Minnesota Ecological Monitoring Network (EMN)

Background and Standard Operating Procedures

DEPARTMENT OF NATURAL RESOURCES

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Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative- Citizen Commission on Minnesota Resources (LCCMR). The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources.

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Background and Objectives

Background and History

Our state is facing many new challenges, including climate change, the introduction and spread of invasive species, and increasing fragmentation and pressure on land and water use. Addressing these challenges requires an understanding of the overall health of Minnesota's natural resources and the major issues that are impacting them. Additionally, land managers are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of our natural resources as a basis for making decisions and working with other agencies and the public for the long-term protection of Minnesota's ecosystems.

Up to this point, there has not been a comprehensive statewide monitoring network that consistently measures and evaluates changes in vegetation that spans native grasslands, wetlands, and forests. Without such information, it will be increasingly difficult to detect which factors are driving environmental changes. Knowing the status and trends in plant communities of any terrestrial ecosystem is critical to understanding the health of most other biotic components of an ecosystem, because vegetation is sensitive to many stressors. A well-planned monitoring program will ideally provide an early warning of undesirable change to managers, conservation planners, etc.

The Environment and Natural Resources Trust Fund provided initial funding to develop and test such a monitoring program to track long-term trends in vegetation, which began in July 2016. The monitoring project is being led by the DNR's Minnesota Biological Survey, a program in the Ecological and Water Resources Division. It also includes active participation by other DNR divisions and a wide range of partners from a variety of agencies and organizations.

The statewide monitoring network will fill data gaps and add to data collected by existing regional or habitat-specific monitoring and biological inventory efforts (e.g., Sustaining Lakes in a Changing Environment, Wetland Status and Trend Monitoring, Minnesota Wetland Condition Assessment, State Wildlife Action Plan Prairie Monitoring, U.S. Forest Service Forest Inventory and Analysis, DNR Cooperative Stand Assessment). Bridging these efforts with systematic statewide information will place existing habitat monitoring and research into statewide context, provide fundamental baseline data, and improve and prioritize data collection. This will increase the value of all monitoring and research and expand the scope of information for natural resource planning and management.

Measurable Objectives

Plant community composition and structure monitoring comprises the core of this vegetation monitoring effort. This document details our plans to track change and detect trends in the number, identity, and relative abundance of plant species, as well as their horizontal cover and vertical structure across the forests, wetlands and grasslands in Minnesota. The broad, scientifically based information obtained through this monitoring program will have multiple applications for management decision-making, research, education, and promoting public understanding of resources. Furthermore, to be relevant to current management issues and anticipate future issues, monitoring programs must be scientifically credible and produce quality data that is readily accessible and explicitly linked to management decision-making processes.

To meet these criteria, our monitoring objectives are driven by a primary question: How are vegetation composition, structure, and plant demography changing over time in relation to weather, climate, landscape dynamics, invasive species, deer browse, and natural processes such as succession? The means objectives listed below were established to meet this overarching question and hopefully designed to help us meet our fundamental objective: *To conserve healthy native grasslands, wetlands, and forest.*

Means Objectives

Vegetation

- What is the rate and direction of change in our native plant communities? We will measure species richness and diversity and test for change in these variables as well as shifts in the relative abundance and dominance of species groups (native vs. non-native species, forb to graminoid to woody species ratio). Tracking shifts in overall community composition will also help us understand whether sites are converging in native understory composition between sample periods, which may reflect biotic homogenization. This is a phenomenon now broadly recognized as the process by which ecosystems begin to lose their biological uniqueness, where richness and/or diversity decreases and species similarity increases over space and time (Olden and Rooney 2006).
- What is the rate and direction of change of key native and non-native species? We will measure species abundance (frequency) and test for change between and among sample periods. This will allow us to determine whether individual species are increasing, in decline, or remaining constant.
- Document the status and trends in the proportion of monitoring plots that have non-native invasive plant species and track shifts in non-native species presence and abundance.
- Determine the rate and direction of change of plant community structure. We will examine the size distributions (basal area) of trees and the status of regeneration of individual species, as well as for all trees, 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.
- Track growth and mortality rates of key tree species and document the relative density of certain species known to be either increasing or decreasing across the state (e.g., red maple appears to be increasing and conversely oak species are in decline).
- Document status and trends in the volume of coarse woody debris.

Landscape Context and Ecological Integrity Assessment

- Determine relationships between landscape context (e.g., size of area surrounding plot and proximity of anthropogenic land use to natural area) and changes in native grassland, wetland, and forest vegetation. This is currently a work in progress and we will work to develop an Ecological Integrity Assessment score based on landscape and plot level vegetation. See Faber-Langendoen et al. 2016; Rocchio and Crawford 2016.

Landform and Substrate

- Qualitatively assess topographic position and aspect at the onset of monitoring.
- In upland forests, assess forest floor condition by documenting litter type and depth and visually inspecting for compaction and exposed bare soil and earthworm activity.

Water Chemistry and Hydrology

- Assess hydrology and its relationships to trends in wetland vegetation.
- Assess trends in surface water pH, specific conductivity and temperature in wetlands as a possible means to explain changes in vegetation.

Pollinators and Other Wildlife

- Collect baseline surveys of select groups of pollinating insect species occurring in targeted vegetation types, such as Hymenoptera and Lepidoptera.
- Document status and trends in high priority vegetation characteristics related to wildlife habitat such as the density of tree snags and presence of leaf litter.
- Determine long-term changes in magnitude and extent of browse on vegetation.
- To what degree are ungulates browsing woody vegetation and which species are more impacted? We will assess the frequency at which woody species are browsed and relate this to changes in plant species, communities, and community structure.

