vegetation monitoring database file according to procedures in the Quality Control and Quality Assurance SOP. Validation is performed at least once each year after data collection and entry are complete, usually by the end of each calendar year. If this annual validation does not meet scheduled reporting requirements of the Network, then the project manager may coordinate more frequent validation to meet needs, or reports can include a statement explaining that results are based on data that have not been validated. The statement should include an explanation of what significance this has for using preliminary data.

11.3.4 Data Distribution

GLKN has a number of different avenues for data distribution depending on the audience served and the degree of analysis and customization needed by the end-user (see GLKN's data management plan, Hart and Gafvert 2005, for more details). One of the primary methods GLKN uses for data distribution is a website with an Internet Mapping Service (IMS) that allows users to explore and query monitoring data using spatial and nonspatial parameters. In addition to the IMS website, individual data requests can be accommodated by developing queries to produce reports of the desired information.

11.3.4 Data Analysis and Reporting

Project staff will follow the procedures for data analysis in SOP #14 and data reporting in SOP #15. Data summary statistics will typically include, but not be limited to:

- Mean
- Median
- Standard deviation
- Minimum
- Maximum
- Count
- Percentiles (10, 25, 75, and 90th percentiles)
- Standard error
- Variance
- Range
- Mode
- Sum
- Kurtosis
- Skew

11.3.5 Data Folder and File Organization

All data from the vegetation protocol should be stored, at the earliest possibility, on the GLKN central server. A diagram showing the folder structure is shown below (Figure 2).

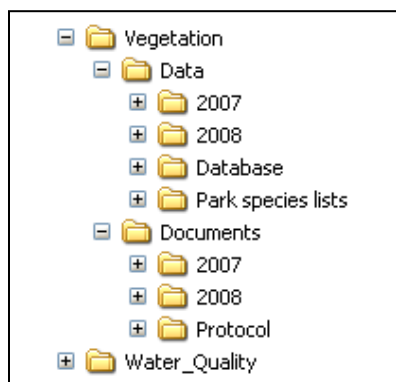


Figure 2. Great Lakes Network folder structure for information related to vegetation monitoring.

Files should be named in accordance with the file-naming standards in the GLKN Data Management plan (see section 6.4 of Hart and Gafvert 2005). Files have a ‘GLKN’ prefix, a descriptive element, and finish with a date element. For example, GLKN_VegMon_20070605.doc contains vegetation field data from June 5, 2007. Do not use spaces in file names.

11.3.6 Data Archival and Distribution Procedures

Data archiving serves two primary functions: it provides a source to retrieve a copy of any data set when the primary dataset is lost or destroyed, and it provides a data record that is an essential part of the QA/QC process. Original data will be archived at the Network office. Original data for printed forms are either the physical datasheets or exact and complete digital copies of the forms that capture all entries and notations. The unedited files are the original data for digital data.

All digital data have a duplicate file created at the earliest opportunity. The data files on field computers and loggers must not be erased until the integrity of these data files are verified on the duplicate storage medium. The removal of original data files from a field computer or logger must be a balance of keeping memory available for new data collection and a need to keep data in their most original form for as long as possible. Field files should only be deleted when memory space is needed for new data collection. Complete details of the GLKN Server archiving procedure are found the Infrastructure chapter of GLKN’s Data Management Plan (Hart and Gafvert 2005); the general strategy for data archiving is also described in this plan and its appendices.

11.4 Literature Cited

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Data Summary and Analysis

STANDARD OPERATING PROCEDURE #12
VERSION 1.0 (7/1/08)

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12.0 Introduction

This SOP provides information on analyses that will be used to prepare annual reports on static descriptions of terrestrial vegetation (14.1) and reports on changes in vegetation that will be produced every six years (14.2). This document also addresses the analyses that will be used to evaluate the relationships among population, community, and environmental variables (14.3). There are many advanced approaches to analyzing complex ecological data sets such as those produced by the Terrestrial Vegetation Monitoring Protocol and its associated Vital Signs. Priority should be given to the descriptive and statistical approaches described in sections 14.1-14.3. Section 14.4 describes several possible extensions that may provide the Network an opportunity to identify more complex relationships and interactions among multiple response and predictor variables. Advances in complex analytical techniques will no doubt continue over time once data have been compiled over several sample periods. The Network should reassess their options at that time.

This SOP specifically focuses on analyses that will be used to test the following primary and secondary objectives:

Primary Objective Questions:

- 1) What is the rate and direction of change of key species?
- 2) What is the rate and direction of change of plant community structure?
- 3) What is the rate and direction of change of plant community composition?

Secondary Objective Questions:

- 1) Are there significant links among population and community variables in interpreting ecological change?
- 2) Are there significant relationships among changes in population and community variables with changes in environmental indicators associated with vegetation?

The General Vegetation Monitoring Protocol of the Great Lakes Network (GLKN) is designed to monitor many sites across several habitat types within each of nine parks. This approach immediately raises the issue of whether and to what degree data from particular sites, habitat types, and parks should be aggregated for analysis. Aggregating data clearly has the advantage of increasing sample sizes and thus statistical power for analyses of ecological change. It also has the effect of averaging local site variation and so better detecting and identifying the more geographically widespread and longer-term trends that are the focus of the GLKN monitoring program. That is, more important systematic regional trends will emerge and not be obscured by the sampling error that occurs within individual sites. If sites within a given habitat type are aggregated for analysis with similar sites at other parks sampled in different years, aggregated analyses also gain the advantage of averaging the year-to-year variation that is otherwise confounded with park-to-park variation by the sampling design. Thus, the advantage of aggregating sites within habitat types can apply both when aggregating data within parks and when aggregating data across parks.

Although aggregating data within habitat types appears ecologically and statistically justified, aggregating data across habitat types could create problems both in terms of being able to detect ecological change and in terms of being able to correctly interpret the trends we detect. While

such aggregation increases the sample size, it does so at the cost of inflating site-to-site (sampling) variance with the additional heterogeneity that exists among disparate habitat types. Introducing this among-habitat variance runs the real risk of not detecting significant trends that may be occurring within certain habitat types. This is because either such trends do not occur in other habitat types (swamping trends that only occur within one habitat type), or because trends may run in counter directions in different habitat types. This risk makes clear the importance of stratification, which will be done here via *post-hoc* analyses of plant community variation. Grouping sites into habitat types should be done either by overlaying sites onto GIS vegetation cover maps or by using ordination analysis of community composition. Relatively few habitat types should be identified to avoid the small sample sizes that result from excessive subdividing.

12.1. Static Descriptions

After each field season, all data are analyzed to produce annual summaries on the status of terrestrial vegetation in the park(s) sampled that year. These annual summaries provide the Network with current status information relevant to policy and management decisions. A variety of analytical approaches are utilized to assess the status of 1) environmental variables associated with terrestrial vegetation, 2) population (species-level) variables, 3) community structure variables, and 4) community composition variables at each park and across parks in the Great Lakes region. Individual plots are the unit of replication for all analyses.

Environmental Variables

Assessing the status of various environmental variables associated with terrestrial vegetation is an important first step prior to evaluating complex relationships among environmental and vegetation response metrics. Many of the environmental variables that will be assessed, including proposed evaluations, are listed in Table 1. Details on some of these environmental variables are provided in SOPs linked to the General Vegetation Protocol. Numerous other landscape-level variables not listed in Table 1 may be obtained from GIS or public databases that document climate trends, etc.

Exploratory Data Analysis: All continuous data variables will be evaluated with descriptive statistics. These will include generation of means and standard errors, and bar charts that compare among sites, habitats or parks (Table 1). Categorical data, consisting of binary variables (e.g., presence/absence) and variables with greater than two categories, will be summarized in tables and bar charts. The tables will list all sites and will indicate presence or absence of all binary variables of interest. Summaries of these data will be presented in clustered bar graphs to make comparisons among sites at the habitat, park and/or regional scale. Similarly, categorical data with greater than two categories (e.g., logging history) will be presented in tables and in clustered bar graphs.

Inferential Data Analysis: For some key variables (i.e., presence of forest pathogens, ungulate browse), we will determine if there are statistically significant differences among habitats or regions within a park to identify areas that may warrant more immediate management or more intensive monitoring.

Chi-square goodness of fit tests will be used to assess significant differences in the presence of earthworms and ungulate browse (Table 1) among different habitats or regions within a park.

We will test the null hypothesis of no difference among habitats or regions in the relative proportion of sites with pest presence.

If the assumptions of homogenous variances and normality are met, **Analysis of Variance (ANOVA)** will be used to assess differences in continuous variables such as total fuel loads among groups (e.g., habitats or regions). Residual plots and differences in the magnitude of standard deviations between groups will be evaluated to determine if the variances are homogenous, and Q-Q plots will be evaluated to ascertain that there are no strong departures from normality. Non-parametric **Mann-Whitney U** or **Kruskal-Wallis** tests will be conducted if these assumptions are not met, even after attempting standard data transformations. In the case of ANOVA, significant main effects will be further evaluated with Tukey's HSD post-hoc test to distinguish among groups (Sokal and Rohlf 1995, Von Ende 2001).

Table 1. Planned static descriptions and analyses for tracking trends of various environmental variables that are associated with vegetation metrics. The geographic area refers to the area that each of these variables was assessed within a given site; note that woody debris is actually measured along linear transects instead of within a specific area. Inferential analyses suggested for static descriptions are intended to be used to assess differences among habitats or regions within parks. The landscape variables that are listed here are intended to be included in the ‘environmental matrix’ for ordination analyses as well as included as predictor variables in more complex analyses described later in the SOP; they do not necessarily need to be evaluated individually in the manner that is suggested for the other variables in this table.

