

Standard Operating Procedure #11:

Data Summary and Analysis

Version 2.1 (1/26/2024)

Prepared by

Sarah Johnson¹, Donald M. Waller¹, Suzanne Sanders², and Jessica Kirschbaum²

¹ University of Wisconsin – Madison

² National Park Service
Great Lakes Network Office
2800 Lakeshore Drive East
Ashland, Wisconsin 54806

Revision History Log

Date	Previous version	New version	Authors
2012	1.0	2.0	Suzanne Sanders and Jessica Grochowski
Figure 1 was replaced; misc. wording not relevant to vegetation was removed.			
2024	2.0	2.1	Suzanne Sanders and Jessica Kirschbaum
Revised to: • make more concise; • reflect the fact that we now use tablets with built-in cameras, rather than paper datasheets and stand-alone cameras; • note that we do not plan on collecting additional GPS coordinates at sites; • improve wording and flow of text.			

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11.0 Introduction

This SOP provides instruction to produce summaries and analyses of terrestrial vegetation over time. Advances in analytical techniques will undoubtedly continue to develop, so network staff should regularly review analysis options.

This SOP specifically focuses on analyses that will be used to answer the following questions:

- 1) *What is the rate and direction of change for metrics of important species?* Here we identify techniques for summarizing and analyzing individual species. These are generally species with management significance, meaning that they are common or that they play a key role in the ecosystem function. It could also indicate that they are native species facing an imminent threat or, alternatively, non-native species that threaten ecosystem health.
- 2) *Are plant communities changing and if so, how?* Changes occurring at the community level are of major interest to network staff and park managers. The metrics to assess community change and the approaches to these metrics are numerous. These range from simple univariate, frequentist options (e.g., assessing change in species richness) to more complex multivariate analyses (e.g., path analysis).
- 3) *Is plant community structure changing and, if so, how?* Measures of community structure include regeneration and succession. We can examine the size distributions of all trees as well as individual species to identify shifts in forest structure. We can also test for change in small size classes of trees, both for individual species and pooled across all species.
- 4) *How are ungulates impacting herbaceous terrestrial vegetation?* We will test for change in presence, abundance, and height of herbaceous species that are preferred browse for ungulates.

The analyses here are intended to assist natural resource managers with decision-making in their respective parks. Analyses presented in this SOP are for the park or sub-park (i.e., habitat or forest type) level and not across parks or network-wide. Aggregating data across parks 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 variance with the additional heterogeneity that exists among parks. Introducing this among-park variance runs the real risk of not detecting significant trends that may be occurring within certain parks. This is because either such trends do not occur in other parks (swamping trends that only occur within one park), or because trends may run in counter directions in different parks.

This risk makes clear the importance of stratification, which was done here via post-hoc analyses of overstory composition. Grouping sites into habitats or forest types was done following the initial sampling event and was based on the tree species present and their density and basal area. We can use these groupings to examine change since the onset of the monitoring program. However, vegetation changes over time, so analysts must use caution if they are using the groups for analyzing “current” data, such as that following the third or fourth sampling events.

Nomenclatural changes in plants occur on an ongoing basis. For this protocol, the Integrated Taxonomic Information System (ITIS) serves as the nomenclatural authority, and we follow taxonomic names as recognized there. More specifically, we recognize taxonomic serial numbers (TSNs) assigned by ITIS and update changes in nomenclature annually by linking TSNs of currently recognized taxa to their outdated counterparts within the database. This ensures that continuity of nomenclature is maintained within taxa.

11.1 Summaries

After each field season, data are summarized and typically presented in graphs or tables to show the status of terrestrial vegetation metrics that year, in context with prior years. These summaries provide the network and parks with information relevant to policy and management decisions. A list of metrics summarized and the mode of summary presented is shown in Table 1.

Table 1. Metrics presented via summaries, and the presentation mode for each.

Metric	Presentation Mode
Tree density by size classes	Density-diameter graph
Tree density (pooled across species)	Box plot
Tree density (key species of interest)	Box plot
Tree basal area (pooled across species)	Box plot
Tree basal area (key species of interest)	Box plot
Sapling density (pooled across species)	Box plot
Sapling density (individual species)	Table
Shrub frequency (individual species)	Table
Coarse woody material density	Box plot
Coarse woody material volume	Box plot
Large advanced-decay coarse woody material density	Box plot
Large snag density	Box plot
Proportion browse of woody taxa (pooled across species)	Box plot
Proportion browse on woody taxa (on individual species)	Table
Presence of preferred herbaceous browse species (pooled)	Box plot
Abundance of preferred herbaceous browse species (pooled)	Box plot
Frequency and maximum height of preferred browse species (individually)	Box plot
Taxa richness	Box plot
Coefficient of conservatism	Box plot
Earthworm invasion rank	Map

Continuous data variables will be evaluated with descriptive statistics such as means and standard errors. Box plots will be used to show metrics over time and across habitats and/or forest types. Categorical data, consisting of binary variables (e.g., presence/absence) and variables with greater than two categories (e.g., degree of earthworm invasion), may be summarized in tables or bar charts or will be shown as a figure.