Terrestrial Pests and Pathogens

- Which pests and pathogens are present and on which tree species in forested monitoring plots? We will look for signs and symptoms of major causal agents of tree damage.
- What is the extent of pest and pathogen damage on trees? We will calculate the percentage of trees that are impacted, and note the severity of these impact(s).
- How are earthworms impacting soils and plant communities in forested areas? We will look for evidence of the presence of earthworms and relate this, when possible, to frequencies of understory herbs and of seedlings.

Lichens and Bryophytes

- Collect baseline surveys in select plots to document dominant bryophytes and lichens to determine the rate and direction of change of these two groups. However, due to limited time, expertise, and funding, we have not been able to develop specific protocols for this objective. It is something we hope to advance further in the coming years.

Sampling Design

Sampling Design Rationale

The EMN Vegetation Monitoring Network is designed to monitor vegetation in a standardized and cost-efficient manner and to provide statistical inferences of status and trends within and across the state with sufficient power to detect change. Sampling will occur at randomly selected, permanent plot locations, which will also help to increase power to detect trends over time.

We initially sought a design that would be a flexible method for recording vegetation composition and structure, but which could be modified depending on the habitat. However, due to the successional nature of plant communities, it was decided that the response design should not be significantly different as it may necessitate having to change the response design over time to accommodate this change. Furthermore, if the protocol is kept sufficiently general, data collected from divergent community types such as forests and grasslands will be directly comparable (Peet et al. 1998).

The protocol has been specifically designed to facilitate comparison of EMN data with other agencies within the state such as that from the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) Program and the National Park Service (NPS) Great Lakes Region.

Several existing sampling methods were considered for the design of EMN's protocols to help facilitate this comparison of data. However, most of the current sampling designs focus on monitoring specific vegetation types such as only forests or prairies. While the base framework that was developed for the National Park Service Great Lakes Inventory and Monitoring Network (NPS GLKN) also focuses solely on forested sites, we have adopted many of its core methods as the final EMN sampling design, with some modifications. In this way, direct comparisons can be made to areas such as Voyageurs National Park and St. Croix National Scenic Riverway, where the NPS has been collecting data since 2007.

We will use this same design for all plant communities being monitored in Minnesota, as it is sufficiently flexible to modify to other habitats such as prairies, as it is similar to other well-known, existing grassland designs, such as the Konza Prairie long-term ecological monitoring protocols. Other designs or existing project have also been considered and in some cases incorporated to a lesser degree into our core methods. These include: U.S. Forest Service Forest Inventory and Assessment (FIA) program (USDA 2018); Don Waller and the Plant Ecology Laboratory at the University of Wisconsin who are measuring the nature and extent of long-term ecological change in Wisconsin by resurveying J.T. Curtis' plots from the 1950s (Curtis 1959); North Carolina Vegetation Survey's nested, multiscale plot module design (Peet et al. 1998), the modified Whitaker plot (Stohlgren et al. 1995), Illinois' Critical Trends Assessment Program (CTAP; Molano-Flores 2002), MN Pollution Control (MN PCA) Wetland Status and Trends (Bourdaghs 2015), EPA's National Wetland Condition Assessment (U.S. Environmental Protection Agency 2011), and several other regional National Park Service Inventory and Monitoring protocols, most notably: Northern Great Plains (Gitzen et al. 2010; Symstad et al. 2012), Heartland Network (James et al. 2009); Northeast Temperate Network (Tierney et al. 2009), and the Eastern Rivers and Mountains (Perles et al. 2014) Network. All of these existing protocols have complementary objectives to our own, have had several years of extensive field testing and have conducted preliminary analyses to determine their designs have sufficient power to detect change.

Site selection and sampling frame

The sampling frame for this project is the state of Minnesota, the boundaries of which demarcate our sample set of potential plot locations using a generalized random-tessellation stratified

(GRTS) design (Stevens and Olsen 2004). By using the GRTS design the resulting sample points are spatially balanced, where there is generally an even dispersion of sampling sites throughout the area of interest (the state of Minnesota). This eliminates potential autocorrelation problems that can arise when two or more sampling points are in close proximity (Stevens and Olsen 2004). It also ensures 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 or how many plots the project will ultimately require to detect trends statewide. Therefore this will allow us to continually add new plots in the future while maintaining spatial balance. 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 2004). Unfortunately, one drawback with any random design is that it does not guarantee that plots will be located in areas of key management significance or rare native plant communities.

Using the state of Minnesota, a large draw of 20,000 GRTS points was necessary to ensure that adequate numbers of prairie, a native plant community that is increasingly rare in Minnesota; there is currently less than 2% of this community remaining in the state. The Cropland Data Layer (USDA), a 30m pixel GIS raster layer, was then used to filter out the high numbers of points that invariably intersect with cultivated, impervious surface, or mining operations detected in this remotely sensed data layer.

Sample sites selected using the GRTS method described above uses spatial stratification to ensure that sample sites are equally distributed within the sampling frame as opposed to stratifying on any predefined landscape characteristic or qualifiable metric, such as native plant communities. The successional nature of vegetation, coupled with the fact that many areas in the state are recovering from some kind of disturbance such as logging activity, or some other type of historical disturbance preclude the use of a stratified-random sampling design. Stratifying on a dynamic variable, such as vegetation, for long-term monitoring goals will ultimately result in misclassification of sites and consequent analytical error. Further, a stratified sampling design will prevent inferences about native plant communities not sampled. For these reasons, a stratified-random approach will not be used.