Environmental Variables	Data Type	Geographic Area	Static Descriptions	Analyses for Tracking Change
Soil Horizon Depths (m ²)	Continuous	0.28m ²	bar charts, ANOVA	t-test, repeated measures ANOVA
Presence of Forest				
Pathogens	Categorical	673.99m ²	tables or bar charts, X^2	logistic regression
Presence of Earthworms	Categorical	0.28m ²	tables or bar charts, X^2	logistic regression
Ungulate Browse Presence	Categorical	53.85m ²	tables or bar charts, X^2	logistic regression
Relative Percent Browsed				t-test, repeated measures ANOVA
Shrubs	Continuous	673.99m ²	bar charts, ANOVA	ANOVA
Coarse & Fine Woody				t-test, repeated measures ANOVA
Debris (m)	Continuous	87.84m	bar charts, ANOVA	ANOVA
				t-test, repeated measures ANOVA
Total Fuel Loads (m ²)	Continuous	673.99m ²	bar charts, ANOVA	ANOVA
Logging History				
Categories	Categorical	~1 ha site area	NA	NA
Fire History Categories	Categorical	~1 ha site area	NA	NA
Forest Patch Size	Continuous	(from GIS)	NA	NA
Distance to Roads	Continuous	(from GIS)	NA	NA
Distance to Open Water	Continuous	(from GIS)	NA	NA

Taxonomy

Correct identification and documentation of plant species is an important aspect of monitoring. Unknown species should be identified as soon as possible and corrections updated in the database prior to continuing with any analyses. It is likely that the field crew botanist may improve his/her identification skills over the season, and it is imperative that they go back and make any needed changes to species that possibly were misidentified at sites sampled earlier in the season. Frequent quality control assessments will be made by the Network botanist, which will consist in field-checking crew member identifications and the quality of their entered data. Nonetheless, the large amount of data collected suggests that there will be a number of plants that cannot be identified, in particular because species flower/fruit at different times throughout the growing season. In many cases, identifying to genus (or even family) will be all that is possible. For all parks, the Integrated Taxonomic Information System (ITIS) will serve as the nomenclatural authority.

Population Variables

We will evaluate the status of key indicator species (Table 2) that we select from the tree, shrub and herb vegetation layers. Species lists will be constructed after each sampling period, and the Network Botanist and local resource managers will select key species based on their susceptibility to various factors such as deer browse, pathogens, reduced natural disturbance frequency, etc. Table 2 lists various species-specific metrics and the scale at which they will be evaluated within a given park after each sample period. Table 3 again lists these variables, but also includes the proposed methods for data evaluation.

Exploratory Data Analysis: Descriptive statistics (e.g., means, standard deviations, skewness, and kurtosis) should be computed and the data checked for approximate normality and homogenous variances. Bar charts will be used to compare the frequency of key indicator species at the site, habitat, and park levels. Species frequency is calculated as the number of sample units that a species is observed within at a given site. For example, the frequency of understory vascular plants will be calculated as the proportion of 1-m² quadrats that a species is present within

Histograms will be generated to evaluate the distribution of total basal area (m²/ha) for key individual tree species within each habitat or park. These distributions will be based on the following diameter classes: 2.5-9.9, 10-19.9, 20.0-29.9, 30-39.9, 40-49.9, 50-59.9, >60 cm. Both relativized and unrelativized frequencies will be assessed with these distribution graphs.

Inferential Data Analysis: In most cases, there likely will be no reason to conduct inferential statistical analyses on population variables for static assessment reports. However, exceptions that would make such static assessments of interest to resource managers may include the need to compare current abundances of a key species between or among areas in a park with different management or disturbance histories. In the case of tree density, we will use standard **2-sample t-tests** or **ANOVAs** (greater than two regions) to test the null hypothesis that the abundance of a particular species is equivalent between or among specific regions. For evaluating differences in the frequency of key herb or shrub species between different regions, we will conduct non-parametric replicated **G-tests for goodness of fit** (Sokal and Rohlf 1995). We will test the null

Table 2. List of key species and functional groups that will be evaluated in analyses of population-level change at each park. Species may be added or removed from this table over time, depending on unforeseen species loss or invasions and the observed statistical power to track changes in these species within or across parks.

Species	Park								
	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
Trees and Shrubs									
<i>Abies balsamea</i> (balsam fir)				X					
<i>Acer saccharum</i> (sugar maple)	X				X	X	X	X	
<i>Ailanthus altissima</i> (tree-of-heaven)			X		X		X	X	
<i>Fagus grandifolia</i> (beech)			X		X	X	X	X	
<i>Fraxinus</i> spp. (ash)	X	X	X	X	X	X	X	X	X
<i>Pinus resinosa</i> (red pine)		X							
<i>Pinus strobus</i> (white pine)		X							
<i>Tsuga canadensis</i> (eastern hemlock)	X			X		X	X	X	
<i>Taxus canadensis</i> (Canada yew)	X	X		X		X			X
Herbs and Functional Herb Groups									
<i>Arisaema triphyllum</i> (jack-in-the-pulpit)	X	X	X	X	X	X	X	X	X
<i>Actaea</i> spp. (baneberry)	X	X	X	X	X	X	X	X	X
<i>Carex</i> spp.	X	X	X	X	X	X	X	X	X
<i>Osmorhiza</i> spp. (sweet root)	X	X	X	X	X	X	X	X	X
Broad-leaved lily & 'lily-like' herbs ¹	X	X	X	X	X	X	X	X	X
Abiotically pollinated herbs	X	X	X	X	X	X	X	X	X
Biotically pollinated herbs	X	X	X	X	X	X	X	X	X
Abiotically dispersed herbs	X	X	X	X	X	X	X	X	X
Biotically dispersed herbs	X	X	X	X	X	X	X	X	X
Ferns and Fern-Allies	X	X	X	X	X	X	X	X	X

¹ *Clintonia borealis*, *Maianthemum canadense*, *Streptopus* spp., *Smilacina* spp., *Trillium* spp., *Polygonatum* spp., and *Uvularia* spp.

hypothesis that the proportion of quadrats occupied by a given species remains constant between different park regions. *G*-tests are very useful for inferring differences in species abundance across a region, in that individual *G* values from particular sites that may often fall short of significance can be combined across sites to obtain more powerful tests of overall change (Wiegmann and Waller 2006). Such tests also allow one to calculate *G*-heterogeneity values, which provide a measure of the consistency of shifts across sites or regions. Because Type I errors may occur with so many *G*-tests, Holm's (1979) correction will be used for the reported *P*-values.

We also may wish to compare basal area distributions of key tree species between, for example, a burned and unburned region of a park. We will employ the non-parametric **Kolmogorov-Smirnov two-sample test** to test the null hypothesis of no difference between two empirical sample distributions (Sokal and Rohlf 1995). To conduct the test, we will calculate the relative expected frequencies of the key tree species within each size class by dividing the frequencies observed within each region by the sample size of that region. We then will calculate the absolute value of the difference (*d*) of each of these relative frequencies for each size class. The maximum unsigned difference (*D*) is considered the largest *d* value. To calculate a test statistic, *D* is multiplied by the product of the sample sizes for the two sample periods. This test statistic is then compared to a critical value to determine the probability of observing a difference of that magnitude (or greater) between the two distributions (Sokal and Rohlf 1995). In the case that the distributions are significantly different, the density-diameter distributions will be referred to in order to determine which size classes may be represented to a greater or lesser degree in the burned and unburned regions.

Community Structure

We will evaluate the distribution of standing vegetation structure in park forests. This will involve assessing the total size of trees and shrubs and the relative abundance of the herbaceous and groundlayer vegetation across sites (Tables 3 and 4).

Exploratory Data Analysis: Total basal area of trees will be averaged over sites and displayed in bar graphs to compare standing structure within habitats or parks. These data on tree and sapling diameters will be combined, and the relative frequency of trees within diameter classes (2.5-9.9, 10-19.9, 20.0-29.9, 30-39.9, 40-49.9, 50-59.9, >60 cm) will be graphed. Similar graphs will be constructed to evaluate the size distributions of standing dead trees among habitats and parks.

We also will compare average height and relative frequency of shrubs (Table 4), irregardless of species, among different habitats or regions within a park. Similarly, we will evaluate the relative frequency of all herbaceous and woody groundlayer vegetation among different habitats or regions. We will again employ bar graphs for these descriptive comparisons.

Table 3. Specific population-level (for key species) and community-level response metrics to be used in analyses. Note that relativizing many of these metrics for analyses (in addition to their raw form) will also offer important information.

Vegetation Layer	Specific Metrics	Geographic Area
Population Variables		
Trees and Saplings	Basal Area / ha	673.99m ²
	Density/ ha	673.99m ²
	Frequency	673.99m ²
	Alive:Dead Ratio	673.99m ²
	Basal Area-Density Distributions	673.99m ²
Shrubs	Frequency	53.85m ²
Groundlayer	Frequency	36m ²
Community variables		
Trees and Saplings	Total Basal Area / ha	673.99m ²
	Total Density /ha	673.99m ²
	Species Richness	673.99m ²
	Mean Similarity to other Sites	673.99m ²
Shrubs	Mean Total Height (cm)	53.85m ²
	Frequency	53.85m ²
	Species Richness	53.85m ²
	Non-Native: Native Ratio	53.85m ²
	Mean Similarity	53.85m ²
Groundlayer	Species Richness	1m ² , 36m ² , 673.99m ²
	Non-Native: Native Ratio	36m ² , 673.99m ²
	Rel. Abund. of Functional Groups	36m ²
	Mean Similarity	36m ²
	Forest Quality Index (FQI)	36m ²

Table 4. Planned static descriptions and analyses for tracking trends of various population and community variables. The inferential statistical tests that are listed under the ‘static descriptions’ column will not always need to be conducted (see text). K-S test refers to the Kolmogorov-Smirnov 2-sample test.

