Vegetation Monitoring for Compensatory Wetland Mitigation Sites

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Version 1

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This document provides information and guidance on developing a vegetation monitoring plan for compensatory mitigation projects in Minnesota and Wisconsin. It includes information on typical vegetation metrics and monitoring methods for assessing vegetative performance standards. It does not address defining project goals, setting appropriate performance standards, and related steps that occur prior to the development of a monitoring plan.

Introduction

Wetland regulatory agencies are tasked with approving credit releases for wetland banks or in the case of permittee-responsible projects (project-specific replacement) approving compensatory mitigation to satisfy permit conditions. These approvals are based on information provided by applicants. The information is typically in the form of **monitoring reports** addressing achievement of project goals and objectives. Most wetland regulatory programs require the development of a **monitoring plan** for compensatory mitigation projects. Monitoring plans typically include methods for documenting hydrology and vegetation changes over time associated with wetland rehabilitation, re-establishment, enhancement, and creation activities. Monitoring plans for most compensatory mitigation projects span at least five years or growing seasons after restoration activities.

Vegetation is monitored because it is often used as an **indicator** of compensatory mitigation project success and overall wetland condition and functioning. Many wetland functions are tied to vegetation, as wetland plants are responsive to a wide array of chemical, physical, and biological alterations (Cronk and Fennessy, 2001). Therefore, vegetation metrics are often incorporated into **performance standards** for compensatory mitigation projects. Performance standards are observable/measurable attributes used to determine if the project is meeting its functional goals and objectives. These standards are tied to specific **credit releases** for compensatory mitigation credits, and monitoring is required to determine when performance standards are met and credits can be released. Monitoring plans are developed for compensatory mitigation projects in consideration of project goals, objectives, and performance standards (***Figure 1***).

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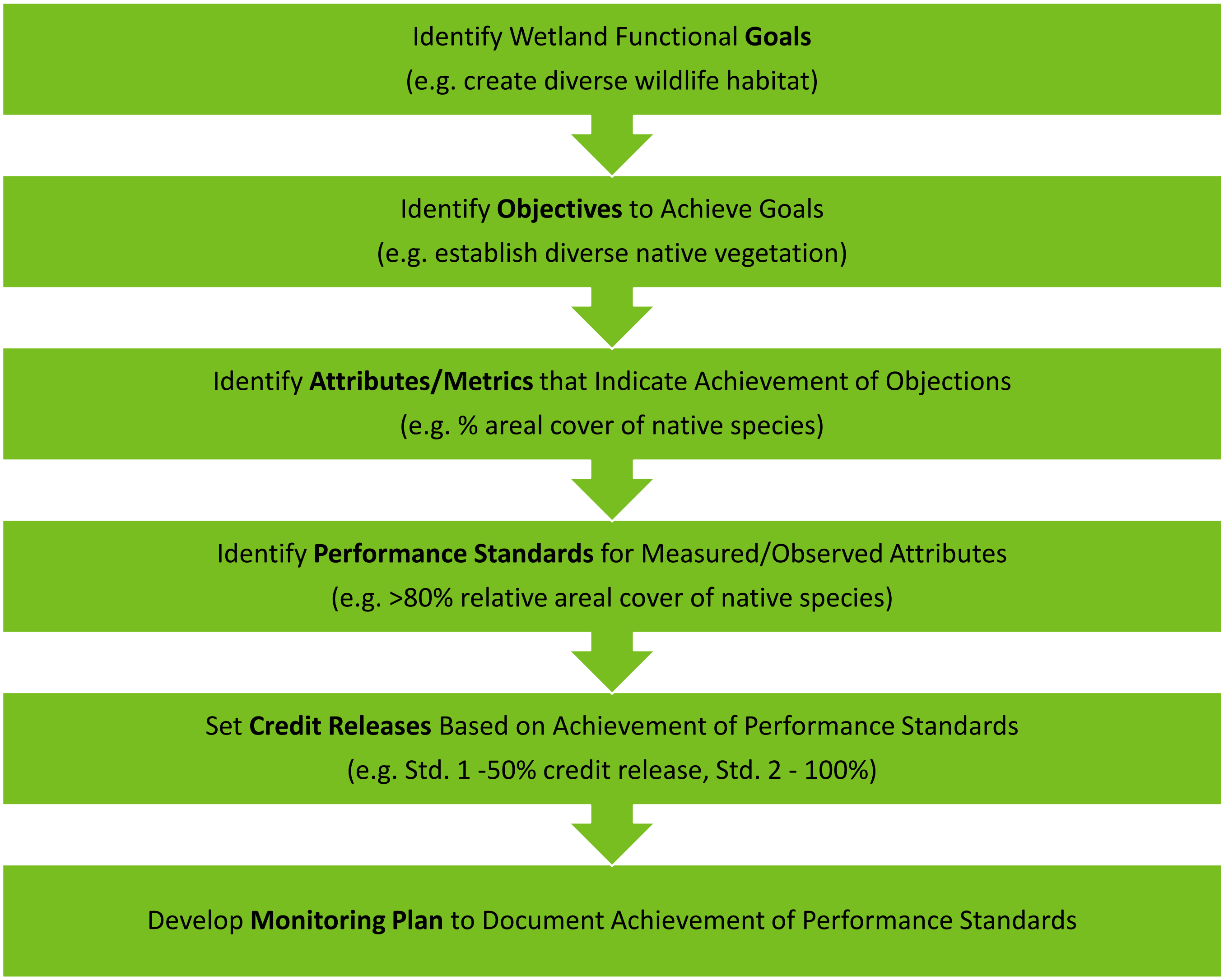
Figure 1. Generalized diagram showing how monitoring relates to goals, objectives, and performance standards.



Developing a Vegetation Monitoring Plan

The following ordered steps can be used to develop a monitoring plan for vegetation.

1. Establish performance standards for vegetation based on project goals and objectives. – *Not addressed in this document*.
2. Identify appropriate vegetation measures (metrics) for monitoring. The performance standards will dictate the metrics to be used (e.g. areal coverage, species richness, etc.). – See *What to Monitor* section.

3. Select appropriate methods to monitor selected vegetation metrics. – See *How to Monitor* section.
4. Select appropriate sampling locations and determine the number of sites (transects, plots, etc.). – See *Where and How Much to Monitor* and *Appendix 1*.
5. Determine appropriate time of year to monitor. – See *When to Monitor* section.

Typical Vegetation Monitoring Plan Expectations

Wetland mitigation projects are highly variable and may require different vegetation standards, metrics, and measurement methods. However, regulatory agencies generally expect to see the following in a typical vegetation monitoring plan:

A. **Existing Conditions**. Existing vegetation conditions should be established to compare against post-restoration conditions. This can range from qualitative to quantitative data depending on vegetation complexity, performance standards, and other project/site characteristics.

B. **Plant Community Identification and Mapping.** Plant communities often change and shift over time following restoration actions. A plant community map should be provided in each monitoring report.

C. **Site Photographs.** Photographs from fixed photo reference points should be provided in each monitoring report to help document site conditions at the time of monitoring and visual changes over time.

D. **Monitoring Units.** Most project sites have areas with differing credit types, credit amounts, plant community types, hydrology, performance standards, management actions, etc. Any of these characteristics can be used to divide the project site into specific monitoring units for which relevant data will be collected, collated, and summarized.

E. **Quantitative Measures of Vegetation Areal Cover.** Most projects will have one or more performance standards related to areal cover of certain groups of plant species (native, nonnative, invasive, hydrophytes, etc.). Some quantitative measure of areal cover is expected in the form of plots, transects, etc.

F. **Species Richness/Diversity.** Most projects will have a performance standard for the number of species within different communities (i.e. species richness). Monitoring plans should include a systematic way of assessing species richness.

G. **Timing.** It is important to collect monitoring data at the same time each year (within 1-2 weeks). Vegetation data will vary over the course of the growing season, and monitoring plans must include specific time periods to collect monitoring data.

H. **Representative Sampling Locations**. Monitoring plans should specifically identify the location of monitoring points, transects, etc. as opposed to a general description of monitoring. The locations should be representative of each monitoring unit.

I. **Replication.** Quantitative measures of vegetation should include some replication. For example, more than one plot, transect, etc. is expected within each monitoring unit. The *How Much to Monitor* section of this document discusses this issue. Appendix 1 describes different methods to assess sampling adequacy when the data does not appear to conform to observations of the regulatory reviewers.

J. **Adaptation.** Monitoring plans are typically based on predicted restoration outcomes. It is rare for a project to develop exactly as predicted given the many variables that effect vegetation establishment and development. The adequacy of the monitoring plan should be evaluated after each year of monitoring and adjusted as needed. This should be done in coordination with the regulatory agencies.