The target population within our sample frame is any native vegetation that can be defined as a native plant community or dominated by native vegetation, which has not been severely altered from this state in recent years. These areas must also then meet the criteria outlined below for selecting sample sites (see *General Criteria for establishing sampling sites in the field*). Areas that meet the criteria occur across all land ownerships −public and private− within the state. Private lands were included in order to truly infer status and trends of plant communities and native vegetation statewide, regardless of ownership. Monitoring will not be conducted at a site without the landowner’s permission.

Sampling Frequency and Replication

A simple panel design is currently in development. The plot resample schedule will ultimately be determined by how many total plots are established and how many we can consistently resample in one field season. It is suspected, however, that plots will be visited on a 7-8 year rotation based on the fact that we have estimated a minimum of 600 plots statewide will be necessary to detect status and trends across several community types. This sample size is based largely on budgetary and logistical constraints, but also estimated according to other programs or state's experiences doing similar monitoring. Additionally, we feel that a 7-8 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. This sampling interval will allow time for some change to occur, yet provide relatively frequent feedback about long-term directional change.

Detectable Levels of change

The primary driver of sample size should be the power to detect change over time in the key parameters that provide information towards a program's objective and we estimate we will need at least 600 plots statewide. However, other important factors affecting sample size are budgetary and logistical constraints such as length of growing season and availability of qualified crew members. While we hope that this monitoring program will ideally be able to detect a 20 percent change in key parameters over ten plus years (i.e., two or three plot revisits), with a power of 0.80 and an alpha of 0.1, realistic and appropriate values for alpha and beta will be determined as more data is collected. A power analysis can be used to determine the sample size needed to detect a set level of change in a parameter at a particular power and alpha level. However, the vegetation monitoring program collects numerous measurements. The sampling design may provide an adequate sample size for some measurements, but may not be adequate for others. Additionally, as the monitoring is expected to continue indefinitely, more data will be added and the power to detect change will increase.

Field Methods

Sampling Design

Initial sampling will need to be robust to varying levels of spatial autocorrelation as expressed by varying degrees of patchiness in underlying species distributions due to the fact that not all communities are spatially structured in similar ways (Goslee 2006). Therefore, we have adopted a multi-scale, nested design approach to capture plant composition, density, and diversity using subplots of different sizes. This is necessary because different communities have different spatial patterns and species frequency. Using a single plot size, while an arbitrary sample of species diversity, does not provide adequate information on species that are found to be extremely abundant or communities that have multiple strata. Sampling at two or more scales provides information about the structure of a plant community and distribution of individual species, allowing for better comparison among communities and an estimate of how many additional species might occur beyond our largest plot size (i.e., were “missed”; Stohlgren et al. 1995). The basic concept of nested plots are the same in terms of sampling efficiency despite different sizes, but smaller areas are devoted to plants with smaller stature or high frequency and larger units for species such as canopy trees.

As mentioned previously, we have adopted a response design similar to that of NPS GLKN (Sanders et al. 2014). Their design combines features from two established plot types: the FIA methodology (for details on the metrics collected see USDA, Forest Service 2018), currently used throughout the country by the U.S. Forest Service, and the methods used extensively throughout the Midwest by the Plant Ecology Lab (PEL) at the University of Wisconsin to resample John Curtis’ 1950s plots (Bushman, 2006; Rogers 2006). Consequently, the Great Lakes Network’s design has been called the “Hybrid plot” (Johnson et al. 2006; Sanders et al. 2014), which consists of three 50 m parallel transects, spaced 50 meters apart. However, for this project, transects will be spaced 20m apart in forests and 10m apart in open wetland and prairie systems in order to better accommodate a variety of landscapes and communities statewide (Figure 1). The Great Lakes Network is primarily focused on larger blocks of contiguous, forested plant communities, whereas EMN has the added challenge of fitting plots within small prairie remnants or small fragmented forests in the southern part of the state. Beginning in 2018, we have also shortened the transects to 45 meters. During our first field season in 2017, a significant amount of time was spent collecting ground layer data from 30 quadrats. After examining species area curves and other information, it was decided that 24 would be sufficient to capture a similar amount of information while spending less time at the plot.

Within each plot, basic information describing the site (e.g., slope, aspect, and terrain position) is collected to allow proper interpretation of other data collected. Photographs are taken of the plot and understory to document change in appearance over time. The bulk of the data will then be recorded on the ground layer vegetation, where a series of nested quadrats ($0.1m^2$ within a 1 m^2 quadrat) spaced every 5 meters along each of the three transects for each plot will be assessed (Figure 1). We will record all species present in each quadrat provided its cover can be assessed below 2 m. These data will be examined for correlation between the frequency of specific indicator species and key stressors such as deer browsing. In addition to simple measures of frequency through presence/absence, the abundance of vegetation within $1m^2$ quadrats will be recorded by means of its respective amount of cover to yield information describing species composition and important non-native invasive species changes. Cover will only be assessed within the $1m^2$ plot.

Despite the drawbacks of assessing cover (e.g., it can be highly subjective and yield a great deal of observer bias, it can vary significantly throughout the growing season due to seasonality and/or other environmental variables such as insect damage), it is the most common measure of plant abundance. If trained surveyors are well calibrated, it can be measured relatively quickly, particularly if using cover classes. It is best practice to continue to calibrate throughout the field season among team members and ideally once arriving at the plot to ensure everyone is considering that day’s vegetation similarly. Team members should come up with their estimates privately, so their measurements are independent. If the separate estimates are close, you can feel confident that a consensus value will be close to the true cover. If the estimates are far apart, the team needs to reexamine the plot to see where the problem arose. While working individually can be faster, working as a team of two on each transect will likely yield higher quality data.