Variables	Static Descriptions (and possible analyses)	Analyses for Tracking Change
Population (single species) Variables		
Basal Area (trees)	bar charts, t-test, ANOVA	t-test, repeated measures ANOVA
Density (trees)	bar charts, t-test, ANOVA	t-test, repeated measures ANOVA
Dead:Alive Ratio (trees)	bar charts, X^2	t-test, repeated measures ANOVA
Density-Basal Area Distributions (trees)	bar charts, K-S test	K-S test
Relative Abundance (frequency of a species in any vegetation layer)	bar charts, t-test, ANOVA, G-tests	G-tests
Community Structure Variables		
Total Basal Area / ha (trees)	bar charts, t-test, ANOVA	t-test, repeated measures ANOVA
Tree Total Density / ha (trees)	bar charts, t-test, ANOVA	t-test, repeated measures ANOVA
Mean Total Height (shrubs)	bar charts, t-test, ANOVA	t-test, repeated measures ANOVA
Relative Frequency (all shrubs)	bar charts, G-test	G-test
Total Density-Basal Area Distributions (trees)	bar charts, K-S test	K-S test
Total Density-Basal Area Distributions of Dead trees	bar charts, K-S test	K-S test
Relative Frequency (all herbs)	bar charts, G-test	G-test
Community Composition Variables		
Species Richness	bar charts, ordination, t-test, ANOVA	t-test, repeated measures ANOVA, ordination
Mean Similarity	bar charts, ordination	t-test, repeated measures ANOVA, ordination
Non-Native: Native Ratio	bar charts, ordination, X^2	t-test, repeated measures ANOVA, ordination
Relative Abundance (frequency) of Different Functional Groups	bar charts, ordination, t-test, ANOVA	t-test, repeated measures ANOVA, ordination
Floristic Quality Index (FQI)	bar charts, ordination, t-test, ANOVA	t-test, repeated measures ANOVA, ordination

Inferential Data Analysis: As was mentioned above for population variables, we will not always need to conduct inferential statistical analyses for static assessments of community structure. These analyses only need be conducted if park managers have *a priori* interest in determining if there are differences in, for example, tree basal area among different habitats or regions with contrasting management or disturbance histories. We will compare total tree basal area or average shrub height between or among habitats or regions with **2-sample t-tests** or **ANOVAs**, and will use the **Kolmogorov-Smirnov two-sample test** to evaluate differences in total basal area distributions between two habitats or regions (see section C above). *G*-tests will be used to assess departures from an equivalent relative distribution of all herbaceous or woody groundcover between different habitats or regions.

Community Composition

We will use several descriptive approaches to evaluate the status of community composition in parks after each sample period (Tables 3 and 4). In addition to total species richness, we also are interested in the relative abundance of the various species making up this sum richness. Besides calculating the number of non-native species relative to native species, we also we will evaluate the relative abundance of species with different morphological or life history traits ('functional traits'). Differential assemblages of species with different functional traits may elucidate patterns in composition that reflect specific disturbances. For example, Wiegmann and Waller (2006) documented species losses over a 50-year period in the Northwoods of Wisconsin. The declining species were typically those that rely on animals for pollination and/or dispersal and that are sensitive to herbivory by deer; whereas, abiotically pollinated or dispersed species, especially graminoids, were noted as increasers.

We also will determine how similar sites are to each other with respect to the identity and abundance of species at a site compared to all other sites, and will evaluate the quality of sites based on the identity of the species present at each site.

Exploratory Data Analysis: Descriptive statistics, including means and standard errors, will be generated to evaluate species richness (number of species) within and among sites of a given habitat and/or park. These exploratory analyses will be conducted separately for each forest layer: trees, saplings, shrubs, seedlings, and herbs. Species richness of herbs will be assessed at the levels of 1-m², 36-m² quadrats and within 673-m² walkthrough areas at each site. Species richness does not take into account composition; hence, it is recommended that separate evaluations be conducted for native and non-native species richness. Native status will be determined by the National Park Service's NPSpecies website:

<http://www.nature.nps.gov/biology/biologicalinventories/npspecies/>. The ratio of native to non-native species will be assessed to identify regions within each park that may be more highly invaded by exotic species.

It is of particular importance to recognize that the number of species encountered in a given sample generally reflects the area sampled (the typical species-area curve) and/or the number of individuals encountered. This makes it necessary to use a standard area or number of individuals when comparing diversity patterns across habitats or parks, e.g., by constructing 'rarefaction' curves (Smith et al. 2000, Gotelli and Colwell 2001). Species-area and species-individual curves

can be created with the free program EstimateS (Colwell 2005). Examples of these graphs can be viewed in Johnson et al. (2006).

To examine similarity in community composition among sites and to identify groups of sites of similar habitat, **nonmetric multidimensional scaling (NMDS)** ordination may be conducted in PC-ORD (McCune and Grace 2002). This will be achieved through the following main steps: 1) Primary matrices containing species frequency values within a given forest strata for all sites will be constructed. 2) Secondary matrices containing environmental variables associated with each site will also be created. These environmental variables can be quantitative or categorical, and can include: depth of various soil horizons, presence (or abundance) of pests and pathogens, deer browse frequency or intensity (see SOP 9), cover type as determined by dominant tree species, logging history categories, etc. Descriptive site metrics, such as native to non-native species ratio, relative site richness, etc., will also be included in this secondary matrix. 3) Ordination analyses will be conducted following procedures outlined in McCune and Grace (2002). We will use the Sørensen (Bray-Curtis, Beals 1984) distance measure for ordinations. Separate ordinations will be performed for trees, shrubs and herbs (the herb dataset will also include woody shrub and seedling species sampled within 'herb' plots). Sites falling close together in ordination space are more similar in composition than are plots lying further apart. Hierarchical cluster analysis will be used to define community types or 'habitats' among sites. Choice of linkage method and distance measure will be made following the guidelines in McCune and Grace (2002).

Other ways to identify sites may also be used. For example, forest type grouping by the Kotar classification method (Kotar and Burger 1996, Kotar et al. 2002) classifies "site potential," which is based on hydrology and nutrient availability, and assessed by the current understory species.

Inferential Data Analysis: After identifying groups of sites with hierarchical cluster analysis, we will use **Multi-response Permutation Procedure (MRPP)** to test the null hypothesis of no difference between two or more groups. MRPP is a nonparametric procedure recommended for ecological community data, as it can be used without meeting the typical assumptions of multivariate normality and homogeneity of variances (McCune and Grace 2002). The same distance measure selected for ordination analyses, Sørensen, will be applied to these MRPP analyses. This analysis will be conducted with PC-ORD, which provides an estimate of the effect size and a p-value. The effect size is estimated with the 'chance-corrected within-group agreement' (A) statistic that provides an estimate of the difference in within-group homogeneity to that which would be expected at random. If $A = 1$, then sites within each group are identical; whereas, $A = 0$ if groups of sites are as different as would be expected by chance. Statistical significance among groups will depend largely on the effect size and sample size, and McCune and Grace (2002) recommend that care be taken in ascertaining that statistical significance translates into ecological significance.

12.2. Detecting Change

Each park will be visited and surveyed every six years. Once a given park has been sampled a second time, tests for changes in metrics can commence. It will be possible to test for trends with more sensitivity and to evaluate changes in trends once the third sampling event for any

given park is complete. In addition to investigating changes in environmental variables and population and community vegetation variables, we also will be assessing the relationships among all of these variables (section 14.3). Such tests, however, depend on an important initial step, taxonomy synchronization, described below in section B.

Environmental Variables

Exploratory Data Analysis: For each metric (Table 1), we will compute descriptive statistics, including means and standard errors, which we will then present in bar charts with bars clustered by sample year. Data from sites within specific habitats will be combined for these analyses, but we also will provide summaries across all sites at the park level.

Inferential Data Analysis: We will take a similar approach that was described in the ‘Static Descriptions’ section, but we will extend our analyses so we can look at significant changes in variables over time. We will determine if there are significant increases or decreases in the presence of key variables (i.e., forest pathogens, earthworms, ungulate browse) over time across sites within specific habitats or regions within a park. We will use **Chi-square goodness of fit** tests to test the null hypothesis of no difference between sample periods in the relative proportion of sites with pests or pathogens present among habitats or regions.

Parametric **paired t-tests** can be used to assess changes between two sample periods for continuously distributed metrics (e.g., total fuel loads; Table 1) when the standard assumptions of homogenous variances and normality are met. **Repeated measures ANOVA** should be used to assess changes in metrics once more than two sample periods have been accumulated. Analyses will be conducted separately for each park or with park added as a factor to the ANOVA. The repeated measures ANOVA models will include time (years) as a within-subject factor and several possible between-subject variables, depending on the questions being asked. The within-subject factor refers to the response variable being measured repeatedly for all sites and the between-subject factors refer to the response variable being measured on sites within independent groups of sites exposed to different conditions. Examples of between-subject variables that we may use include: cover class, presence of pests or pathogens, soil type, and park when data are aggregated across parks to look for regional trends (see Table 1 for list of environmental variables). The factors will be included into the ANOVA model so as to correctly represent the nested structure. The standard assumptions of ANOVA will be checked, but we also will check the sphericity assumption specific to repeated measures ANOVA. Mauchly’s test for sphericity will be used to assess whether the variance-covariance matrix is such that the magnitude of differences between any two years of the within-subject variable (time) are equal (Von Ende 2001). Von Ende (2001) states that this assumption often is not met when the model includes time as a within-subject factor. If the sphericity assumption is not met, then a correction factor (i.e., Huynh-Feldt Epsilon) to adjust the degrees of freedom will be used, because F-statistics for within-subject factors and their interactions with other variables become inflated with departures from sphericity (Von Ende 2001).