What to Monitor

Project proponents in consultation with reviewing regulatory entities should select vegetation measurements that correspond to specific goals and objectives for their project. There is no default vegetation measurement required for every project, however there are attributes that are frequently used such as relative areal cover of native/non-invasive plant species and species richness. This section discusses commonly used and reliable indicators of a plant community's condition.

Vegetated and Unvegetated Areal Cover

Areal vegetative cover is a metric used to approximate the vegetative biomass of a particular plant species or set of plant species (e.g. native species) and the relative dominance of those species within a monitoring unit. Percent areal cover is the percentage of a defined area (e.g. plot) that (when viewed from directly above) is covered by the aboveground components (leaves, stems, flowers, etc.) of a plant species. There are other methods to approximate plant species biomass such as stem density (stems per unit area) or basal area (cross sectional area of stems aboveground at 4 feet), but areal coverage is the most common.

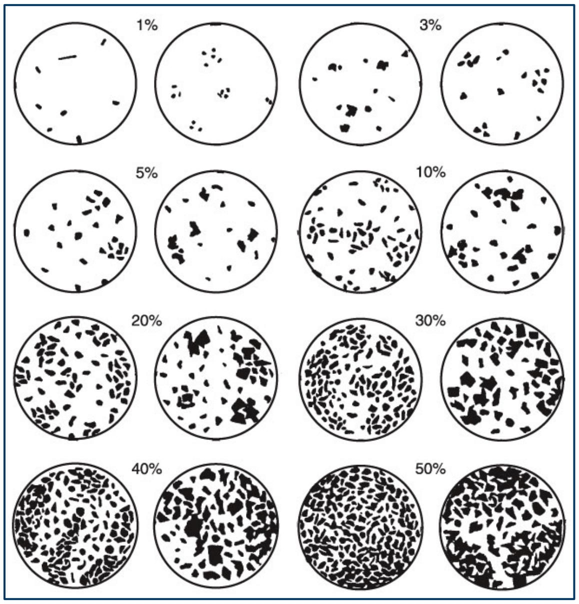
Areal coverage estimates should be completed separately for different layers of vegetation (herbaceous, shrub and/or vine, and tree layers). The 1987 Wetland Delineation Manual and regional supplements provide specific definitions of vegetation layers which are suitable for use when monitoring compensatory mitigation sites (***Table 1***).

Table 1. Vegetation strata as defined by the 1987 Wetland Delineation Manual.

Stratum	Description
Tree	Woody plants ≥ 3 inches (7.6 cm) in diameter at breast height, regardless of height.
Sapling/shrub	Woody plants < 3 inches (7.6 cm) in diameter and greater than 3.28 feet (1 m) tall, excluding woody vines.
Herb	All non-woody plants regardless of size, and woody plants less than 3.28 (1m) feet tall
Woody Vine	Woody vines greater than 3.28 feet (1m) in height

Percent areal cover for the herbaceous layer is estimated by an observer standing directly over the sampling unit (e.g. plot or transect section) and estimating the percent of the area that is covered by the vegetative components of a particular plant species. Tree and shrub layers are estimated by standing in the sampling unit and looking up to estimate the percent of the area covered by leaves, branches, and trunks for each species. The coverage of each species should be assessed independently and separately from other species. Using a visual comparison chart (***Figure 2***) can help observers to estimate areal coverage more consistently. This estimate is the **absolute cover** of the species for the sampling unit. It is common for the sum total of absolute areal coverage estimates to exceed 100% in densely vegetated plots with multiple and overlapping species.

Figure 2. Chart comparing various estimates of percent cover (Terry and Chilingar, 1955).



Most vegetation performance standards include a requirement that a certain percent **relative cover** of native/noninvasive plant species, hydrophytes, and/or perennial species be achieved. Relative cover is calculated by dividing the absolute cover of a species or set of species (e.g. hydrophytes) by the total absolute cover of all species in a plot and multiplying the result by 100 (***Figure 3***).

Relative cover is often more useful measure of plant species abundance than absolute cover because it measures abundance independent of overall vegetation density, is comparable among different sites, and minimizes observer bias. ***Table 2*** shows an example where two different observers estimate the absolute cover of species differently. Despite the fact that Observer 1 estimated absolute percent cover of species significantly lower than Observer 2, relative cover values for each species were similar.

Figure 3. Formula and example for calculating percent relative cover from absolute cover estimates.

$$\frac{\text{\% Absolute Cover Species A}}{\text{Total Absolute \% Cover All Species}}(100) = \text{\% Relative Cover Species A}$$

Example:

Species	Absolute % Cover
A	30
B	40
C	80
Total	150

30/150 (100) = 20% Relative Cover Species A

40/150 (100) = 27% Relative Cover Species B

80/150 (100) = 53% Relative Cover Species C

Table 2. Example of % relative cover calculations for two different observers.

	Observer 1		Observer 2	
Species	Absolute % Cover	% Relative Cover	Absolute % Cover	% Relative Cover
A	20	18	30	20
B	30	27	40	27
C	60	55	80	53
Total	110		150	

Some performance standards are related to the percentage of a certain area that are unvegetated. This is estimated by an observer standing directly over the plot or transect section and estimating the percent of the area that is not covered by vegetation and averaging that value across plots/transects in a sampling unit.

Timing of areal coverage estimates is an important consideration. Areal vegetation coverage will usually increase from early to midway through the growing season and then decrease toward the end of the growing season depending on the species present and their growth form (trees, shrubs, herbaceous). Areal coverage estimates should be conducted at roughly the same time period during the growing season from year to year to ensure comparable results.

Species Richness

Species richness is simply the number of species present in a plant community type. Different plant community types (wet meadow, shallow marsh, etc.) generally have different degrees of species richness. Usually only native species are considered when reporting species richness. It is important to consider species richness in comparison to a reference condition reflective of the plant community goals and performance standards. For example, some communities have characteristic dominant species resulting in low richness but a desirable composition — such as those dominated by lake sedge (*Carex lacustris*), common beaked sedge (*Carex utriculata*), or wild rice (*Zizania palustris*).

Species richness can be assessed from data collected for areal coverage estimates. However, it is often desirable and more thorough to use assessment methods such as meander surveys (described later) to supplement species lists generated from areal coverage estimates. It is also desirable to summarize species richness by vegetation strata (herb, shrub, tree) because richness expectations will typically vary by strata.

Floristic Quality Assessment

Figure 4. Boneset (Eupatorium perfoliatum) has a C value of 4 in Minnesota and 6 in Wisconsin.

Floristic quality is indicative of the ecological integrity of a plant community. A community with high floristic quality has a species composition, diversity, and functional organization comparable to those of natural habitats within a region. Floristic quality is assessed in Minnesota and Wisconsin by identifying species and their relative abundance using various sampling methods. For this metric, plant species in a state or region are assigned a Coefficient of Conservatism, or **C value**, based on their response to stressors (***Figure 4***). Species with high C values (7-10) are expected to be largely restricted to areas with minimal anthropogenic disturbances or adapted to unique natural conditions (including natural disturbances). Species with low C values (1-3) are expected to be largely found in ruderal or highly degraded habitats. All non-native species are assigned a zero. Coefficients of conservatism have been developed for all species in Wisconsin, and all wetland species in Minnesota. Regionalized coefficients of conservatism are under development for both upland and wetland species in Minnesota. Species lists, areal cover estimates, and associated C values for plant communities can be used to calculate a **Floristic Quality Index** (FQI) value. The FQI is reflective of wetland condition.

Floristic quality measures can be effective at showing changes in a community's condition over time and are often related to biological or ecological integrity. Floristic quality metrics require accurate identification of plant species and the ability to detect and identify small, less-showy species in low abundance. Floristic quality assessment results are relatively consistent among different skilled observers and different methods of data collection (DeBerry et al. 2015). There are several resources for floristic quality assessment Wisconsin and Minnesota (***Table 3***).

Table 3. Reference resources for floristic quality assessment in Wisconsin and Minnesota

Wisconsin Department of Natural Resources	Development of a Floristic Quality Assessment Methodology for Wisconsin.
	Timed-Meander Sampling Protocol for Wetland Floristic Quality Assessment.
	Wisconsin Floristic Quality Assessment Calculator (excel spreadsheet).
Minnesota Pollution Control Agency	Floristic Quality Assessment for Minnesota Wetlands
	Wetland Monitoring Standard Operating Procedures: Vegetation sampling procedures for wetland biological monitoring sites.