If trees and shrubs are present, all woody species ≥2.5 cm diameter-at-breast-height (DBH) will be measured for status (live/dead), size (DBH) and condition within a belt transect that centers around each transect. These data will yield information on tree growth, mortality, and stand structure and composition. Tree seedlings will be tallied by species within quadrats in order to assess advance regeneration and the effects of deer browsing.

Coarse woody materials will be assessed along each of these three transects, if present, whereby data are collected on all downed wood which intersects the transect plane with a diameter ≥ 7.5 cm (3 in) at the point of intersection.

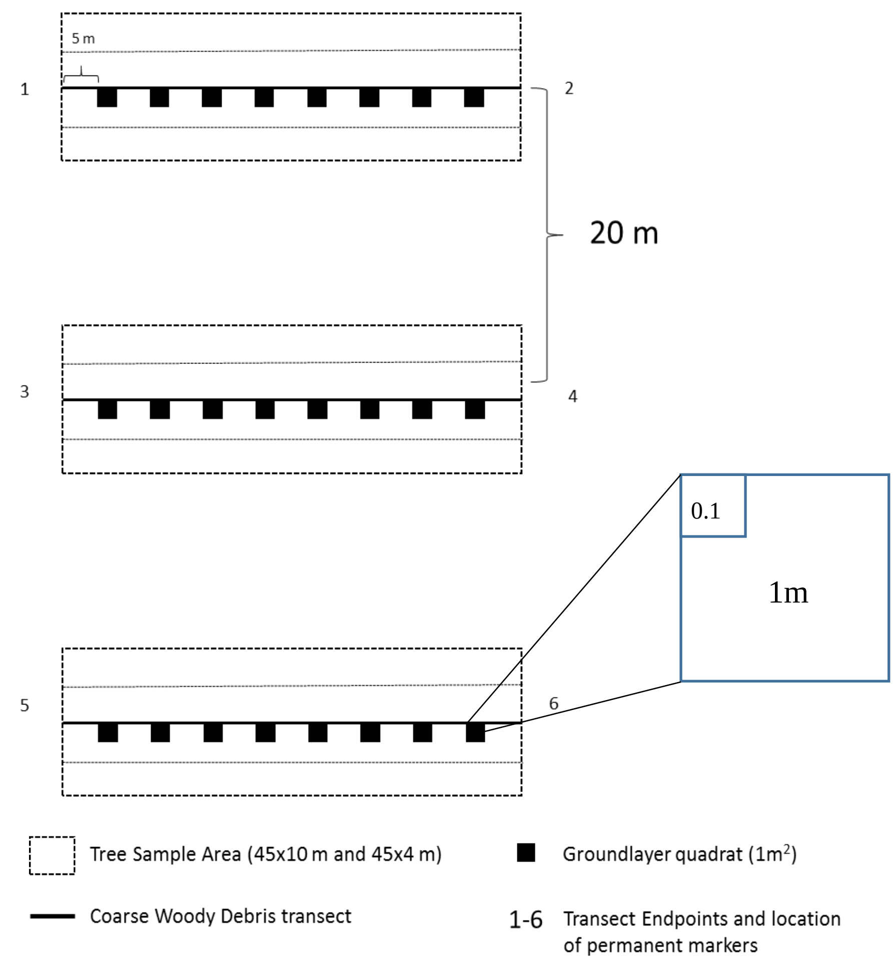


Figure 1. Modified Great Lakes Network (Sanders et al. 2104) plot configuration with the addition of the EMN nested quadrat and nested tree belt transect.

General Criteria for establishing sampling sites in the field

The following *general* guidelines describe criteria regarding whether sites shall be included within the larger network of sites to be monitored. More specific criteria related to either forests, grasslands or wetlands are outlined in their respective sections.

1. Areas with little or no potential for terrestrial vegetation (e.g., large areas of bare rock) are excluded. Within each plot, the ground must be at least 70% vegetated or potentially vegetated. For example, in many northeast areas of the state, there are large expanses of exposed bedrock. If any single transect is covered by >30% bedrock, the site must either be moved (see below) or abandoned, as this cover type will never be vegetated. In contrast, areas that have recently been burned, harvested (but not disked, trenched and converted to plantation), or experienced a blowdown will become vegetated over time. These areas will be included in monitoring provided they have not been recently harvested in the last 5-10 years. At time zero (i.e., the establishment of the plot), baseline data should reflect the community prior to any disturbance from harvest.
2. The plot must not have an obstacle (e.g., stream, trail) that runs the length of a transect. However, a transect is allowed to cross one of these obstacles (see below for more details).
3. The plot needs to be placed ≥ 100 m from edge of disturbance (not native vegetation such as a major road, cultivated areas, homestead, or mowed area).
4. Plot should avoid areas on >30° slopes, or use best judgement about whether the slope is safe for sampling while at the same time not creating a potential for erosion as a result of sampling.
5. All transects should be established within fairly homogenous vegetation or native plant community type. Transects should avoid crossing from wetland to upland or any other significant changes in community. Document any subtle changes in native plant community (see NPC classification guide) if there are differences between each transect that are unavoidable or if there are small inclusions of another community type that are typical of the larger community (e.g., small wetland swales or low pockets).
6. There must not be any obstacles that present a safety hazard to the crew. This includes, but is not limited to, steep cliffs near the transects or hornet/wasp nests directly where plot marking will be placed.
7. Small, isolated habitat (≤15 acres) that is surrounded by agriculture or other anthropogenic disturbance on all sides.
8. Extreme anthropogenic degradation should be avoided, where significant alteration of the community has resulted in <30% native flora. Examples of areas to avoid: large openings with food plots for hunting purposes have been created within a forest; junk (e.g., old cars or machinery) or garbage piles are present within the plot; frequent mowing that is maintaining non-native grass cover; substantial areas of plantings such as a pine plantation or non-native plantings in the understory/groundlayer such as daylilies or hostas; several hiking or skiing trails throughout where their impact is unavoidable, etc.