Significant differences in time will be assessed with *a priori* within-subject contrasts and significant between-subject effects will be followed up with Tukey’s HSD post-hoc test to distinguish among groups (Sokal and Rohlf 1995, Von Ende 2001). Profile plots with the response variable on the y-axis, time (sample period) on the x-axis, and groups plotted with

different symbols will aid in the interpretation of significant interaction terms. For significant interaction terms, contrasts will be constructed and used in univariate analyses (i.e., t-test or ANOVA) to assess significant differences between groups among sample periods. Contrasts will be constructed to assess significance between specific groups at specific time intervals to avoid inflating the Type I error rate with multiple unneeded analyses. Holm's (1979) adjustment will be conducted on all p-values reported from these contrast assessments to further limit the probability of making Type I errors with multiple analyses.

Taxonomic Synchronization

As data will be collected by different botanists among parks and among years, potential taxonomy errors in identification could occur. In addition, updated taxonomy may result in different species names being used across sample periods. To address these issues, the taxonomy must first be synchronized among sample periods before conducting analyses. The following steps outline this process: 1) A list of all species found within each site for all sample periods will be generated. 2) Database queries will be run to produce tables that present the frequency of each species at each site by sample year. 3) This list will be reviewed by the Network Botanist to address any taxonomic discrepancies among years. For example, this exercise may indicate that the botanist identified *Dryopteris intermedia* at all sites one year, but that another botanist in another year only recorded *D. carthusiana* at these sites. In this case, these two species are known to be somewhat difficult to differentiate in the field, and voucher without numerous voucher specimens (which may not be allowed for some parks) one would not be able to discern which botanist was correct. 4) All decisions to lump species or to change species identifications will be documented in the metadata (see SOP 13). Changes should not be made to the original datasets, but instead be saved to a 'synchronized' dataset directly linked to the metadata. 5) This process will be repeated with the raw data each time new data become available.

Changes in Population Variables

Typical plant community datasets are full of zeros or low numbers, reflecting the fact that most species are infrequent across plots and across sites (McCune and Grace 2002). We likely will have limited power to detect significant changes in the abundance of individual species within sites and habitat types (Johnson et al. 2006); although, data aggregated across the region may prove to be informative. We will thus be circumspect when making inferences about population changes. As more power can be attained with aggregated or composite indicators, we will place most of our emphasis on composite groupings of species based on functional traits or taxonomic relatedness (Johnson et al. 2006). The following proposed analyses will refer to 'species', however, this term should be replaced with 'composite indicator' in these cases where species-level analyses are not being conducted. The metrics and the proposed analyses that we will use to evaluate them are listed in Table 4.

Exploratory Data Analysis: For groundlayer vegetation, we will generate species lists and compute the frequency of occurrence for key species for each sample period. We will calculate the change in these species' frequencies between each successive sample period and present these results in histograms or line graphs. By plotting positive and negative values, the histograms will clearly depict increasing or decreasing frequencies of species.

We will evaluate changes in average basal area and average density of key tree species by presenting these data, along with standard errors, in bar charts. Changing ratios of alive and dead individuals of these key species also will be monitored through time; we will present those data in stacked bar graphs. We will use clustered bar graphs for cases where we wish to compare the metrics over time between or among habitats or regions in a park. Because we also will have abundance and size information for trees, we will produce density-size distribution curves for select tree species. This will include species susceptible to browse, as well as those with known regeneration or disease problems. The data on tree and sapling diameters will be combined and the relative frequency of trees within specific diameter classes (2.5-9.9, 10-19.9, 20.0-29.9, 30-39.9, 40-49.9, 50-59.9, and >60 cm) will be presented in line or bar graphs at the habitat or park levels.

Inferential Data Analysis: Changes in species abundance over time will be evaluated using non-parametric replicated **G-tests for goodness of fit** (Sokal and Rohlf 1995) and **repeated measures analysis of variance (ANOVA)**. These analyses will allow us to determine whether individual species' (or composite groups') abundances are significantly increasing, declining, or remaining constant.

Replicated G-tests will be used to analyze the frequency data collected for herbs, shrubs and seedlings (Table 4). We will test the null hypothesis that the proportion of quadrats occupied by a given species remains constant over repeated sampling intervals. G-tests are very useful for inferring changes in species abundance across a region, in that individual G values from particular sites that may often fall short of significance can be combined across sites to obtain more powerful tests of overall change (Wiegmann and Waller 2006). Such tests also allow one to calculate G-heterogeneity values, which provide a measure of the consistency of shifts across sites or regions. Because Type I errors may occur with so many G-tests, Holm's (1979) correction may be used when reported P-values are being considered.

Repeated measures ANOVA will be used to analyze continuously distributed variables such as tree basal area and density (Table 4). The procedures for this analysis are described above in section A for detecting changes in environmental variables. We will determine if the density-diameter distributions of key species are significantly changing with time by implementing the **Kolmogorov-Smirnov two-sample test**. This will provide a sensitive test of the null hypothesis that the density-diameter distributions for trees sampled one year is the same as the sample distribution observed in a second sample year. This test is described in more detail above in section 14.1 part C.

Changes in Community Structure

We will evaluate the distributions of the relative sizes of individuals within each stratum between sample periods to evaluate how community structure is changing. These comparisons of structural changes should provide insight into successional and regenerative processes in the parks. They can also be used to assess how vegetation is being affected by other drivers of change such as deer (see SOP 9). From our understanding of basic successional processes, we generally expect tree stem density to decrease and stand BA to increase over time. Tracking structural changes over time will also allow us to make connections with other 'Vital Signs', such as bird and mammal communities that depend on this structure for food and shelter.

Exploratory Data Analysis: Community structure will be assessed by examining the size distribution of all species combined across sites within specific habitats or regions of parks. Response variables to be analyzed include tree basal area, tree density and shrub height (Table 4). Tables, graphs, or both that present means and measures of variability (e.g., standard errors) will be generated to provide a descriptive view of changes in size metrics through time. Total tree density-size distributions will be constructed for each sample period, and we will identify shifts in overall forest structure within specific habitats or regions. Diameter size classes (2.5-9.9, 10-19.9, 20.0-29.9, 30-39.9, 40-49.9, 50-59.9, >60 cm) will be presented on the x-axis of these graphs. Similarly, we will evaluate changes in the size distributions of standing dead trees among habitats and parks.

We will calculate the instantaneous rate of change ($\ln\lambda$) in average basal area, average density, and average shrub height between two sample periods by using the equation

$$\ln(\bar{X}_{\text{year } 5}) - \ln(\bar{X}_{\text{year } 1}) = \ln\lambda.$$

We will use bar charts to evaluate the instantaneous rate of change in these metrics by graphing $\ln\lambda$ for each site within a specific habitat or region of a park.

Inferential Data Analysis: Separate **repeated measures ANOVAs** (or **paired t-tests** if there are only two sample periods) will be conducted for each response variable to determine how these structural metrics are changing over time within each park. These response variables will be transformed if they do not meet the ANOVA assumptions of homoscedasticity and normality. Refer to section 14.2 part A for more details on this analysis.

We will implement the **Kolmogorov-Smirnov two-sample test** to determine if there are differences in the density-diameter distributions of total tree structure, regardless of species, between time periods. The procedures for this test are outlined above in section 14.1 part C.

Changes in Community Composition

The understory and overstory data will be evaluated (Table 3) to determine whether species richness has changed, whether the ratio of non-natives:natives has shifted, whether sites have become more or less similar in species composition and relative frequency, and whether site quality is changing, reflecting changes in the identity of species at a site. The magnitude and direction of change for each of these components of community assessment also will be assessed.

Exploratory Data Analysis: Descriptive statistics and graphs will be generated to compare metrics associated with each forest layer through time prior to conducting more rigorous statistical analyses. These initial data summaries should include assessments on the following metrics: 1) mean quadrat richness (1-m² herb plots only), 2) mean site-level richness of the groundlayer, 3) ratio of non-natives:natives, 4) mean site-level shrub richness, 5) mean tree richness, 6) mean coefficient of covariation (FQI, see below), and 7) site similarity (see below).

We will determine if the biological integrity of sites has changed over time by tracking changes in the Floristic Quality Index (FQI). FQI is a highly sensitive quantitative tool that assesses the quality of a site, specifically the degree of degradation, by taking into consideration the identity of species at these sites (Swink and Wilhelm 1979, 1994). Use of a FQI is dependent upon coefficients of conservatism (C) that are assigned to all species in the flora by trained botanists. Values of C range from 0-10, with 10 referring to those species that are very sensitive to degradation; hence, they are never found outside of intact natural communities. Weedy species that show no devotion to specific habitats are represented by C values of 0 (Swink and Wilhelm 1994). All non-native species will be scored a '0' for these analyses. The original formula for computing FQI has been demonstrated to confound C with species richness (Rooney and Rogers 2002), hence, it is suggested that average of C ($\bar{C}$) be used as the index of floristic quality (Wilhelm and Masters 1994, Francis et al. 2000, Rooney and Rogers 2002). Values of C have been assigned to floras within Illinois (Taft et al. 1997), Michigan (Herman et al. 1997) and Wisconsin (Bernthal 2003). Wisconsin values for C will be applied to species lists associated with sites sampled in lower Minnesota (Saint Croix National Scenic Riverway and Mississippi River and National Recreation Area); whereas, Ontario's values of C (Oldham et al. 1995) will be applied to the species list produced at Voyageur's National Park and Grand Portage National Monument. Because values are specific to habitats within each state, they may differ for species as one travels further away from that state. Hence, we will consult with Minnesota master botanists to assure that these values of C are suitable for species lists associated with Minnesota sites. We also will consult with MN botanists in the case some of the species on our list are not on Wisconsin or Ontario's list of species with C values. Isle Royale National Park was taken into consideration when assigning C values to Michigan's species (T. Reznicek, pers. communication), so we will use the Michigan database for that park, despite the fact that it likely is ecologically more similar to Minnesota and southern Ontario.