11.2 Detecting Change

As of 2022, all parks have been visited at least twice so analyses testing for change can commence. Nonetheless, not all sites were established during the initial visit in each park. In total, across all parks, we established 320 sites during the first round of sampling, then added 126 additional sites during the second round, bringing the total to 446 sites. Thus, not all sites will factor into analyses following the second round of sampling. Further, while we can look at change following the second visit, the third sampling round will allow us to test for trends in metrics. Here we detail potential approaches, presented to align with our monitoring questions. These approaches include both univariate and multivariate techniques.

Changes in Species of Interest

Species of interest change over time, depending on drivers and stressors in the system. For overstory species, our metrics of interest are density (trees/ha) and basal area (m^2/ha), both continuous variables. For herbaceous species, we use site-level frequency of presence in herbaceous quadrats (bounded between 0 and 1.0) as the dependent variable, and for shrub taxa, site-level frequency of presence in shrub circles (again bounded between 0 and 1.0). In general, we use linear mixed models to test for change, with the effects of Forest Type and Year considered fixed effects while the Site effect will be random. Specific details of model fit will depend on the metric and data and are not presented here.

Community Change

There are numerous ways to assess plant community change, and favored methods will undoubtedly evolve over time. Here we outline methods that are either widespread or address important issues in network parks. As novel statistical techniques and ecological problems arise, modifications will be employed.

One of the most basic assessments of community change is whether species richness varies over time. We determine site-level species richness (α -diversity; Magurran and McGill 2011), although we do not include graminoids such as grasses (Poaceae) or sedges (*Carex* sp. L.) in our analyses here because not all individuals can be identified to the species level at all points during the sampling window. Likewise, we do not include ephemeral species because they are only found at sites sampled early in the season. We test for change using linear mixed models, as outlined above (see changes in species of interest), with richness—an integer—being the response variable.

We build on species richness by also assessing mean coefficient of conservatism (mean CoC) (Sanders and Grochowski 2014, Rooney and Rogers 2002). The CoC values are assigned to individual species within an area, such as at the state level. They range from 0–10 and reflect a species' likelihood that it will be present in habitats with alterations from pre-settlement conditions (Herman et al. 2001, Swink and Wilhelm 1994). Species with a value of 10 (e.g., *Sarracenia purpurea* L. (pitcherplant)) are those whose locations are limited to high-quality communities where conditions have changed little since pre-settlement time. In contrast, CoC values of zero are assigned to non-native species and those with little fidelity to conditions found in remnant communities. Values of C have been assigned to floras in Michigan (Herman et al. 1997) and Wisconsin (Bernthal

2003). Wisconsin C values are applied to species lists associated with sites sampled in southern Minnesota (Saint Croix National Scenic Riverway and Mississippi National River and Recreation Area), while Ontario's C values (Oldham et al. 1995) will be applied to the species list produced in northern Minnesota at Voyageurs National Park and Grand Portage National Monument. We use values defined for plants of the Chicago region (Swink and Wilhelm 1994) for sites at Indiana Dunes National Park. Mean CoC is calculated as the mean value of the CoC at each site for all species included in the species richness determination (thus we exclude graminoids and ephemerals). We test for change of mean CoC (a continuous number constrained between 0 and 10) between the time periods using linear mixed models, as detailed above.

Community change can also be assessed by testing for shifts in the proportions of species in groups. For example, we may expect to see an increase in the ratio of abiotically pollinated species relative to biotically pollinated species as climate change continues and links between pollinators and their host plants get disrupted (Gilman et al. 2011). Functional and geographic groups of interest and the classes that comprise these groups are shown in Table 2. To test for changes in class ratios, we can use replicated G-tests to address the null hypothesis that the proportions of species occupying sites do not shift over time.

Table 2. Functional and geographic groups in which to test for community change and the classes that comprise those groups.

Functional Group	Class Ratios
Life history	Annual:biennial:perennial
Growth form	Forb:graminoid:woody
Pollination	Abiotic:biotic:N/A
Nativity	Native:non-native

We can also employ multivariate techniques to examine community change. One important question is whether biotic homogenization (Olden et al. 2006) is occurring in parks. By definition, this is the process by which regions (sites in our case) become more similar to one another over time. Biotic homogenization can be addressed via numerous statistical methods; for GLKN, we are interested in potential declines in β -diversity (Pinceloup et al. 2020), i.e., between-site species richness. To test for this, we create site $\times$ species matrices of species frequencies for each sampling event in a park. From these, we derive Bray-Curtis dissimilarity matrices, and calculate the group centroid as the mean difference between all pairs of site combinations. The β -diversity for each site is the difference between the site and the group centroid. We can then test whether group dispersion around matrix centroids differs between sampling events using the “betadisper” function with the “vegan” package of the R environment (Okasanen et al. 2020).