Moving plots in the field

If the field crew cannot establish the plot because there are unavoidable obstacles or safety hazards that were not detected on aerial photography prior to arrival, or any of the situations listed above are present, the plot may be moved if it appears there is enough suitable habitat nearby. Movement of a plot must only be to the closest location meeting the criteria outlined above (while maintaining 20 m distance between transects). In rare circumstances, transects can be modified to fit a narrow stretch of habitat, such that there would only be two transects that are 65m in length and have 12 quadrats each.

Additional examples which may necessitate moving a plot include: 1) areas where multiple native plant communities are present; for example, distinctly different conditions or inclusions are present such as large open pools or ephemeral ponds with standing water within a hardwood forest; 2) significant topography is present and the plot needs to rotate to fit on one aspect so that transects are parallel with existing contours; 3) significant non-native vegetation dominates such that native flora is less than approximately 30%; 4) excavations, disked soil, or recently harvested (within the last 5 years), etc. Treefall gaps do not constitute uncharacteristic habitat or vegetation and should be included in the monitored transects if present. If the transect crosses an interruption in vegetation, such as a stream or path etc., where more than one quadrat falls within the interruption, then the transect is terminated on the closest edge of the interruption and resumed, at the same point along the transect, on the distal side of the path and it is noted as “not sampled” on the data sheet.

An effort should be made to not move the plot more than approximately 200 meters from the original location of the GRTS point. However, exceptions to this will invariably arise and the field crew will need to use their best judgment in deciding where to move the plot while using as little human bias as possible. Therefore, if there is suitable habitat within the same community type nearby, but only beyond these distance parameters (i.e., 200 m), then perhaps it’s best to move the plot regardless of the distance before abandoning the GRTS point altogether. For the sake of efficiency, it is sometimes best to allow for some leniency of plot placement rules, as long as it’s within a reasonable distance. One needs to consider the time it took to access the site, how long it will take to access the next nearest site, etc., before deciding to abandon the plot.

If there is suitable habitat in more than one direction from the original predetermined monitoring location, the plot location is moved into the closest suitable habitat. If suitable habitat occurs the same distance away from the location, in more than one direction, then the location is moved to the suitable habitat with the lowest compass bearing (e.g., if there is suitable habitat to the east [90°] and south [180°], the center point is moved to the east).

Additionally, while setting up the plot, if an obstacle, such as a steep cliff, a pond with water more than waist-deep, or a safety hazard such as a wasp nest is encountered, a transect can be less than 45 meters long. A short transect is acceptable only if it affects a small portion of the plot and it appears that in future years the hazard is only temporary. An alternative to plot establishment might be if the crew has transects 1 and 2 set up, and they encounter an obstacle or safety hazard while trying to establish transect 3, the most time efficient manner of completing plot set-up is to return to point endpoint 1, and establish the 3rd transect 20 meters to the north of transect 1. This new point is designated as endpoint point 1, and a new point 2 can be established 45 meters east (or whatever bearing it happens to be) of it. What were previously points 1 and 2 will become points 3 and 4, and what were previously points 3 and 4 will become points 5 and 6.

Initial Plot Establishment

The coordinates of the randomly selected GRTS point typically represent the northwest corner of the plot (i.e., endpoint 1 of transect 1). Plots will normally be established along an east-west direction to remove bias. However, allowances will be made to modify or move the randomly selected point so that the plot can be fit within an irregularly shaped area or to accommodate a steep slope, such as in southeast Minnesota where slope and aspect are unavoidable. In the latter example, the plot should only be established such that it aligns with the prevailing aspect (parallel with topographic contours) if it is clear that the plant community changes on the adjacent aspects, as well as the upper and lower slopes. In situations where there is rolling terrain where there isn't one prevailing slope or aspect, keeping the plot within one plant community with similar soils and environmental conditions with relatively homogenous vegetation should be the primary goal. If any atypical conditions apply and the plot is moved significantly from the random point location, it should be detailed on the main data sheet and noted how the plot was moved and why, along with a detailed diagram of the plot layout.

If the plot is rotated or shifted from the normal east-west direction, endpoint 1 should always remain in the upper-left position regardless of the rotation of the transects and irrespective of true north. For example, a plot rotated 90° from normal, with transects oriented in a north-south direction, will have endpoint 1 at the northeast corner.

Once it is decided where the plot will be established, begin by laying out all transects before sampling begins. It is most efficient to start by having a pair of crew members lay out the perpendicular side of the plot with a 50 m tape, beginning at endpoint 1 and ending at endpoint 5 using the details described in the next paragraph (Figure 1). Transect 1 is then initiated by another pair of crew members using a 50 m tape, once it is clear that endpoint 1 will not be changed. Crew members who established the first perpendicular side are then responsible for continuing with laying out Transect 3 (between endpoint 5 and 6). Meanwhile, staff laying out Transect 1 will establish the second perpendicular line between endpoint 2 and 6. Transect 2 will be completed by whomever is available to finish this last transect, as it will be much easier now that a box has been delineated by meter tapes and there is another perpendicular side to aim for.