Plant Community Types

A plant community is a contiguous and relatively uniform assemblage of plant species that is distinguishable from different neighboring assemblages of plant species. Compensatory mitigation projects In Minnesota and Wisconsin generally identify wetland plant communities in accordance with *Wetland Plants and Plant Communities of Minnesota and Wisconsin* (Eggers and Reed, 2014). This classification system includes 15 different plant community types, but wetland regulatory programs lump some communities together for program implementation purposes. Upland plant communities are generally identified in Minnesota in accordance with *Minnesota's Native Plant Community Classification: A Statewide Classification of Terrestrial and Wetland Vegetation Based on Numerical Analysis of Plot Data* (Aaseng et al. 2011) and associated guides. Wisconsin's wetland community types can be identified using the [Key to Wetland Natural Communities by WDNR]. Vegetation performance standards typically vary by plant community type, so it is important to identify and map communities as they develop and change on a project site. In addition, plant communities are generally reflective of the prevailing hydrologic regime of the area.

Patches of Invasive and Non-Native Plant Species

Plant species such as reed canary grass (*Phalaris arundinacea*) and wild parsnip (*Pastinaca sativa*) are aggressive, non-native species that tend to outcompete native species and degrade the quality of wetlands and uplands on a compensatory mitigation site. Their presence in contiguous patches can indicate the need for control measures to prevent their spread. Identifying and mapping patches of invasive and non-native species is sometimes required by regulatory agencies, however, it is always beneficial for the project proposer to include this in their monitoring plan to better target their vegetation management activities.

Sampling Methods and Techniques

This section describes common sampling methods and techniques for monitoring vegetation characteristics described in the previous section. Because sampling methods vary in their strengths and applicability, monitoring plans often involve a combination of methods, as one method is usually inadequate for documenting vegetation metrics in relation to performance standards.

Mapping

Mapping vegetation refers to outlining contiguous areas of similar vegetation characteristics (e.g. species present, community type, different management strategies used, etc.) on an aerial image or plan view drawing. Recent aerial imagery, or other types of imagery (color infrared, radar, etc.) of sufficient resolution can be used. Ground observations are often needed to discern and confirm features identified and mapped on imagery.

Mapping information can be quantified (total area of polygons) and used to estimate areal extent of a vegetated feature by dividing the total polygon area by the total project area or project zone of interest. This method lacks the precision of plot and transect sampling, but it is useful on large sites and/or when it may be too labor intensive to adequately represent the site with plots and the vegetation characteristics of interest are readily discernable on available imagery. For example, in ***Figure 5*** areas of invasive species are readily distinguishable on this site and can be mapped with reasonable accuracy.

Figure 5. Mapped areas of invasive species on a compensatory mitigation

Photographs and Video Imagery

Taking photos or video of a project site over time is an effective, qualitative way of supplementing monitoring data. Repeated photos taken at set “photo-reference points” provides visual documentation of restoration progress over time (***Figure 6***). Photo reference points can be selected to show vegetation changes of large areas of a project site, within individual sample plots, or on specific restoration features such as berms/dikes. It is important to take photos at roughly the same time each year so that photos are comparable from year to year. Video imagery taken from unmanned systems such as drones can be a very effective way of visually documenting vegetation, particularly where water levels and soil conditions make foot access difficult. Most monitoring plans should include some type of qualitative photo or video documentation.

a

b

c

d

Figure 6. Repeated photos at fixed photo reference point points. (a) 2010 landscape photo, (b) 2013 landscape photo, (c) 2018 plot photo, 1st year of restoration, and (d) 2019 plot photo, 2nd year of restoration.

Plots

Plot-based sampling involves quantifying vegetation data (cover, richness, composition, stem counts, etc.) within a defined area, such as a square, rectangle, or circle. The sampling data from multiple plots are typically averaged to represent a monitoring unit or community.

The size, shape, and distribution of plots are important considerations for monitoring. Plots must be large enough to include the representative diversity of vegetation types, but small enough for observers to reasonably visualize and estimate percent areal cover. Generally, these requirements can be met for herbaceous vegetation using smaller plots as compared to larger plots for shrubs and trees. Vegetation sample plot sizes in the *1987 Wetland Delineation Manual* and regional supplements are adequate for most plot-based monitoring (***Figure 7*** and ***Table 4***). Other plot sizes can be used such as those associated with the Minnesota DNR's releve method (Minnesota DNR, 2013)

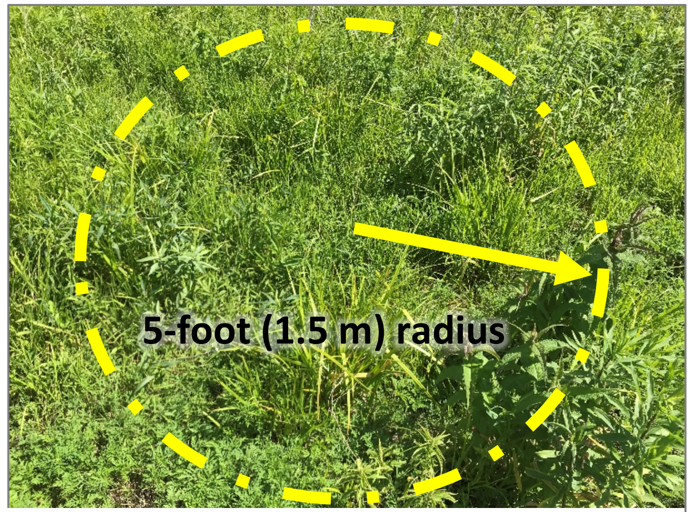


Figure 7. Example of a circular plot for the herbaceous layer.

Table 4. Recommended plot sizes for different vegetative layers per wetland delineation manual supplements.

Vegetation Layer	Recommended Plot Size
Herbaceous (all herbaceous vegetation and all woody vegetation less than one meter)	5 ft (1.5-m) radius circular plot
Shrub (all woody vegetation one meter or greater in height and less than 3 inches diameter breast height)	15 ft (4.6-m) radius circular plot
Tree (all woody vegetation 3 or more inches in diameter breast height)	30 ft (9.1-m) radius circular plot
Woody vine (woody vines greater than 3.28 ft in height)	30 ft (9.1-m) radius circular plot

Other factors such as community homogeneity and the type of monitoring metric being measured may require different plot sizes. For example, Minnesota and Wisconsin recommend specific plots sizes for evaluating vegetation associated with forest regeneration (MN DNR, 2016; WDNR – Chapter 21).

A standard plot shape such as a circle, square, or rectangle is usually chosen and used for monitoring a project. However, it is sometimes necessary to modify the shape of one or more plots to ensure that the plot(s) are located entirely within a similar plant community or a similar area based on some other characteristic (e.g. topography, wetland credit area, etc.). Modified plot shapes should encompass the same area (square feet or meters) as the rest of plots on a monitoring site to ensure consistency and comparable results (***Figure 8***).

Figure 8. Example of re-configured plot. A 30-foot radius plot (left) in this location would include both forested and open field communities. A rectangular plot (25 x 115 ft) encompassing the same area as a 30-foot radius plot (2,826 sq. ft.) would confine the plot to the forested area only.

The distribution of monitoring plots can be random or targeted. Monitoring for research purposes often involves the random placement of plots in sufficient quantity to discern statistically significant differences and trends. In contrast, typical monitoring of wetland mitigation sites involves the targeted placement of plots in areas that are representative of the overall site or sampling unit. This is consistent with the vegetation sampling approach for routine wetland delineations. This approach generally requires less plots and is more flexible and adaptive to restoration sites with multiple intersecting plant communities. The *1987 Wetland Delineation Manual* describes field procedures for comprehensive determinations that can also be used for distributing sampling plots.

Often an elevation line and knowledge of expected water levels is used to pick representative sampling locations based on expected post restoration plant community development. However, it may be necessary to relocate plots as wetland mitigation sites develop over time and plant communities and characteristics shift.

Belt Transect

A belt transect is a linear plot of specific width established along a particular bearing through a representative area of the monitoring unit. Belt transects can be used to sample a large representative area in a relatively short amount of time compared to individual plots. Belt transects require a starting point and bearing to be established as opposed to the establishment of multiple plot locations needed to cover the same area. Belt transects are best used to sample shrubs and trees, particularly stem counts to document either woody plant establishment (such as shrub-carr establishment) or control (reduction of invasive species such as buckthorn). Stems can be tallied by species in categories such as stem height or diameter (***Figure 9***). Stems per square meter or foot can be calculated based on the number of stems counted within the area encompassed by the belt (length times width). One meter wide transects are recommended for sampling smaller shrubs (< 3.28 ft or 1m tall) and 2-meter (6.56 ft) wide transects are recommended for larger shrubs. Wider transects can be used for sparse populations of woody vegetation. For spatially dispersed sampling, multiple shorter transects are better than one long transect.