We will compute the mean C ($\bar{C}$) for each site, with C values for each species within 1m² groundlayer quadrats weighted by abundance (frequency at a site). We will calculate the instantaneous rate of change ($\ln\lambda$) in $\bar{C}$ between two sample periods by using the equation

$$\ln(\bar{C}_{\text{year } 5}) - \ln(\bar{C}_{\text{year } 1}) = \ln\lambda.$$

We will compare the instantaneous rate of change in $\bar{C}$ across sites within a specific habitat by graphing $\ln\lambda$ for each site using bar charts with bars ascending or descending to depict positive or negative changes.

Similarly, we will compute the instantaneous rate of change in numerous other vegetation metrics at the site level, such as groundlayer species richness, shrub species richness, frequency of woody vegetation in groundlayer quadrats, tree BA, tree density, etc. We will then generate matrix scatterplots to look for trends between the rates of change among these variables, including the rate of change in $\bar{C}$. In addition, we will construct matrix scatterplots to look for relationships between these rates of change and static values (from most recent sample year) among sites for each of these metrics (e.g., $\bar{C}$, groundlayer richness, average tree BA, etc.).

Tests of similarity among sites will be conducted using a collective index of species composition and relative frequency. To do this, the degree of similarity of each site to all other sites in a

given park will be determined using the Sørensen (Bray-Curtis) distance (S) for each pair of sites using the formula:

$$S_{jk} = 1 - [(\sum |x_{ij} - x_{ik}|) / \sum (x_{ij} + x_{ik})]$$

where x_{ij} and x_{ik} are the number of quadrats (or microplots or subplots) in which species i is found at site j or k (McCune and Grace 2002, Rooney et al. 2004). Values of S close to zero indicate low similarity of composition (relative abundance) whereas values close to 1 indicate strong similarity between sites. The ecological analysis programs PRIMER (PRIMER-E Ltd.) or R can be used to quickly generate similarity matrices.

Changes in similarity of community composition among sites sampled through time will be evaluated using NMDS ordination and vector change analyses. Separate ordinations will be conducted for trees, saplings, shrubs and herbs (the herb dataset will include woody shrub and seedling species sampled within ‘herb’ plots). For each ordination, a primary matrix containing species abundances for all sites stacked by year will be overlain by an environmental matrix that includes a column for year and other columns containing a variety of environmental variables such as soil horizon depth, presence/absence of pathogens, deer browse frequency, cover type, logging history, etc. The ordinations will be graphed and vectors used to connect sites sampled during different years. The length and direction of these vectors will be analyzed to determine the magnitude of change through time and to determine if sites are changing in a consistent manner (i.e., whether sites are converging, diverging, or shifting composition parallel to each other.)

Inferential Data Analysis: **Repeated-measures ANOVA** (or **paired t-tests** if less than 3 sample periods) will be used to determine if mean quadrat richness (1 m² herb plots only), site-level richness, ratio of non-natives:natives, $\bar{C}$, and site similarity values have significantly changed in each forest stratum through time. The same approach for repeated measures ANOVA will be used as outlined above in section 14.2 part A. The ratio of non-natives:natives will be calculated using the same approach as documented in section 14.1 part D. If it can be determined from these analyses that sites are becoming more similar with time, then it is concluded that biotic homogenization is occurring (Rooney et al. 2004, Olden and Rooney 2001). Reports of changes in similarity should not be made without considering the ecological context. Specifically, if biotic homogenization is increasing, then it should be noted whether this is based on species loss or gain.

Exploring Relationships Among Variables

Identifying links among variables will provide us with a better understanding of factors that likely are driving the changes that are observed in individual variables. We will use several analytical approaches to evaluate relationships within and among environmental, population, and community variables (Fig. 2). These analyses are intended to be cursory investigations into the very complex linkages and interactions among numerous response and predictor variables. More elaborate and powerful analyses are suggested in the ‘Possible Extensions’ section (14.4) of this document. In exploring these relationships (Fig. 2), we can generate numerous questions about direct and indirect linkages among variables. For instance, are changes in the understory population and composition variables associated with changes in the overstory? Are these

changes in the understory related to changes in environmental variables? Are changes in the overstory related to changes in environmental variables? Are changes in the shrub layer associated with changes in the overstory and/or changes in environmental variables? Can changes in some environmental variables be attributed to changes in other environmental variables? We will conduct exploratory and inferential analyses to address each of these questions, along with other questions that likely will arise.

These direct and indirect linkages among variables may be evaluated as static relationships, or may be a function of changes among variables (Fig. 2). We do not separate static descriptions and change detection in this section, as some of these variables can actually be combined in some analyses. For example, tree BA (e.g., current year's data) and changes in tree BA may both be included as variables in analyses (e.g., as predictor variables in a multiple regression).

Exploratory Data Analysis: Scatterplots are a descriptive tool that will allow us to identify linear and non-linear relationships, as well as no association, between variables that we assume a priori to be related. We will generate matrix scatterplots to evaluate the strength of trends among these quantitative environmental, population, and community variables (Table 4, Fig. 1) at the site level. These scatterplots will include static metrics (from the most recent sample year) and rates of change for all variables. Relationships between some variables may be confounded by habitat type or some other variable used to group sites (e.g., presence or absence of deer). We will explore these relationships by plotting these different groups with markers of different shape or color.

Profile plots will be used to explore trends and interactions between quantitative and categorical variables over time. Quantitative responses will be plotted on the Y-axis and time will be plotted on the X-axis. Sites grouped by different habitats or regions will be represented with separate lines on the plot. Intersecting lines will indicate that there is an interaction between this habitat grouping and time, with respect to the quantitative variable being graphed.

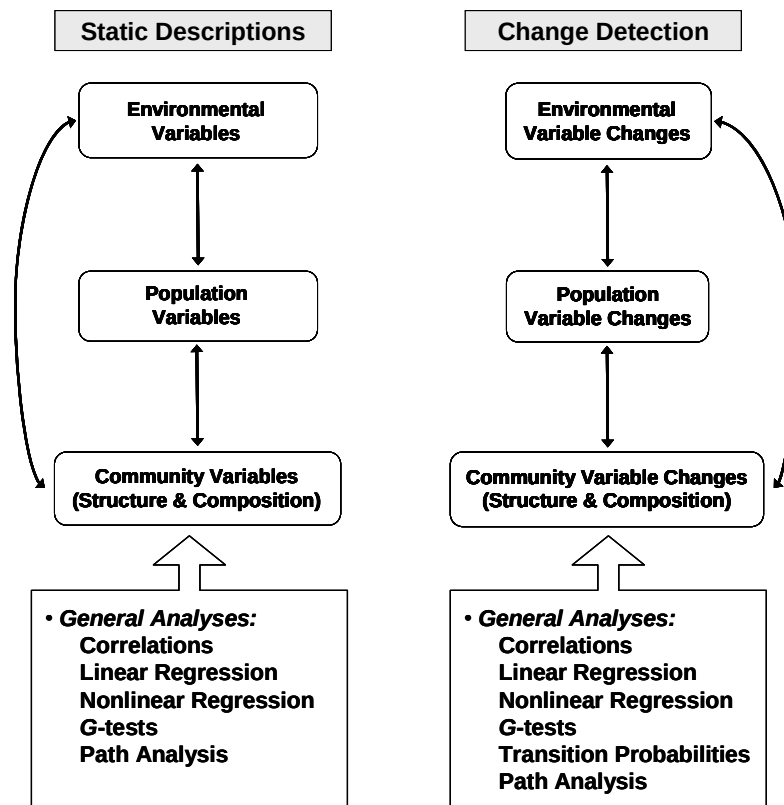


Figure 1. Relationships among environmental and vegetation variables, and suggested analyses. These relationships will be evaluated to detect changes among variables, as well as to make some static descriptions.

Inferential Data Analysis: For all variable pairs that indicate a possible linear relationship, we will conduct correlation analyses. Unlike regression analysis, correlation analysis does not distinguish between predictor and response variables, but instead tests whether or not two variables vary together (interdependence; Sokal and Rohlf 1995). Correlation analysis is especially useful when the direction of dependence between two variables is not known *a priori*.

Pearson's product-moment correlation coefficients will be computed if the data are bivariate normally distributed. In the case that these data do not meet that assumption, we will instead employ non-parametric **Spearman's rank correlations** (Sokal and Rohlf 1995). Correlation coefficients are a measure of the degree of a linear relationship between two variables. These values range from -1 to 1, with -1 indicating a strong negative relationship, 1 indicating a strong positive relationship, and 0 indicating no linear relationship between the two variables. Standard statistical packages also test the null hypothesis that the two variables are uncorrelated. We will implement Holm's (1979) correction on all reported *P*-values. We will avoid drawing strict inferences regarding causation before fully exploring the ecological significance of these results.

We will use **multiple regression analysis** to identify all predictor variables (quantitative or categorical) that significantly explain some of the variation in a continuous response variable

(e.g., shrub height, $\bar{C}$, etc.). Partial correlation coefficients will provide information about the degree that a single variable is correlated with the predictor variable when the effect of all other variables is held constant. We only will include response variables that appear from the scatterplots to be linearly associated with the predictor variables.