Transects will be established using a sighting compass, which increases accuracy across all three transects and for future resampling efforts. The mirror enables the user to simultaneously sight the bearing while checking that the compass needle is aligned with the north arrow in the compass housing. When using a sighting compass with a mirror, hold the compass at eye level with the mirror tilted to a 45° angle (the horizontal part of the sighting cross shall align with the center of the compass housing). The direction can now be verified with the compass bearing by aligning the notch at the top of the mirror, the sighting cross, and the opening in the mirror with the transect tape visible on the ground. This will no doubt take some practice in the field. No declinations will be set on any compass used for the project, due to the fact we are working statewide and declinations vary around the state. Frequent calibrations should be carried out amongst crew members to ensure that everyone's compass is within 1-2 degrees of one another. We will use true north as the reference from which all bearings are taken, with compass declination set to zero. Given that monitoring plots are being established statewide, it is not practical to change declination frequently throughout the summer depending on the work location.

Specific instructions for laying out a transect are as follows: the compass sighter locks in the specific azimuth for the transect being established and directs the runner to walk in the direction of the desired azimuth, with or without tape in hand. If meter tape is in hand, it needs to remain in the runner's right hand so as to not trample vegetation where the quadrats will eventually be placed. The runner will repeatedly stop when the sighter cannot easily see the runner. When this happens, the runner turns and faces the sighter, holding a pink flag vertically in front of them so the sighter can easily see the flagging and verify that the runner is still on the correct path. The sighter will direct the runner to move the pink flag in the appropriate direction to line up with the desired azimuth and the runner will adjust their position accordingly. This flag will then be hung on the nearest piece of stable vegetation (if present) at eye level or higher so that adjustments are easily corrected and a straight path is eventually established. Using pink flagging is helpful especially in forested or shrubby conditions. Use of this method is typically not needed in open conditions such as prairies or open wetlands. Continue until the entire length of the transect is complete. Field conditions may require adaptions to these instructions and should be considered general guidelines.

Meter tapes that demarcate transects should follow the contour of the ground as much as possible, anchored at either end with chaining pins. This may require threading the tape under logs and other downed debris and through the middle of shrubs so that there is minimal slack or curvature in the line. Bright flagging tape should be hung in a visible location to mark each endpoint (from trees and shrubs, when present), as well as at frequent spots along each transect (particularly in forests) to facilitate sighting back along the compass bearing to verify accuracy. This is helpful when visibility is low, due to dense shrubs or other vegetation, and the opposing endpoints are no longer visible.

While laying out transect lines, it is important that the tape be kept in the <u>right</u> hand at all times, as the quadrats will be placed on the right side of the meter tape, and this will minimize trampling. To avoid trampling the vegetation in the quadrats, staff must be aware of quadrat locations and always walk on the <u>LEFT</u> side of the tape when heading away from the transect start point, and conversely walk on the right side when heading away from the endpoint of the transect.

All transects should be parallel to one another and meet the perpendicular sides at the appropriate locations (i.e., 0, 20, and 40 meters). It is important to note that all transects are based on horizontal distances so if there are significant contours throughout the plot, all three transects may not end at the perpendicular meter tape equally.

It is also important to be cognizant of the amount of traffic in order to minimize trampling throughout the interior of the plot, particularly on steep slopes, fragile organic soils, or where thick herbaceous vegetation or moss cover is present and easily compacted. Always place and unload packs outside the plot boundary, not within. Crew members should plan ahead and retrieve all gear for a particular set of measurements at one time, rather than taking extra trips across the plot. Crew members should minimize steps on the transects and extra-care should be taken to avoid trampling the quadrats and any soft, coarse woody debris on or near a transect.

At the completion of sampling, all chaining pins, meter tapes, flagging tape, and other sampling gear are pulled up.

Limiting transport of non-native species or other material

Crew members should be responsible for taking reasonable actions to limit the spread of nonnative invasive species between plots. Before leaving a site, or at the end of the day, and especially before going to the next plot, crews should visually inspect gear, clothing and boot treads, removing any obvious attached seeds, plant fragments, or excess soil.

When the crew returns to the vehicle, a more thorough investigation of clothing, backpacks, and footwear should be done. Use the coarse fibered brush to remove any material that is stuck in treads of boots. It may be necessary to unlace and clean out seeds that are trapped under boot laces. If necessary, use water to clean off mud that may contain seeds or earthworm castings once you have returned at the end of the day.

Permanently marking plots

Each of the six transect endpoints are permanently marked. The degree of permanent marking varies by habitat and ownership. For example, a private landowner, designated wilderness areas (e.g., BWCAW), or a State Park may request that permanent marking be done at a minimum. No plots are marked in such a manner as to be evident from roads, trails, or other heavily used public use areas.

If no plot marking modifications are requested by the landowner, then all transect endpoints are marked with a 1 ft piece of rebar (3/8 inch diameter) capped with a plastic cap stamped with “DNR STUDY.” This is sunk flush with the ground. Where there is bedrock or some other obstruction preventing the rebar from being placed adequately into the ground, first attempt to hammer the rebar in at an angle so that the top of the piece is in the correct place representing that transect endpoint. If that is not possible, the rebar is placed a short distance away from the actual transect endpoint, and the distance and bearing from the rebar to the transect endpoint are recorded on the datasheet.

If the plot is not suitable for rebar placement or the land owner has requested that no rebar be used, then the first choice shall be to use an Underground Magnetic Utility Marker (DEEP1) in place of rebar. Optional alternatives to rebar include: a) Burying a DEEP1 utility magnet by digging a shallow hole approximately 4 inches below the soil surface, or deep enough so that it will not easily be dug up or washed away but still detected by a metal detector in the future. b) Create a rock pile over a DEEP1 magnet in such a way that the magnet will not easily be uncovered. This would be necessary for places where a hole cannot be dug such as on bedrock. c) Use a large magnetized "magnail" with flagging tied around it such that the flagging sticks out above the soil, or with a whisker marker attached at the end. Magnails are sometimes easier to insert into rocky soils.