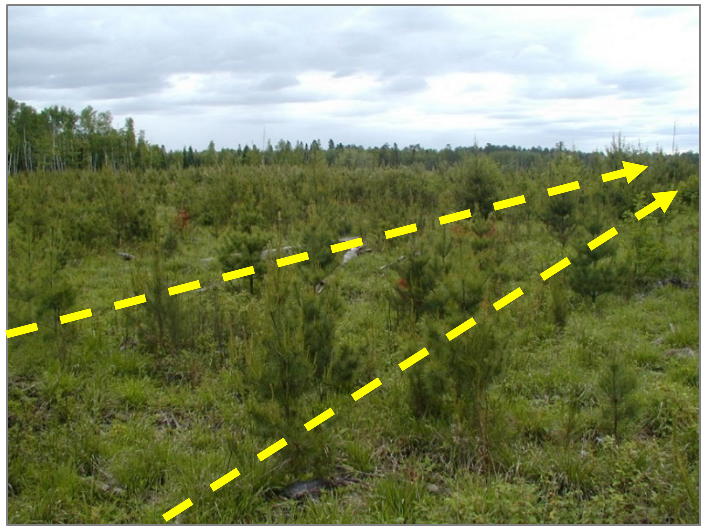


Figure 9. The "belt" of a belt transect depicted by the dashed lines. Woody stems meeting certain height and diameter criteria can be tallied by species to estimate stems per unit area.

Point-Intercept

The point-intercept method is an objective, efficient, and accurate method to estimate vegetation areal cover (Evans and Love, 1957). This method works well in open or semi-open terrain with herbaceous vegetation. Inundated communities and communities with dense shrubs or large trees are more challenging to traverse in a straight line, increasing difficulty and bias. This method estimates common vegetation well, but species with <5% cover often go undetected. Point-intercept sampling is conducted by establishing straight line transects through a monitoring unit, walking along the transect, and recording plant species overlapping the transect line at pre-defined points or intervals. Transects are established by laying out a line or meter tape along a bearing. Observation points can be random (use random numbers table or program) or at set intervals (e.g. every 5 meters, every 20 feet, etc.). The **step-point** method is a practical variation where the observer selects a distant landmark along the bearing point to walk toward and then records plant species present at the toe of the boot after every pre-determined stride interval (e.g. every 5 strides) (***Figure 10***).

Figure 10. A step-point transect with circles representing sample points at the tip of each stride interval.

Point-intercept is often used to estimate percent relative cover by plant species. Percent cover is estimated by dividing the number of "hits" (times the plant species is encountered at observation points) by the total number of hits (excluding observation points where no vegetation is encountered) (***Figure 11***).

Figure 11. Formulas and examples for calculating percent relative cover and percent bare ground from point intercept transect.

$$\frac{\text{\# of Hits for Species A}}{\text{Total \# of Hits for All Species}} (100) = \text{\% Relative Cover Species A}$$

Example:

Species	Hits
A	4
B	11
C	6
Total	21

4/21 (100) = 19% Relative Cover Species A

11/21 (100) = 52% Relative Cover Species B

6/21 (100) = 29% Relative Cover Species C

$$\frac{\text{\# of Sample Points with No Veg}}{\text{Total \# of Sample Points}} (100) = \text{\% Bare Ground}$$

Example:

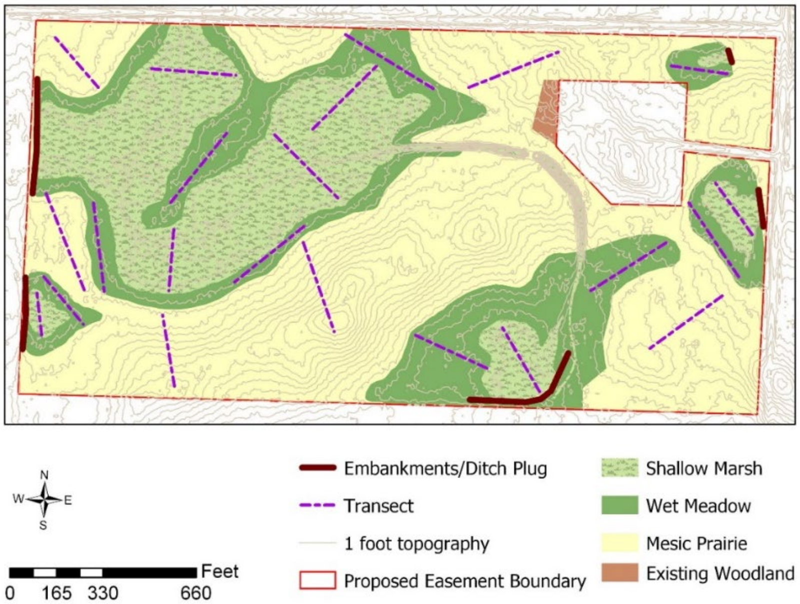
Species	Hits
A	7
B	14
No Veg	8
Total	29

8/29 (100) = 28% Bare Ground

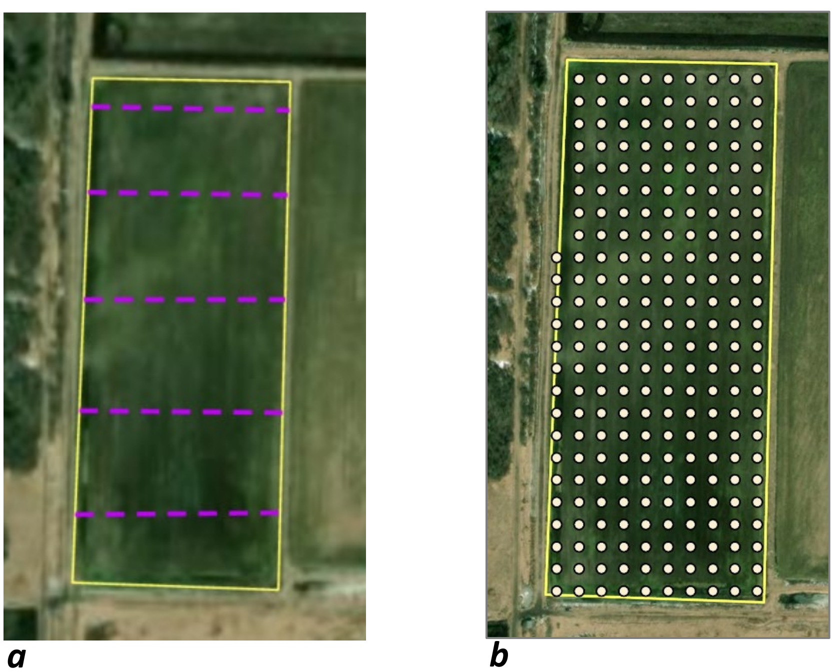
This method can either ignore layers (only count the top layer intersected) or include all layers (record hits for all species intersecting the point). When estimating percent relative cover by layer, hits for each layer should be recorded separately at each observation point.

As with plots, locating transects in representative locations is important (***Figure 12***). Some sites might require multiple short transects while fewer, longer transects may suffice for other sites depending on the size and arrangement of monitoring units. Transects can also be arranged parallel to each other to form a grid pattern over an area, in which the grid would be a sample unit. A grid is best for patchy vegetation or where monitoring units are difficult to discern or predict.

__Figure 12. Examples of transect layouts for compensatory wetland mitigation sites.__



__In this example, average transect length is 300 ft long, with expected intercepts at every 8-10 ft. Placement includes representation of community edges and centers while spanning topographic ranges.__



__In (a) five point-intercept transects (660 feet long) are planned in a 20-acre organic flat with an interval of 5 paces between points resulting in 50 pts per transect and a total of 250 sample points. In (b), a grid of point intercepts is established resulting in 232 evenly spaced sample points. The grid pattern may be a better choice when vegetation is heterogeneous, or patchy in distribution.__

Meander Surveys

Meander surveys are paths walked by observers (or canoed in standing water) through representative areas of monitoring units to observe, estimate, and record vegetation data. Meander surveys differ from simple reconnaissance walks in that the meander path is mapped (usually with a GPS unit) and time spent is tracked and recorded.

Meander surveys are a quick and efficient method for estimating species richness (i.e. the number of species present in a monitoring unit) and detecting invasive species. They can also be used to estimate percent relative cover of plant species, but such estimates are less accurate than other methods (plots, transects), particularly for large areas (e.g. >10 acres). One advantage of meander surveys is their ability to detect less abundant species that may be missed by plot or transect methods.