Categorical predictor variables, such as deer presence, will be entered into the regression analysis as ‘dummy variables’ – deer presence will be scored as ‘1’ and absence scored as ‘0’. We will use Q-Q plots to check that the residuals are normally distributed, and we will construct residual plots to check that these data meet the assumption of homoscedastic error variances. If our data do not meet these assumptions, we will consider employing standard data transformations on the response variable (Y), the predictor variables (X) secondarily, and both response and predictor variables lastly. Sokal and Rohlf (1995) recommend considering logarithmic transformations on the predictor variable(s) in cases where proportional changes in the predictor variable result in a linear response by the response variable. This may apply to the relationship of tree BA and tree density – we generally expect that tree BA may increase with successive decreases in density. We will avoid complex transformations that may impede our ability to make meaningful interpretations of the results (Sokal and Rohlf 1995). Standard statistical packages should report values (‘tolerances’ or ‘variance inflation factors’) that indicate the degree of collinearity between predictor variables; we will remove variables from our model to avoid collinear relationships. In addition to reporting the adjusted R^2 values and overall P -value for the regression model, we also will report partial correlation coefficients, t -statistics and P -values for each predictor variable and interaction term in the model.

We will use **non-linear regression** to assess statistical relationships between variables not fitting elliptical or circular patterns in the scatterplots (Sokal and Rohlf 1995). Standard multiple regression equations will be fitted with increasing powers of X so as to produce a line that better fits the non-linear data. We generally will not attempt polynomial equations with powers of X greater than the cubic term, as one degree of freedom is lost with each polynomial term that is added to the equation. We will proceed with the typical procedures for analyzing data with multiple regression analysis; however, we will not report significance for the coefficients of the powers of predictor variables (Sokal and Rohlf 1995).

We will explore the effect of continuous variables on categorical (or a combination of categorical and quantitative) response variables with **logistic regression analysis**. In contrast with linear regression, where the response variable is continuous, logistic regression will allow us to determine predictor variables that significantly explain variation in a categorical response variable. These response variables are typically one of two possible values (e.g., present/absent or yes/no) and will be coded as 1 or 0. Thus, in logistic regression, the mean of the distribution will equal the proportion of 1s. For example, if evidence of earthworms (coded 1) is located at 42 sites and no evidence of earthworms (coded 0) is found at 58 of 100 sites assessed, the mean of this distribution is 0.42. In logistic regression, the natural log of this probability will be determined (the logit) and maximum likelihood estimation will be used to estimate the probability of an event (earthworm presence, in this case) occurring. Besides probability, logistic regression can also be used to determine the variance in the dependent variable explained by the predictor variable and to order the importance of predictor variables if multiple ones are tested (Sokal and Rohlf 1995).

Understanding a phenomenon in nature most often involves understanding the numerous factors and interactions leading to the event state. Multiple regression analysis offers the ability to deal with correlation among predictor variables to explore the effect that each of these variables has on the response variable when the effect of all other variables is held constant. Multiple regression, however, only considers one response variable, and is limited by not having the capability to test relationships between multiple predictor variables. **Path analysis** is an analytical approach that allows one to test potentially complicated patterns of causation among a set of several predictor variables (Mitchell 2001). The first step in path analysis is to construct a diagram that reflects hypothesized relationships among variables (for example see Fig. 2). These hypothesized causal relationships will be constructed *prior* to any exploratory analyses to avoid biasing the results. Quantitative and categorical variables can be included, however, categorical variables will be entered into these analyses as ‘dummy’ (0’s and 1’s) variables. It is recommended that there be 10-20 times the number of observations in the data set than there are number of factors included in the path analysis. Some of the major assumptions of path analyses include: 1) that causality be considered (logical order of variables), 2) that the effects be linear, and 3) that the effects be additive. The analysis also assumes that the residuals are normally distributed, so transformation of some variables may need to be considered (Mitchell 2001). Multiple regression equations will be analyzed for all response variables such as they are represented in the diagram. Standardized partial regression coefficients will be generated via each of these analyses. These constitute the path coefficients which can then be combined to determine the direct and indirect effects of predictor variables. Direct effects represent the proportion of variance in the response variable that can be attributed now to one specific predictor variable that affects the response variable directly. However, a given predictor variable may have *indirect* effects on a given response variable via the other variables (the products of the path coefficients connecting them). These direct and indirect effects can be summed to calculate the total effect of that predictor variable on a given response variable. This exercise allows us to determine if the direct and indirect effects differ in magnitude or in sign. These results will be presented visually in path diagrams with variably-sized arrows to indicate the magnitude of relationships between variables (with dashed lines depicting negative relationships (Mitchell 2001). There are sometimes more than one path diagram that can be constructed to test hypothesized relationships among variables. Path analysis will be followed with **structural equation modeling** to evaluate the explanatory power of competing models (Mitchell 2001). Grace’s (2006) book also provides a helpful resource for structural equation modeling and path analysis.

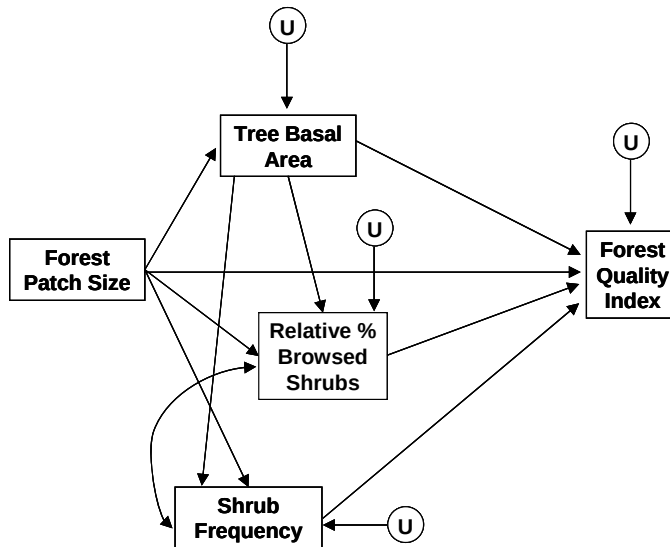


Figure 2. Example path diagram showing hypothesized relationships among variables considered to influence Forest Quality Index ($\bar{C}$) among sites. Residual variance, or “unknown” factors are represented as “U”. Direct causal relationships are presented with single-headed arrows on straight lines. Double-ended arrows on the curved line represents a correlation with unknown directionality.

12.4. Possible Extensions

As time, resources, and expertise allow, we will consider applying a number of advanced analyses to our data. Some of these possible analyses are discussed below; however, it should be kept in mind that this is not meant to be an exhaustive treatment of all possible analyses. As we become more familiar with working with these complex long-term data, we will surely develop a better sense of what analyses will best serve our needs.

Once groups of sites have been identified, **classification and regression tree analyses** could then be used to determine if specific environmental variables (Table 1) predict site groupings (or communities). Regression tree analysis uses a recursive algorithm to identify environmental predictor variables associated within homogenous subsets of the overall dataset. This recursive partitioning approach identifies ecological relationships in the data that linear models may not capture. Other advantages of using regression trees include: 1) they are not affected by multicollinearity, 2) they easily deal with a mix of quantitative, ranked, and categorical variables, of which there can be more than two categories, 3) they are not affected by missing values, and 4) they provide a useful visual representation to facilitate interpretation (Urban 2002).

These data can be compiled for all sites within a park or across multiple parks (for those with available data) and **regression tree analysis** can be conducted to determine if understory structure can be attributed to specific environmental site characteristics. Such an evaluation will highlight sites or specific habitats within (and possibly among) parks that may currently be experiencing negative effects from pests, pathogens, or some other driver of change.

Classification and regression tree analysis can be used to determine whether sites changing in a similar manner are associated with specific environmental predictor variables. To do this, homogeneous groups of sites based on similarity of vector changes must first be identified using

a clustering technique such as the flexible-beta linkage method in PC-ORD (McCune and Grace 2002). This clustering of sites should be based on the change matrix (McCune and Grace 2002, p 77). The standard Sørensen (Bray-Curtis) distance measure should not be used in this case, as it does not perform well when applied to vectors with negative exponents. Instead, the measure of Euclidean, Relativized Euclidian or Correlation distance should be selected (M. Fulton, *pers. comm.*). Environmental site characteristics (Table 1) can then be assessed to determine what influence they may have had on the organization of sites within clusters by using regression tree analyses available through a variety of commercial software such as S-PLUS (S-PLUS®, Insightful, Inc.) or SPSS AnswerTree 3.1 (SPSS® Inc., Chicago, IL) as well as freeware (QUEST, CRUISE, GUIDE, and LOTUS) that can be downloaded from W. Loh's website (<http://www.stat.wisc.edu/~loh/>).

Rather than testing innumerable single-variable hypotheses about change in given variables, for several variables (e.g., absolute herbaceous cover, relative forb cover, frequency or cover of an individual forb species) we will utilize **information-theoretic analyses** to compare, in a strength-of-evidence framework, the relative plausibility of numerous competing models to determine which combination of variables best explains variability in those response variables.

This approach ranks models of varying complexity not only on their fit to the data, but also with a criterion of parsimony (i.e., using the least complicated model possible to describe dynamics succinctly). Information-theoretic approaches use a likelihood framework to rank models based upon how much information is lost when a given model is used to portray 'truth.' The true model is defined as one that represents reality without any error; i.e., a model that would contain all of the information about the system under investigation (Hobbs and Hilborn 2006). Akaike's Information Criterion (Akaike 1973) thus estimates the expected value of information lost with the equation: $AIC = -2 \ln(L) + 2K$. L is the likelihood associated with the maximum likelihood estimates of the model parameters, given the data set, and K denotes the number of parameters in the model (including all error terms). For this approach to be confirmatory rather than exploratory, the set of competing models must be specified before any analyses are undertaken (Burnham and Anderson 2002). In addition to computing AIC (or AIC_c for small sample sizes, QAIC for overdispersed data, or BIC for a Bayesian approach), we will also calculate ΔAIC , Akaike weight, and the evidence ratio for each model. Though these approaches are designed more to rank various models rather than identify importance of individual factors, we will calculate relative importance of each factor. If we are interested in using the models to predict future values of vegetation, model averaging will be performed. All analytical procedures will follow guidelines of Burnham and Anderson (2002). Beever et al. (2003, 2006) provide illustrations of uses of information-theoretic analyses to understand dynamics of natural resources in wilderness areas. See Table 5 for an example of a partially-filled-out table for a vegetation metric that might be especially important for the Great Lakes ecoregion. Knowledge of past and current vegetation composition and environmental variables (Table 1) can be used to predict future vegetation composition in Network parks. **Artificial neural networks (ANNs)** can be useful for forecasting community composition, as these models make inferences based on generalized patterns in complex ecological data. ANNs take a non-mechanistic approach; hence, these are very pragmatic models for dealing with unforeseen and unidentified mechanisms responsible for current and changing vegetation composition (Tan and Smeins 1996).