The GPS locations of all transect endpoints, as well as any offset rebar, are recorded with the Trimble R2 GPS Receiver paired to work with ArcCollector on an iPad. In the case where rebar is offset, two waypoints are recorded for a single endpoint (the endpoint and the offset locations). For each point, attributes that are recorded in the iPad for each endpoint are SiteID (the GRTS site number, e.g., 00504), Endpoint ID (1-6), Date of sampling, Person Recording (initials of crew member), and a check box for whether an endpoint is offset. For endpoints where there is an offset point, both points are given the same Site ID and Endpoint ID attributes, but changing the Offset field to 'Yes' for the rebar, and leaving it as 'No' for the waypoint of the actual endpoint.

Three reference trees (where applicable) will also be tagged with a numbered aluminum tree tag affixed to the tree with a 2 inch aluminum nail (aluminum nails are not as damaging to milling equipment in the event the trees are cut down). The distances and azimuths from the rebar endpoints to the trees are then recorded. In the event of an offset rebar, distances and azimuths are taken from the rebar and not the actual transect endpoint (make note of this in the Witness Tree form). Additionally, at each 10m mark (10, 20, 30, 40m) along each transect, a magnetized 6 inch stake nail ("magnail") paired with a whisker flag will be placed in the ground to aid in future quadrat re-establishment and transect realignment. However, no whisker flags shall be used with nails where grazing occurs. Whiskers can cause a choking hazard for cows as they like to pull out the whiskers while grazing.

In wetlands, magnetized plastic EcoStakes will be substituted for rebar. The EcoStake is pushed into the peat while allowing the brightly-colored magnetized head to remain above the peat surface. Additionally, magnails will not be used in wetlands, given that they will rust, sink into the water, or will quickly be overgrown by fast-growing peat. Instead, a plastic pink survey stake (1 foot in length) that has colored flagging tied to the top will be used to mark every 10 meters. If any trees are present in the wetland near endpoints that can be used as witness trees, place a tree tag similar to forested methods and describe the azimuth(s) and distance from the plot endpoints.

Document any and all equipment used for any permanent marking on the cover sheet so that in future years, crews will know what to look for. For example, noting that either rebar, magnails, or magnets marked the endpoints and that magnails or other equipment marked the 10 meter transect locations.

Forest Sampling Criteria, Plot Establishment and Response Design

Forest sampling criteria includes:

- Ideally, plots should be established within an area measuring approximately 150 meters in diameter of suitable homogenous forest habitat. This area includes space to include a plot with adequate buffers on all sides of the plots; the minimum area for establishing plot is 50 m x 50 m.
- Forested communities ranging from dry upland forests, woodlands or savannahs to wet forested lowlands such as black spruce swamps and bogs or riparian forests. A forested plots is one where canopy cover is >10% cover or there is a *potential* for canopy cover. Potential canopy is defined as areas with recent blow down or other disturbance where there is limited canopy cover, but has the potential to recover to >10% cover. Transects in forested sites are established at 20m apart (compared to open sites such as prairies or sedge meadows were transects are 10m apart).
- Lightly grazed areas are acceptable.
- Sites slated for harvested, as long plot establishment (i.e., initial data collection or at time zero) can be completed before harvesting occurs. Additionally, initial sampling of a site should capture data that represents a forest that has not been harvested in the recent past (i.e., not within 20 years).

Sites shall not include:

- Areas where ground cover is replaced by plantings of pasture grass, cultivars, or manicured lawn (e.g. city parks with managed plantings, golf courses, etc.).
- Plantations where the native plant community has been converted to what is essentially a monoculture and is no longer a recognizable native plant community. For example red pine plantations where minimal ground layer vegetation exists.
- Significantly altered (disked, trenched, planted) or heavily managed areas where post-harvest treatments included prescribed plantings, herbicide or seeding, for example.

Forest Response Design

Within each plot, basic information describing the site (e.g., slope, aspect, native plant community classification, and terrain position) will be collected to allow proper interpretation of other data collected. Photographs will be taken of the plot and understory to document change in appearance over time. Stand structure and disturbance will be qualitatively assessed from visual inspection. Each tree $\geq$ 2.5 cm diameter-at-breast-height (DBH) will be measured for status (live/dead), size (DBH) and condition. These data will yield information on tree growth, mortality and condition, and stand structure and composition. Tree seedlings and saplings <2.5cm will be quantified by species within quadrats in order to assess advance regeneration and the effects of deer browsing. Understory woody and herbaceous species within $1m^2$ quadrats will be recorded to capture information on composition (including presence of non-native species), abundance, diversity and richness. These data will also be examined for correlation between the frequency of specific indicator species and key stressors such as deer browsing. Coarse woody debris will be quantified along transect lines.