Meanders can be timed to improve replicability. Comparing data collected by meander surveys from different areas is useful if the terrain is relatively similar. Comparisons are more difficult if timed meanders are conducted in significantly different terrain types where the ability to cover a similar sampling area in a set amount of time is compromised due to difficult terrain conditions (e.g. thick vegetation, deep water, woody slash/debris, etc.). Reconnaissance of the timed meander area is usually needed to determine the boundaries of the homogeneous community the survey will represent and roughly plan a representative route. Sampling units should be 10 acres or smaller per meander transect. In Minnesota, a rapid floristic quality assessment method has been developed that utilizes timed meanders (Bourdaghs 2019). In this method a base meander time of 30 minutes per assessment area is established with additional time added depending on the number of species encountered in the final 10 minutes (>6 or <6). The Wisconsin Department of Natural Resources also has developed a similar timed meander sampling protocol (Trochlell 2016).

This method requires less time than establishing transects and plots, but lacks the precision needed to accurately evaluate some measures (e.g. percent relative cover). It can be used to cover large areas and in conjunction with other reporting objectives such as plant community mapping, detection of invasive species, and identifying areas in need of further management. In areas that are newly seeded, meanders alone may be sufficient to evaluate vegetation after initial seeding activities when cover crops are present and desired species have yet to establish. However, plots or point-intercept transects are often conducted in combination with meanders to provide better accuracy on species cover beyond the first year of monitoring. Meanders also are a good option for detecting areas of invasive species where desired native species diversity and cover are already well-established and documented.

Shoreline Hook

A shoreline hook (typically a hand garden cultivator attached to a 20-foot rope) can be used to estimate submergent aquatic plant presence and cover in water areas greater than 2 feet deep. A standard approach used in Minnesota is to select at least 3 representative locations on the shoreline in which three tosses are made with the hook at each location: one perpendicular, and two offset 45° from perpendicular (***Figure 13***). Cover is estimated by observing the number and prevalence of species on the cultivator tines combined with visual observations from the shoreline location (Bourdaghs 2019).

Figure 13. Shoreline hook method. Hand garden cultivator tool (upper right) is thrown from the shoreline or edge of the community in three directions.

Summary

Table 5 summarizes some advantages and disadvantages of the monitoring methods discussed. A combination of methods is recommended for most compensatory wetland mitigation sites.

Table 5. Summary of monitoring methods for common vegetation metrics used to determine compensatory wetland mitigation project performance standards.

Vegetation Metric	Monitoring Method	Advantages and Disadvantages
Areal Cover	Plots	With adequate replication and placement, provides reliable estimates of cover. Works well for all strata and for both small and large areas. More time consuming than some other methods due to time spent locating plots and identifying and estimating cover for each species in each plot.
	Point-Intercept Transects	With adequate replication and placement, provides good estimates of cover. Works best for the herbaceous stratum. Difficult to use in inundated areas. Works well for both small and large areas. The step-point variation is less time consuming than plots. Inaccurate for species with small overall cover (~ <5%).
	Meander Surveys	Flexible method for a variety of project sizes and landscape settings. Works well for all strata. Can be conducted from a canoe for shallow open water areas. Cover estimates not as precise as plots or point-intercept samples. Ten acres should be the maximum size for most meander surveys. Suitable to report on dominance, or standards not requiring high precision. Suitable for detecting invasive species.
	Mapping	Requires recent, high resolution imagery to map features such as canopy cover and patches of bare ground or invasive species. Efficient for large tracts of land or difficult to access areas. Imprecise method dependent on quality of aerial imagery and discernability of specific vegetation types from an aerial perspective. Best when combined with other more precise methods.
Species Richness & Floristic Quality	Meander Surveys	Best method for assessing species richness, assessing floristic quality, and detecting invasive species. Timing the meander is critical in making year to year and area to area comparisons.
	Plots	High replication and larger plots needed to detect rare or uncommon species. Best used to supplement species lists collected from transects.
	Point-Intercept Transects	Can be used for species richness, but not as reliable as meander transects. Can be enhanced for species richness observations by noting additional species along the transect and outside observation points.
Shrub or Tree Stem Counts	Plots / Belt transects	A belt transect or long linear plot is more efficient for stem counts compared to multiple small plots.

Where and How Much to Monitor

A monitoring plan describes not only how, but where and how much vegetation will be sampled. Like sampling for routine onsite wetland delineations, vegetation data for mitigation monitoring illustrates and supports observations by wetland professionals. The data should represent the vegetation conditions, but it typically does not need to prove or disprove a hypothesis within a certain confidence interval like most research efforts. Results are reviewed by regulators at a field visit, during which time they confirm if the reported data appear to be representative of the site's condition.

Establishing Monitoring Units

To establish representative sampling locations, project sites should be stratified, or divided into vegetation monitoring units that are expected to be similar. Once the boundaries of the monitoring units are established, sampling locations for plots or transects are placed within each monitoring unit to represent the entire unit.

Units should be established based on where differences in plant communities and plant community development are anticipated in light of established project performance standards. These differences often result from one or more of the following factors:

- Land use histories (e.g. cropped land vs pasture vs undisturbed forest, etc.);
- Expected hydrology (depth, duration, frequency) often associated with different elevations;
- Soil types;
- Seed mix and/or planting areas (typically associated with different planned community types);
- Management techniques used (e.g. burning vs mechanical removal vs herbicide treatment); and/or
- The proximity and influence of different stressors (e.g. forest buffer vs urban landscape vs agricultural field, etc.).

Boundaries for monitoring units should be based on one or more of these factors that are predicted to have the most influence on vegetation development during the monitoring period (***Figure 14***). The process of stratifying a site for sampling is not an exact science because it is based on *predicted* outcomes. Sound professional judgement and practical experience are needed to establish monitoring units. It is possible, if not expected, that some predictions will fall short given all of the variables that affect wetland restoration outcomes. The monitoring plan should be evaluated annually, adjusting stratification and sampling as necessary to ensure that it is representative of the vegetation metrics (areal coverage, species richness, etc.).

Some projects or project areas do not involve the removal of existing vegetation and re-planting/re-seeding, but instead rely on changes in hydrology and/or management activities to alter vegetation over time. In these instances, existing plant community composition is often the primary basis for stratification into different monitoring units.

Figure 14. Example of a site stratified by pre-construction land use, resulting in three monitoring units (row cropped, sod, and fallow). Additional monitoring units would be created if multiple plant communities are expected in one or more of the three.

Sample Point Locations and Number

The number of sample locations within each monitoring unit will depend on the type of sampling, how large the monitoring unit is, and how variable the plant community is or is expected to be. More sample locations/points are recommended if variability is expected to be high. Time and costs should also be considered, but documenting progress toward meeting performance standards is the most important factor. Sampling points can be added or subtracted as necessary during annual monitoring plan evaluations. At a minimum, some replication (multiple samples) within identified vegetation monitoring units is recommended (see ***Appendix 1***).

Locating sample locations within each monitoring unit can be targeted, systematic (e.g. a grid pattern), or random (unbiased selection based on random numbers or other random selection methods). In all cases, sample locations should show adequate dispersion or coverage of the monitoring unit. For example, representative areas should include both edges and centers of the communities – with more samples in the zone with the greatest area. Samples should be spatially dispersed across the monitoring unit. GIS tools are available to create spatially dispersed points (see Create Spatially Balanced Points). This tool is a more efficient alternative to the "Create Random Points" tool, the former using inclusion (sample) probabilities to guarantee the design is spatially balanced.

When to Monitor

In Minnesota and Wisconsin, most species are best observed between June 15th and August 30th. Results for plant species richness and areal cover measures will vary depending on the time of the year the sampling is conducted. Some spring ephemeral species, for example, can only be detected prior to June. If sedges are of interest, they are generally more easily identifiable in June. Many asters are more easily identified in late August. Multiple visits per year are best to observe how well a site is establishing. To best show changes over time, sample at the same time each year, especially if floristic quality assessments are conducted. If a credit release is anticipated, consider allowing time in the growing season to schedule a regulatory field review.

Monitoring Plan Considerations

Monitoring plans should provide clear information about what will be monitored, how monitoring will be conducted, where and when it will be done, how the data will be analyzed, and how the information will be reported. Having this information summarized in a consistent format will aid the regulatory review of projects and help guide staff who will be conducting the monitoring. Plans should tie back to project goals and performance standards, and the applicant should describe why they selected the proposed sampling methods.

Important monitoring considerations include the following:

- Different monitoring units may need different sampling techniques. For example, point intercept transects may measure native cover well in an herbaceous community, and plots may be more suitable for a shrub-carr community in a different monitoring unit.
- Different sampling methodology may be needed as a project site develops and performance criteria become more specific. For example, a meander transect may be adequate for early phases of vegetation development while a combination of methods such as point intercept sampling or plots for estimating relative cover, and recorded meanders for species richness may be needed for later phases.
- It is important for sampling units to be representative of the area being monitored.
- Sampling effort is related to the scale and complexity of a project.
- Adapting monitoring methods over time to account for changing site conditions is often necessary.