A second approach to testing for biotic homogenization is to test for species compositional change between time periods. Using the Bray-Curtis dissimilarity measures, we perform a PERMANOVA (“pairwise.adonis” function, “vegan” package in R) (Okasanen et al. 2020). This multivariate test is performed as a two-way ANOVA, testing the effects of both Year and Forest/Habitat Type. While we anticipate significant differences between habitats, difference between Years could indicate

homogenization. To confirm, we use nonmetric multidimensional scaling and display values on two-dimensional ordination diagrams.

As described above, we use species frequencies for constructing site $\times$ species matrices when evaluating whether biotic homogenization is occurring. We can, however, also use species presence, in lieu of abundance. While the choice of metric generally does not influence the direction of change (McKinney and Lockwood 2005, Cassey et al. 2008), drivers impacting changes in abundance-based β -diversity can differ from those leading to changes in occurrence-based diversity (Cassey et al. 2008). For tests using presence, site $\times$ species matrices will have binary values (zero or one).

Mesophication is a particular type of community change playing out where fire is either no longer occurring or happening at frequencies much less than historically observed (Alexander et al. 2021). Where mesophication occurs, shifts from fire-dependent species (e.g., jack pine, red pine, white oak, black oak) toward more mesic species, notably red maple, become evident over time. This type of community change can be detected via homogenization tests but could also be detected via ratios of fire-dependent to fire-sensitive species, followed by G-tests, as described above.

As noted earlier, options for examining community change are many and varied and continuously evolving. Our choice of which tests to carry out depend on the nature of the data and the drivers and stressors. It should not be assumed that analyses are limited to those approaches detailed above.

Changes in Overstory Community Structure

We use the Kolmogorov-Smirnov test to compare the size distributions of trees. This is a two-sample, non-parametric test of the null hypothesis that the density-diameter distribution of trees sampled in one year does not differ from the distribution in a second year. Since this test can only be used to compare two samples, it is typically used to compare the initial sampling event with the most current event.

We can also test for changes in small size class trees, either individually or pooled over multiple species. The density of small size class trees can reflect regeneration problems and provide insight on future succession. To test this, we identify the size class of interest (e.g., 2.5–5.0 cm diameter at breast height) and perform linear mixed models as described (see “Changes in Species of Interest” above).

Ungulate Impacts Over Time

We test for change in presence, abundance, and height of herbaceous species that are preferred browse species for ungulates.

We identify species in each park that are both relatively widespread and preferred as browse by either white-tailed deer (eight parks) or moose (ISRO only) (Table 3). For each species, we then assess change. For presence, we use site-level frequency of presence (bounded between 0 and 1.0) in herbaceous quadrats as the dependent variable. For abundance, we use density (individuals/ha) derived from counts in 30 1-m² herbaceous quadrats. This metric is a continuous variable. To test for change in height, we determine the tallest individual in each herbaceous quadrat (where present) then calculate the site-level mean. This metric is also a continuous variable. One must be careful when

interpreting this metric, and qualitatively factor in any changes in presence and abundance. It is possible to have situations where the maximum height does not change or even increases because the quadrat is in an area protected from deer (such as an unreachable outcrop). It is possible (for example) that the species of interest has disappeared from all other quadrats at that site. In this situation, apparent increases in height do not reflect the true impact on browse at that site.

Table 3. Herbaceous preferred browse species selected for additional data collection in each park.

Species	APIS	GRPO	INDU	ISRO	MISS	PIRO	SACN	SLBE	VOYA
<i>Aralia nudicaulis</i>	X			X		X	X	X	X
<i>Clintonia borealis</i>	X	X				X			X
<i>Lupinus perennis</i>			X						
<i>Maianthemum racemosum</i>			X		X				
<i>Maianthemum stellatum</i>									
<i>Osmorhiza</i> sp.			X						
<i>Polygonum biflorum</i>					X				
<i>Streptopus amplexifolius</i>									
<i>Streptopus lanceolatus</i> var. <i>roseus</i>	X			X		X	X	X	X
<i>Streptopus</i> sp.		X							
<i>Trillium cernuum</i>		X							
<i>Trillium grandiflorum</i>				X			X	X	
<i>Uvularia grandiflora</i>					X				

In general, we use linear mixed models to test for change in these three metrics, with the effects of Forest Type and Year considered fixed effects, while the Site effect is random. Specific details of model fit vary and are not presented here.

11.3 Literature Cited

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