Table 5. Total herbaceous frequency, all understory species combined, at APIS during vegetation monitoring at 35 sites during 2007-2019. Presumably, 'Year' would account for interannual fluctuations in weather and other random factors. 'Deer' is the finest-scale estimate of density of white-tailed deer (*Odocoileus virginianus*) at the site the year before the vegetation sampling. 'Cmty' denotes the vegetative community that is present at a site. A "+" sign means that all factors united by the symbol are put into the model; a "*" sign means that in addition to those two factors each being in the model, the interaction of the two factors is also present in the model. The null model has no factors (other than the error term), and gives evidence of how relatively meaningful the models are. All column definitions follow Burnham and Anderson (2002).

model #	model description	# Parameters	-2*LOG(l)	AIC _c	ΔAIC _c	Akaike weight	Evidence ratio
1	Year	2	35.4	54.7	0	0.45	1
2	Deer density (="Deer")	2	42	56.8	2.1	0.15	2.89
3	Veg. cmty type (="Cmty")	2	35.3	56.9	2.2	0.15	3.03
4	Year + Cmty	3	37	58.6	3.9	0.06	6.98
5	Year + Deer	3	41.7	58.8	4.1	0.06	7.62
6	Year + Cmty + Deer	4	41.7	58.8	4.1	0.05	7.65
7	Cmty + Deer	3					
8	Year + Tree Cover	3					
9	Year * Cmty	4					
10	Null	1	102.6	108.7	54	0	>10 ⁶

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Reporting

STANDARD OPERATING PROCEDURE #13

Version 1.0 (7/1/08)

Suzanne Sanders and Joan Elias

NPS – Great Lakes Network

Revision History Log:

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Add rows as needed for each change or set of changes tied to an updated version number					

13.0 Introduction

A primary goal of the NPS Servicewide I&M Program is to ensure that the results and knowledge gleaned from monitoring are shared with all appropriate parties, especially the parks and their natural resource managers. Because the Network's main focus is to assist parks with monitoring needs, we will strive to provide park managers with clear, meaningful products to convey our findings.

While the Network primarily addresses concerns of the parks, its monitoring program has the potential to serve a much broader community. For example, monitoring projects can provide a starting point for external scientific research (especially to establish cause-effect relationships), and can provide insights for adaptive management on other public lands. The Network is also accountable to multiple organizations within the federal government, including the NPS I&M Program and the U.S. Congress. To ensure accountability and to meet the requests of all parties, we will provide the types of reports and communications detailed below.

13.1 Annual Summary Reports

A summary report will be produced annually for the Vital Signs associated with the vegetation protocol that were monitored during the previous year. The primary audience for the annual summary reports will be parks. These summaries will be communications to document our efforts and convey the findings of the previous field season. At a minimum they will provide:

- a brief introduction that describes why that Vital Sign is being monitored;
- an outline of the sampling strategy, including the number of sites sampled, parameters measured, and analyses performed;
- data summaries, including tables and figures to enhance visual presentation, as well as a text explanation of the findings;
- any other relevant or significant findings; and
- a limited discussion section in which important results are interpreted.

The project manager (terrestrial ecologist (planned)) will take the lead in writing the report and will coordinate an internal review. Drafts of annual summary reports will be completed by January 15 for a two week review period by the parks. The final reports will be provided to parks on March 1 of the year following the monitoring.

13.2 Analysis and Synthesis Reports

Detailed reports in which data are analyzed and synthesized will be produced on a periodic basis, with the frequency depending on the given Vital Sign. For the general vegetation protocol, analysis and synthesis reports will be written every six years, after each completion of the sampling rotation. They will be written in the format of a scientific journal article (abstract, introduction, methods, results, discussion, literature cited) and will contain in depth analyses as outlined in the protocol (Sanders et al. 2008) and SOP #14 (Data summary and analysis). Further, these comprehensive reports will:

- place the observed results in both a regional and historical context by relating them to other published literature;
- discuss the significance of the results in terms of environmental change; and

- provide management recommendations based on the findings.

The project manager (terrestrial ecologist (planned)) will take the lead in writing the analysis and synthesis reports, and will coordinate an internal review. The target audience of these reports will be the parks (primarily the natural resource managers), the Network, and both regional and Servicewide I&M. Outside of the park service, the target audience includes the four state departments of natural resources (Indiana, Michigan, Minnesota, and Wisconsin); the Northeastern Area Forest Health Protection unit and the North Central Research Station, both of the of the National Forest Service; and the broader scientific community.

Drafts of analysis and synthesis reports will be completed by January 31 of the year that follows completion of the monitoring cycle. The parks will have a 30 day period for comment and input. In addition, these drafts may also be sent to outside sources for further review. The extent of review will depend on the analytical complexity of the methods and the gravity of inference and recommendations. The final reports will be due on April 1 of the year following completion of the monitoring cycle.

The first analysis and synthesis report will be written following a full rotation of monitoring. At this time, vegetation and the associated Vital Signs will have been monitored in each park for one season, allowing a comparison of vegetation characteristics across parks. In subsequent years, as parks are monitored repeatedly, more in-depth analyses will be conducted for individual parks as well as across parks.

13.3 Scientific Journal Articles

Because the vegetation monitoring protocol has been designed with rigorous standards for sampling design and analysis, monitoring results are expected to be highly defensible and meet the standards of the peer-review process. The publication of monitoring results in scientific journals will allow the Network to reach the scientific community in a way that internal NPS reports cannot. Further, peer-reviewed publications can promote collaborative investigation by members of the scientific community, either independently or in cooperation with the Network. Ultimately, this process should foster a greater understanding of ecosystem components and processes.

For these reasons, the Great Lakes I&M Network will strive to publish analysis and synthesis reports in peer-reviewed scientific journals. We will encourage the preparation of manuscripts by having reviewers of analysis and syntheses reports recommend whether publication is warranted and suggest appropriate journals. The quantitative ecologist and Network coordinator will track these recommendations and encourage and provide work time respectively.

13.4 Other Communications

While reports are a definitive method of documenting the progress of each program, other means of communication can further disseminate information to a broader audience. To this end, we will provide the following additional types of communications:

Briefings to park biologists: The project manager will present the findings from the water quality monitoring program to the biologists from the parks in which monitoring was conducted

the previous year. These presentations, which will likely occur at the annual technical committee meeting in March, will provide a concise synopsis of monitoring results as well as management considerations.

Conference presentations: When possible, the project manager will present monitoring results at regional and national scientific conferences. Such presentations will allow the Network to reach the broader scientific community, as well as land managers and conservation practitioners.

Potential conferences include those sponsored by the Ecological Society of America, Society for Conservation Biology, The Wildlife Society, the Natural Areas Association, the NPS Water Professionals Meeting, and the George Wright Society. At a more local scale, the Western Great Lakes Research Conference, which is sponsored in part by the Network, is a valuable venue for information exchange.

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Procedures after the Field Season

STANDARD OPERATING PROCEDURE #14

Version 1.0 (7/1/08)

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NPS-Great Lakes Network

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14.0 Introduction

The procedures associated with completing the sampling season must be performed in earnest in the weeks immediately following the conclusion of sampling, and continued through the following April. The purpose of this SOP is to identify these procedures, thereby promoting better project management. Please note that the procedures noted here from January through April overlap with pre-season procedures, listed in SOP #1.

14.1 August

- Soil sample processing
- September 1 – 7: Perform reviews of field crew members
- September 1 – 14: Perform general administrative and personnel issues associating with terminating field crew members

14.2 September

- September 1 – 30: Perform data archival procedures
- If any species previously unknown to occur in a park were observed, add these to the park species list, and to NPSpecies.

14.3 October

- October 1 – 14: Review protocol and make changes.
- October 15 – 31: Begin data analysis and report writing

14.4 November

- November 1 – 30: Continue data analysis and report writing.

14.5 December

- December 1 – 31: Continue data analysis and report writing.

14.6 January

- January 1 – 15: Data analysis and report writing.
- January 15: Present draft of annual summary report to all parks where monitoring occurred. They will then have two weeks to review it.
- January 31: Present draft of analysis and synthesis report to all parks². They will then have 30 days to review it.

14.7 February

- February 1 – 28: Revise annual summary report based on comments by parks.

14.8 March

- March 1: Present final copy of annual summary report to parks where monitoring occurred.
- March 15 – 31: Give presentation of results to technical committee at the annual meeting, usually scheduled at the end of March.

² To be done every six years at the completion of each monitoring cycle.

14.9 April

- April 1: Present final copy of analysis and synthesis report to parks¹.
- April 1 – 30: At the discretion of the Terrestrial Ecologist and Network Coordinator, prepare analysis and synthesis report as a manuscript to a peer reviewed scientific journal¹.