Reporting Monitoring Results

Summarizing monitoring results in a transparent and comprehensible manner is critical. Reviewing agencies rely on monitoring reports and field visits to determine if a project is meeting performance standards, and if additional measures are necessary to meet project objectives. Similar to sampling, the content and level of detail in a report is related to the scale and complexity of a project.

Below is a sample outline for what an annual monitoring report should include for monitoring vegetation:

- Project overview, including:
    - Date of project approval.
    - Dates and brief descriptions of project implementation activities (e.g. construction, seeding, vegetation management, etc. as applicable).
    - Vegetation performance standards.
- Metrics measured, monitoring methods and data collection dates.
- Monitoring results
    - Field conditions (drought, wet, normal) at the time of data collection and observations. Description of any anomalies or constraints affecting monitoring results.
    - General observations, plant community map, photos, etc.
    - Species richness and relative areal cover estimates (and/or other metrics as required by performance standards) summarized by monitoring unit.
    - Tables and/or graphics comparing data on metrics with applicable performance standards.
    - Tables and/or graphics comparing data with past monitoring data and baseline pre-project data (if available).
- Discussion of:
    - Monitoring data results as they relate to performance standards.
    - Adequacy of monitoring sample points/transects and monitoring unit boundaries and any proposed adjustments for next year.
    - Vegetative management actions planned for upcoming year.

In addition to providing the data collected in the form of charts, tables, and graphics, the report should include a narrative summary in which data averages, ranges, and variability are analyzed and discussed. In the narrative, it is good to describe the composition observed for each community. For example: *Average relative native cover from the wet meadow transects was 88%, with a range of 75-100%. Common native species and their average cover were rice cutgrass (Leersia oryzoides), green bulrush (Scirpus atrovirens), sedges (Carex spp.), and fowl bluegrass (Poa palustris), ranging from 5-28% relative cover. Introduced species included barnyard grass (Echinochloa crus-galli) at 1% relative cover, reed canarygrass (Phalaris arundinacea) at 3% relative cover, and curly dock (Rumex crispus) ranging from 1-3% relative areal cover.* ***Table 6***, ***Table 7***, and ***Figure 15*** are examples of reporting vegetation monitoring data.

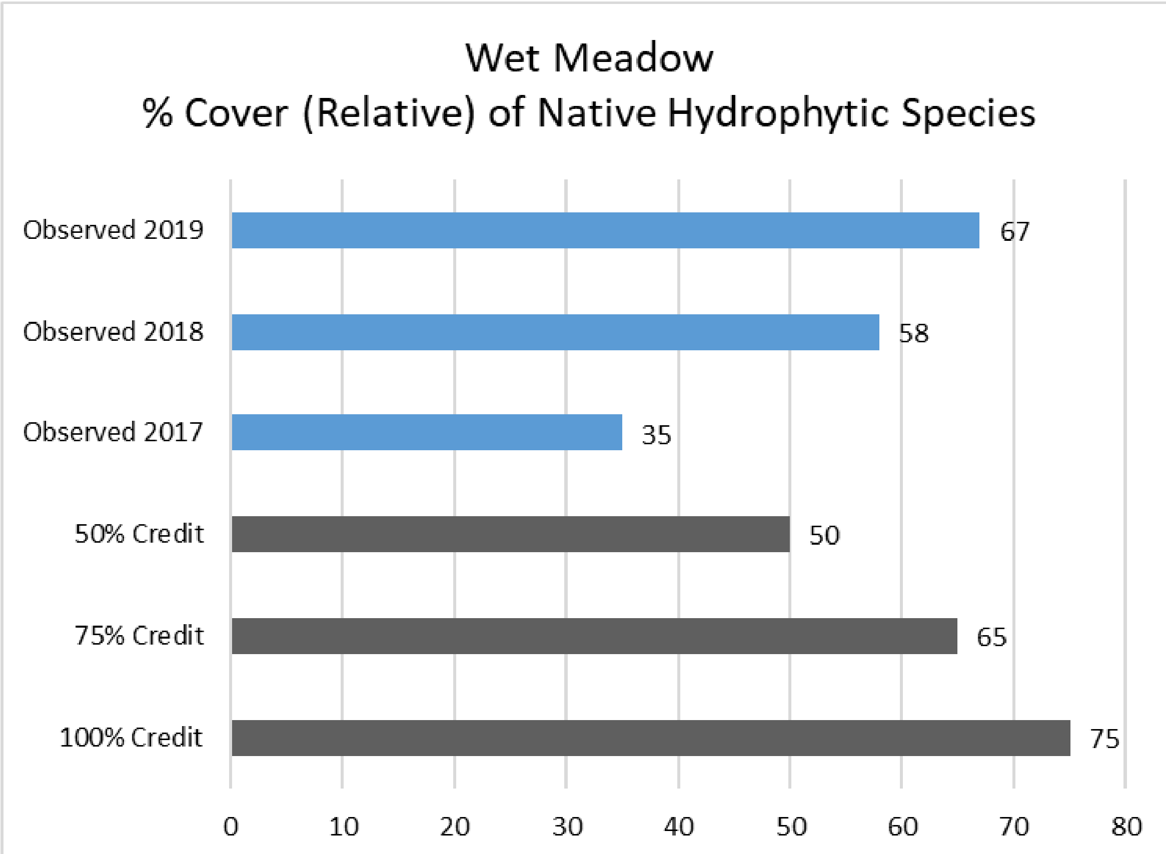
Table 6. Example of summarizing relative areal cover estimates by plant community and plant group.

		% Relative Cover Estimated from Point Intercept Transects (A – F)						
Community	**Plant Group**	**A**	**B**	**C**	**D**	**E**	**F**	**Avg.**
Mesic Prairie	Native	70%	95%	100%	60%	100%	60%	81%
	Introduced	30%	5%	0%	40%	0%	40%	19%
Wet Meadow	Native	85%	90%	90%	75%	100%	86%	88%
	Introduced	10%	0%	0%	10%	0%	14%	6%
	Bare/none	5%	10%	10%	15%	0%	0%	6%
Shallow marsh	Native	100%	90%	96%	59%	90%	77%	85%
	Introduced	0%	0%	4%	12%	0%	4%	3%
	Bare/none	0%	10%	0%	29%	10%	19%	12%

Table 7. Example of comparing data on vegetation metrics to previous years and performance standards.

Community	Interim 1 Performance Standards	2018	2019
Mesic Prairie	Native, non-invasive vegetation >50% relative cover	39%	66%
	≥5 native, non-invasive species	18	23
	Non-native and/or invasive species <50% relative cover	61%	34%
	Bare ground <40% absolute cover	4%	0%
Wet Meadow	Native, non-invasive hydrophytic vegetation >50% relative cover	55%	72%
	≥5 native, non-invasive species (≥2% relative cover each)	9	9
	Non-native and/or invasive species <50% relative cover	15%	10%
	Bare ground <40% absolute cover	3%	1%
Shallow Marsh	Native, non-invasive hydrophytic vegetation >30% relative cover	96%	95%
	≥2 native, non-invasive species	24	18
	Non-native and/or invasive species <60% relative cover	3%	3%
	Unvegetated areas <60% absolute cover	16%	10%

Figure 15. Example graphic comparing relative cover data between years and in relation to credit releases tied to performance standards.



Recommended Further Reading

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Appendix 1. Assessing Sample Adequacy

Sampling for wetland mitigation monitoring is typically conducted by picking sample locations that are representative of conditions/characteristics in a monitoring unit (i.e. representative sampling). Some sampling replication (i.e. more than one sample) is expected for most monitoring. More sampling locations increase confidence in estimated values, but also increase costs. The number of sampling locations is usually determined for wetland mitigation projects through discussion and compromise between the applicant and the reviewing agencies based on specific site characteristics and projected project results. However, there are more objective means to determine sample adequacy that may be used when there are disagreements about the number of samples required to adequately assess vegetation metrics. This appendix describes some methods for determining sampling adequacy for different types of vegetation measures. Using multiple methods on the same data can strengthen conclusions on sample adequacy.

Plotting Species Accumulation and Performance Curves

Species accumulation and performance curves can be used to assess sampling adequacy. For the species richness metric, the cumulative number of species observed is plotted against the number of sample units (plots, transects, or time from a meander sample). This is sometimes referred to as species accumulation or species effort curve. The number of sampling units is generally considered to be adequate when the curve flattens out indicating very small increases in the number of species observed with increased samples. The example in ***Figure 1*** indicates that approximately 9 or 10 samples are adequate. Even when using this method to assess sampling adequacy, it is still important to consider practical matters related to achievement of performance standards for the wetland mitigation site. If the species accumulation curve indicates that sampling is inadequate to achieve a complete species list, but the number of species observed meets the performance standard, then further sampling is not needed. In the example below, if the species richness performance standard is 15 species and there were 4 sampling locations resulting in 25 species observed, then increasing sampling locations to 9 or 10 as indicated by the curve is not necessary.

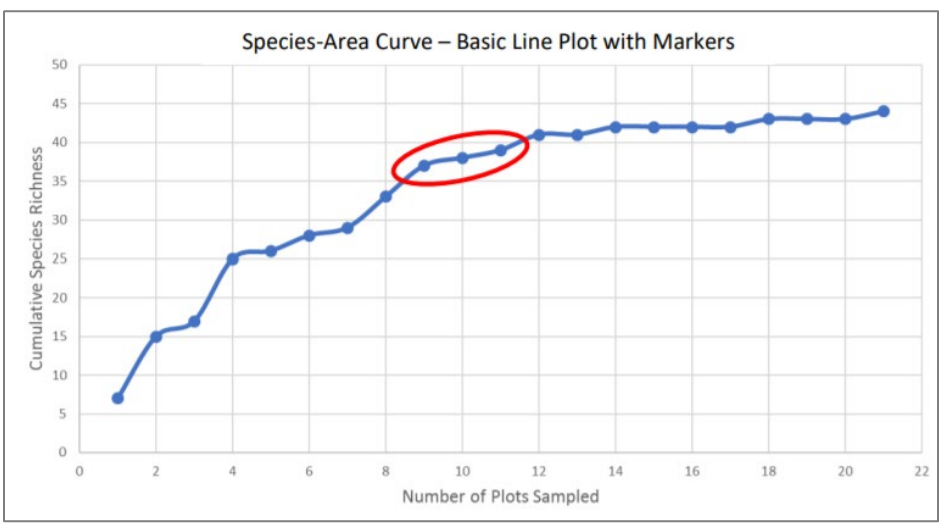


Figure 1. Example of a species-area curve showing that 9-11 plots is where the graph begins to flatten out, representing an adequate sample effort (from DeBerry 2018).

How to create a species-area curve (***Figure 2***):

1. Create a table showing x (effort, such as the number of sample units) and y (cumulative total species richness), listing results in the order sampling occurred.

2. Create a scatterplot with straight lines or a trendline.

Sample Unit (plot)	Cumulative Native Species Richness
1	12
2	14
3	18
4	20
5	21
6	21
7	26
8	28
9	29

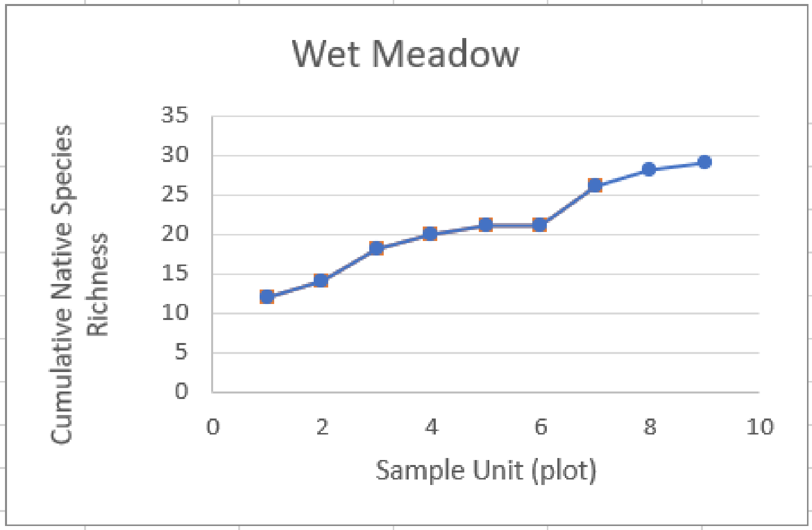


Figure 2. Example of table and resulting native species accumulation curve. The curve has not flattened out, yet the performance standard (18 native species) has been met.

3. Interpret results: Review the chart (scatterplot), and determine if additional samples are needed to adequately represent species richness. In this case, the performance standard is 20 native species, which was met by the 4th sample.

For percent areal cover metrics, the cumulative areal cover is plotted against the number of sample units (***Figure 3***). This is sometimes referred to as a performance curve. The number of sampling units is generally considered to be adequate when the curve levels out indicating very small changes in percent areal cover with increased samples. Unlike accumulation curves for species richness, these performance curves for areal cover can fluctuate up or down as sample locations are added. For percent relative cover, the cumulative average is typically plotted on a 0 to 100% scale at 10% intervals. Leveling out of the curve can be reasonably interpreted as when a cumulative moving average is within 10% for three or more consecutive readings. More restrictive interpretations (e.g. ± 5%) can be used if greater precision is desired. Figures 3a and 3b show leveling out of curve examples for cumulative relative cover data. Like accumulation curves for species richness, there are practical considerations related to performance standards. Additional samples may not be needed even if a performance curve fails to level out based on the number of samples plotted, but all samples are consistently well above the performance standard.

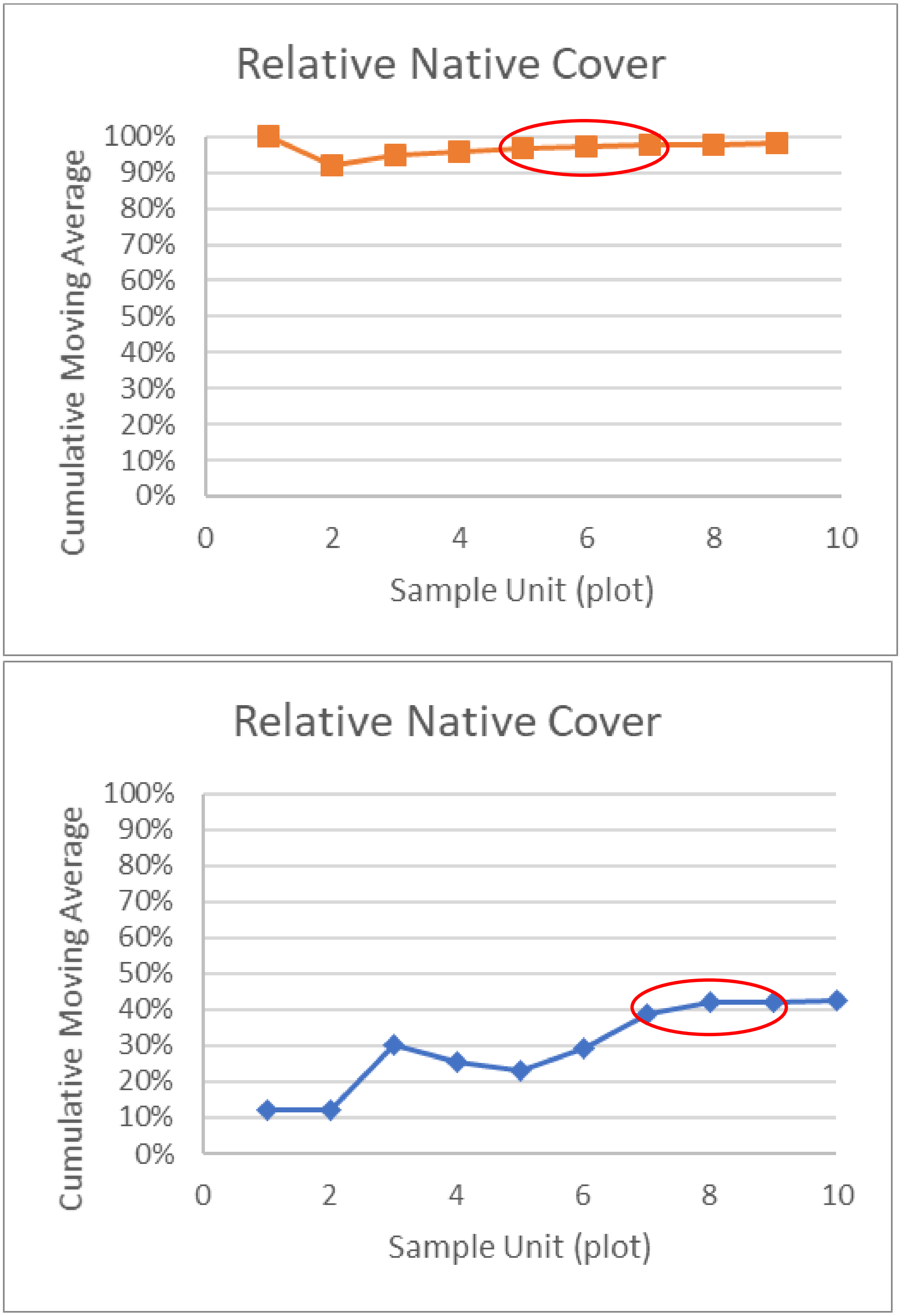


Figure 3. Examples of performance curves of cumulative moving averages.