Procedures for Revising the Protocol

STANDARD OPERATING PROCEDURE #15

Version 1.0 (7/1/08)

Suzanne Sanders and Joan Elias
NPS – Great Lakes Network

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15.0 Introduction

Because of the long-term nature of the National Park Service's monitoring program, the projects must necessarily accommodate change. Refined field methods, advances in analysis techniques, and feedback from field crews and project managers can all contribute to improving the monitoring protocol. The purpose of the current SOP is to define a systematic and routine process for incorporating these changes into the protocol.

15.1 Steps for Revising the Protocol

1. Attempt to incorporate the changes by first modifying only the SOP(s), without making changes to the protocol narrative. However, if it is clear that changes will also be needed on the narrative, then revise it as well.
2. Make all revisions using the Track Changes feature of Microsoft Word. For minor changes, at least one other person must review the revision. If the change is more extensive, a discussion of the changes by Network staff is warranted before acceptance of the revision. For major changes, review from outside of the Network should be sought. Examples of major changes include modifications of the sampling design, significantly altered field methods, and revised analysis techniques.
3. Record the changes in the revision history log of the SOP and/or in the narrative, as appropriate. Include the date of revision, full name(s) and affiliation(s) of author(s), description of and reasons for the changes, and section of SOP or narrative where changes were made.
4. Rename the version of the SOP and/or narrative. For minor changes, only revise the version number after the decimal point (e.g., change V. 1.1 to V. 1.2). For major changes, revise the number before the decimal point (e.g., V. 2.3 to 3.0). Also change the version number of the SOP or protocol in the header or footer, as appropriate.
5. Notify the data manager of the change(s) so that the metadata of the project database will be updated.
6. Distribute the revised version to all appropriate parties, including the members of the field crew and appropriate GLKN staff. The revised version must also be posted on the Network's website.
7. Maintain a library of previous versions. Such historical information may be crucial for understanding, interpreting, and analyzing data.

Quality Assurance/Quality Control

STANDARD OPERATING PROCEDURE #16

Version 1.0 (7/1/08)

Suzanne Sanders

NPS-Great Lakes Network

Revision History Log:

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

16.0 Introduction

The success of the vegetation monitoring protocol is dependent upon the integrity of the data. This SOP details procedures for ensuring the data collected are of the highest possible quality, addressing standards to follow both while in the field, and afterward.

16.1 Field Procedures

Quality assurance/quality control procedures for all plots

The standard data collection methods detailed in SOP 6: Field Methods and Data Collection should be followed, precisely. This will ensure accurate data collection and allow consistency between observers. In addition, each field team will be supplied with a checklist of criteria to address prior leaving a field site. This is designed to minimize human error, especially for parameters that cannot be easily obtained once a field team has depart a site. These include ensuring that:

- The parking location for the boat/car is documented, and any relevant notes on plot access are included.
- The Kotar or NVCS forest type is recorded.
- All shrub circles have species cover percentages.
- All transects have coarse woody debris recorded.
- All groundlayer species listed have at least one box checked.
- Any parameter where there was nothing located (e.g., no shrubs in a circle or no CWM on a transect) is marked as such.
- Any tree species on the groundlayer sheet have abundance numbers associated with them.
- The “dead” column is checked for all unknown dead trees.

Quality assurance/quality control check plots

At least 10% of plots in all years will be resampled by the program manager and a field assistant, with the resampling occurring within four weeks of the original sample date. The field assistant cannot be part of the team that conducted the original sampling.

Data should meet the following guidelines for each resampled plot:

- tree basal area for each transect should be $\pm 10\%$ for each species
- shrub cover for each shrub circle should be $\pm 5\%$ for each species
- the number and volume of coarse woody material pieces in each transect should be $\pm 5\%$ for each species
- the total number of species per plot should differ by no more than 3
- the frequencies for individual groundlayer species within each transect should differ by no more than 10%

To reduce the problems associated with trampling, no individual plot should be resampled more than once every 10 years.

16.2 Data Processing

Global positioning system data

All global positioning system points should be differentially corrected within 30 days of collection, otherwise, the data collections interval of CORS stations is reduced from either 1, 5, or 30 second intervals, to 30 minute intervals.

Vegetation data

To locate and amend potential errors resulting directly from the manual entry process, all entered data should be checked with one person reading the original data sheets and a second person checking the Access report generated for each site/parameter.

Standard queries should be run following the two person data checking process. These queries are intended to reveal mistakes resulting from data entry errors, or certain recording errors in the field. These queries include checks for the following:

- multiple entries of an individual species within any transect in the groundlayer data
- multiple entries of an individual species within any shrub circle
- coarse woody material pieces entered that are less than 8 cm diameter at intercept
- trees entered with DBH < 2.6 cm
- tree species entered as seedlings in the groundlayer data without counts

Appendix B: Field Data Forms

Plot: _____ **Date:** _____

Kotar Type: _____

NVCS Type: _____

Photopoint picture numbers:

Point	Picture ID number
1	
2	
3	
4	
5	
6	

Plot Access:

Plot Description:

Check before leaving field site:

- ☐ The Kotar and NVCS cover types have been recorded
- ☐ The location of where the boat or car is parked (and any other access advise) is noted
- ☐ All data sheets are present
- ☐ All Unknown Dead Tree's have "dead" checked
- ☐ All shrub circles have species cover percentages
- ☐ All transects have coarse woody debris
- ☐ Any parameter where there was nothing (e.g., no shrubs in a circle or no CWM on a transect) is marked as such
- ☐ All groundlayer species have boxes checked
- ☐ Any tree species on the groundlayer sheet have numbers associated with them

Reference Objects for Each Permanent Point

Plot: _____ Name: _____ Date: _____

For each of the 6 permanent points, record the distance and angle from 3 prominent trees to the point.

Point	Reference Tree Species	DBH	Tag #	Distance to Point (m)	Azimuth to Point (°)
1					
1					
1					
2					
2					
2					
3					
3					
3					
4					
4					
4					
5					
5					
5					
6					
6					
6					

Tree Data

Page ____ of ____

Plot: _____ Name: _____

Date: _____

[illegible]

Shrub and Sapling Datasheet

Page ____ of ____

Plot: _____ Name: _____ Date: _____

Shrub Circle 1

Species	Percent Cover (Shrubs)	Count (Saplings)

Shrub Circle 2

Species	Percent Cover (Shrubs)	Count (Saplings)

Shrub Circle 3

Species	Percent Cover (Shrubs)	Count (Saplings)

Sapling = less than 2.6cm DBH and taller than 15cm for conifers or 30cm for hardwoods, with evidence of last year's growth.

Shrub Circle 4

Species	Percent Cover (Shrubs)	Count (Saplings)

Shrub Circle 5

Species	Percent Cover (Shrubs)	Count (Saplings)

Shrub Circle 6

Species	Percent Cover (Shrubs)	Count (Saplings)

Sapling = less than 2.6cm DBH and taller than 15cm for conifers or 30cm for hardwoods, with evidence of last year's growth.

Coarse Woody Debris Data

Page ____ of ____

Plot: _____ Name: _____ Date: _____

[illegible]

Tree walkthrough data

Plot: _____ Name: _____ Date: _____

Add one entry below for each unique tree species recorded in the tree transects. Then add any additional tree species located in a 20 minute timed walkthrough of the entire plot. During this time, also estimate the percentage of cover by *canopy* species (as likely seen from above) for the entire plot. Make sure to include the percentage of gap in the canopy. Since percentage of cover is estimated based on the aerial view only, some species that do not reach the canopy will have values of 0%. For those species that do reach the canopy, the collective value (including the gap) should equal 100%.

	Species	Percentage of cover
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		

Trees present only as saplings that were not recorded in shrub circles (add to herb walkthrough datasheet)

Browse Data: Direct Effects

Plot: _____ Name: _____ Date: _____

Transect 1

Plot	Species 1	Browsed?	Species 2	Browsed?	Species 3	Browsed?
5 m						
10 m						
15 m						
20 m						
25 m						
30 m						
35 m						
40 m						
45 m						
50 m						

Transect 2

Plot	Species 1	Browsed?	Species 2	Browsed?	Species 3	Browsed?
5 m						
10 m						
15 m						
20 m						
25 m						
30 m						
35 m						
40 m						
45 m						
50 m						

Transect 3

Plot	Species 1	Browsed?	Species 2	Browsed?	Species 3	Browsed?
5 m						
10 m						
15 m						
20 m						
25 m						
30 m						
35 m						
40 m						
45 m						
50 m						

Comments:

Browse Data: Indirect Effects (Voyageurs NP)

Plot: _____ Name: _____ Date: _____

Transect 1

Quadrat 5

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 10

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 15

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 20

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 25

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 30

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 35

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 40

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 45

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# row sed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 50

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Transect 2

Quadrat 5

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 10

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 15

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 20

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 25

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 30

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 35

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 40

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 45

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 50

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Transect 3

Quadrat 5

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 10

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 15

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 20

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 25

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 30

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 35

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 40

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Quadrat 45

Species	max height (xx.x cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed
<i>C. borealis</i>					
<i>Streptopus</i> sp.					
<i>M. canadense</i>					

Quadrat 50

max height xx.x (cm)	l,rs,s	# not repro/ unbrowsed	# repro/ unbrowsed	# browsed

Unknown Plants

Plot: _____ Name: _____ Date: _____

Unknown ID #	Photo ID #'s	Plant Description

All species walkthrough data

Plot: _____ Name: _____ Date: _____

Add one entry below for each unique herbaceous species (or genera where appropriate) recorded in the groundlayer quadrats. Then add each additional herb species located in a 30 minute timed walkthrough of the entire plot.

1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
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23	
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27	
28	
29	
30	
31	
32	
33	
34	
35	
36	

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.

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National Park Service
U.S. Department of the Interior



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