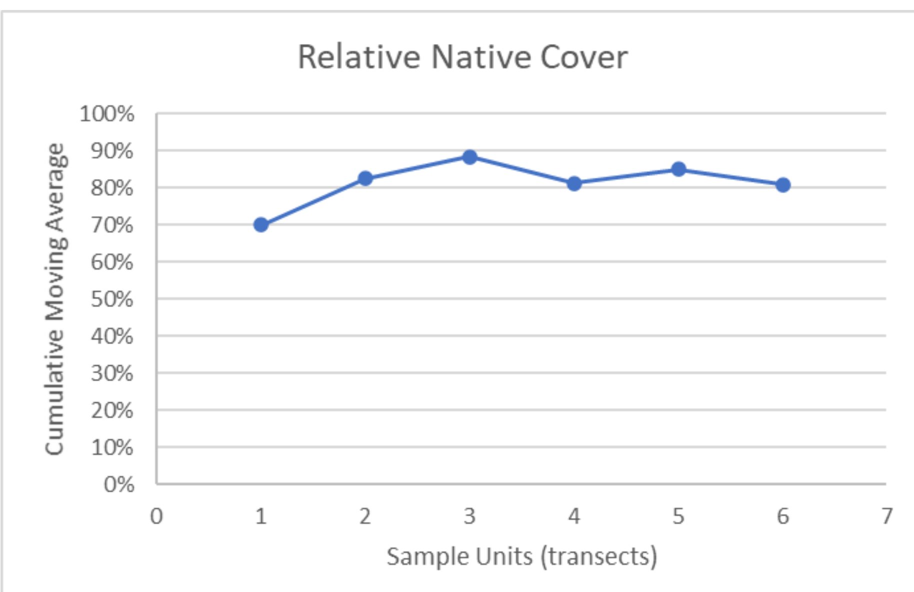
How to create a performance curve of cumulative moving averages:

1. Create a table with columns in the following order: sample units (effort), cumulative moving average, and metric of interest (percent native cover in this example). List the sample units in the order the sampling occurred (i.e. not in order of smallest to largest). Calculate the cumulative moving average for each plot by averaging the native cover for all sample units before that sample and including that sample. In the example below, cell B5 is the average of native cover observed for samples 1-4, or C2:C5 in the formula.

B5 | =AVERAGE(C2:C5)

	A	B	C	D	E
1	**Sample Unit (transect)**	**Cumulative Moving Average**	**Percent Native Cover**		
2	1	70%	70%		
3	2	83%	95%		
4	3	88%	100%		
5	4	81%	60%		
6	5	85%	100%		
7	6	81%	60%		
8					

2. Select cells from columns A and B (A1:B7) to create a scatterplot (with lines) from the table.



3. Interpret results: For this site a performance standard is ≥80% native cover. The last 3 plotted points flatten out between 80-85%. This plot demonstrates that 6 transects is sufficient (assuming the locations are representative) to confidently state that the performance standard is met.

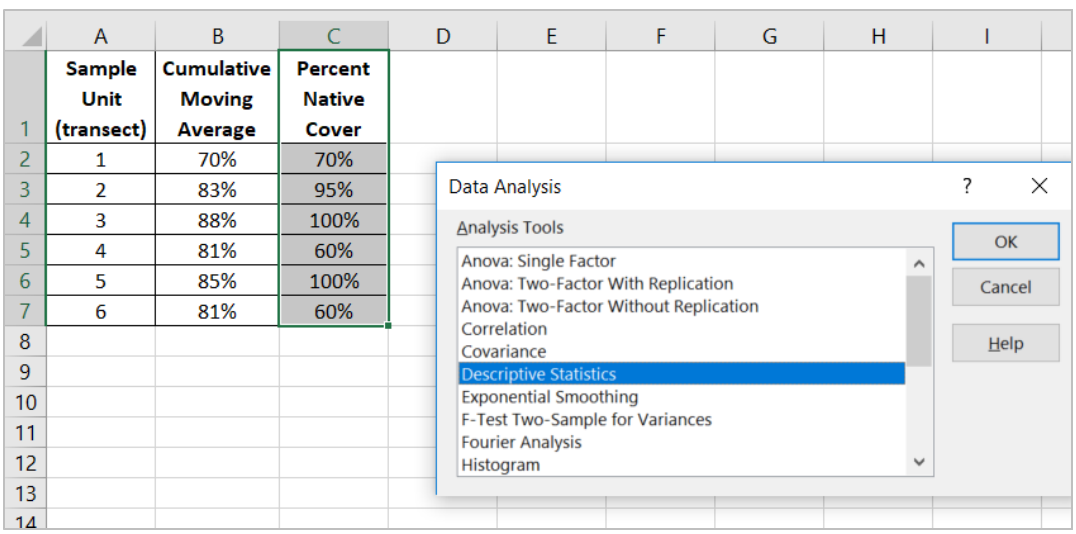
Standard Error of the Mean

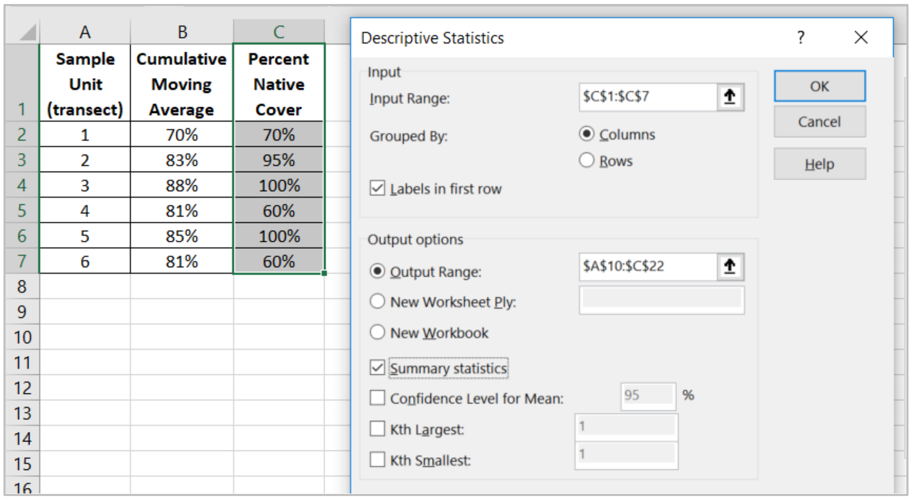
Calculating the standard error of a data set collected from different sampling locations can be useful in assessing sample adequacy. Standard error is a statistical way of describing how precise the mean (average) of multiple samples is to the true mean. As sample size increases, the standard error decreases indicating a more precise estimate of the true mean. Standard error is calculated by dividing the standard deviation of samples by the square root of the number of samples. This statistic is easily calculated by most spreadsheet software products. McCune and Grace (2002) suggest if the standard error is ≤ 0.2 of the mean (20% if expressed as a percentage), one can be reasonably confident sampling is adequate or representative of the reported mean (or average).

How to calculate standard error:

1. Create a table with these two columns: sample units and metric of interest (such as percent native cover). List the sample units in the order the sampling occurred (i.e. not in order of smallest to largest). In the example below, the same data for plotting moving averages was used.

2. When the data analysis toolpak is loaded in excel, descriptive statistics can be selected from the tool to show summary statistics for a selected set of data. Those statistics include the mean and standard error and can be compared against a calculated value (such as 20% of the mean).





3. Calculate the threshold that must be met for the standard error, such as 20% of the mean.

9					
10	*Percent Native Cover*				
11					
12	Mean	0.80833333		20% of the mean =	0.161667
13	Standard Error	0.08001736			
14	Median	0.825			

4. Interpret results: For this site a performance standard is ≥80% native cover. In this example, the standard error of the mean is 0.08, which is less than the calculated threshold (0.16). This measure of variability (standard error) is below the acceptable limit. These calculations demonstrate that 6 transects are sufficient (assuming the locations are representative) to confidently state that the performance standard is met.

Minimum Percent of Area Sampled Criterion

Some vegetation sampling methodologies require a minimum amount of area sampled per monitoring unit. For example, a vegetation sampling protocol may require that at least 2% of the monitoring unit be sampled. This can be determined by summing the total area of plots and dividing it by the total area of the monitoring unit. However, DeBerry (2020) shows that this amount can be more than needed for herbaceous sampling but may be more applicable for sampling woody vegetation. While a percentage value can be readily determined for a site, it should not be used to assess adequacy unless there are published methods and studies that support a certain percentage in a similar context.