Recording General Plot Characteristics (area delineated by the transects 40x45 m)

- **Plot identification:** Record the plot identifier– this is the GRTS SiteID number, along with the date. This is also recorded on each datasheet thereafter.
- **Access and Directions:** Describe directions for walking to the plot, including trails, landmarks, distances, and bearings from identifiable landmarks or reference points. Include parking recommendations where applicable. Be very specific, so that future crews can successfully follow your directions.
- **Site Ecological Description:** Record description of plant community, ecological observations, or any unusual plot features or problems encountered during plot setup, including reasons for discarding any pre-selected plot locations. Note any problems or irregularities, and make note of what types of plot markers are used and whether there were any issues, such as bedrock. Note any features which indicate plot history, including evidence of past agricultural, silvicultural (e.g., cut stumps observed), or recreational use regardless of how long ago it may have been. If transects are notably different, document this. Also describe how the plot was permanently marked and where, for example, that rebar or magnets were used to mark endpoints and that magnails were placed at 10, 20, 30, 40 meters on all transects. Indicate if any endpoint rebar was offset or any other deviation from the standard methods were used.
- **Photopoints:** A photo is taken at each of the six transect endpoints, facing directly into the plot. Beginning in 2022, photos will be taken with the iPad and associated with ArcCollector and geotagged when recording Trimble GPS endpoints. Therefore, at endpoints 1, 3, and 5, photos are taken facing the opposing endpoints 2, 4, and 6. Conversely, for endpoints 2, 4, and 6 photos will be taken facing 1, 3, and 5 endpoints. All photos are taken at a med-high resolution. Do not zoom-in on the scene, stoop down or adjust your height. Take the photo at normal height of viewer allowing for the most vegetation to be captured from the ground layer to the shrub layer and canopy. Allow the camera to automatically select the appropriate aperture for the given light conditions. Check photo quality on the screen. Take additional photographs if the quality is questionable. If lighting is questionable, take one photograph with flash and one photograph without flash. Naming convention for photos, once back at the office, will be as follows: PLOT ID#_endpoint#_camera photo#, such as, **00038_1_263.jpg.**

These are best recorded after all the quadrat data are collected and the additional species walkthrough is complete.

- **Stand structure**: For forested plots, record the basic stand structure in the plot using the following codes:
    1. **Even aged:** A succeeding stand dominated by a single cohort of closely competing trees of relatively uniform size and height with a closed tree canopy (>= 60% tree canopy cover).

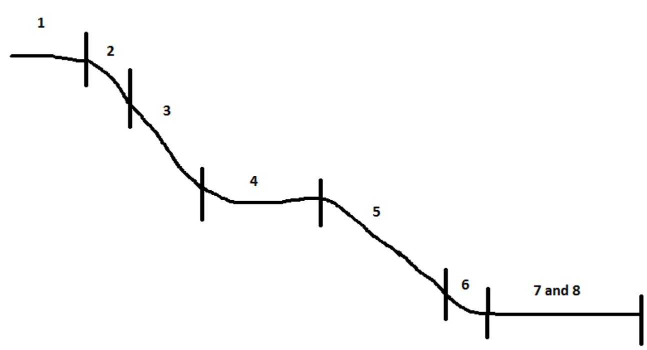
2. **Multi–aged:** later-successional or mature stand characterized by a distinct canopy with typical regeneration below including trees of may sizes and heights. Typically has a closed tree canopy (>= 60% tree canopy) but gap dynamics may be evident.
3. **Mosaic:** Plot contains at least two distinct structural classes or size classes of trees, each covering at least 25% of the stand.
4. **Early successional:** A succeeding stand without a closed tree canopy (<60% canopy cover).
5. **Woodland:** A stand with at least 25% but less than 60% canopy tree cover, giving the area an open appearance. Trees are open-grown, or growing in small groups interspersed with shrub or herbaceous cover or bare rock. Do not use this code for early-successional plots apparently succeeding to forest, or a forested plot that currently has < 60% canopy cover due to gap dynamics.
6. **Savannah:** Trees are scattered or in scattered clumps, with total cover 10-70% and typically 25-50%. Bur oak is the most common species and occasionally aspen. This differs from woodlands by having significant presence of prairie species in the understory.
7. **Stunted peatland:** Canopy is patchy to interrupted (25-75% cover) and dominated by stunted (<10m tall) black spruce or tamarack.

- **NPC class or type code:** Record the community code or name using the appropriate NPC Classification from NPC guides. This is typically done after all ground layer data are collected for the day. This will be used in post-stratification analyses.
- **% Cover by Strata for whole plot**: Estimate the total cover of plant foliage for each of the strata listed below within the plot. A rapid cover estimate is made, ignoring overlap among species. It may help to visualize cover by collapsing each layer into a 2-dimensional space, ignoring normal spaces occurring between leaves. For the canopy, estimate the percentage of plot area covered by live tree crowns directly overhead and record appropriate code. If canopy foliage is not present due to seasonal variation or temporary defoliation, visualize the amount of live crown normally present. Do not visualize foliage that formerly existed on dead branches. Use the following cover classes: <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%

1. Groundlayer and low shrub layer: <2 m above ground
2. High-understory: 2 to ~5 m above ground.
3. Subcanopy: Height defined for each plot. Must be >5 m.
4. Canopy: Height defined for each plot
5. Super Canopy: Tall overstory that is not a dominant cover (typically conifers)

- **Plot slope and aspect**: The general slope (i.e., slope recorded in degrees and measured using compass) and aspect (e.g., NW) of each plot is recorded. This is in reference to the overall general area that contains the transects and quadrats, not the slope or aspect of each transect separately. In transects with considerable micro-topography throughout their length, an estimate or average of the overall or dominating aspect and slope conditions should be recorded. Aspect is recorded as the direction that a slope faces – the slope that the plot occurs on. It can be thought of as the compass direction a hill faces (e.g., north-facing). Record the angle of slope for the whole plot to the nearest 1 degree. Use your sighting compass for this measurement by rotating the graduation ring until "W' (270°) is at the index line. Open cover completely and hold compass at eye level, on its side. The clinometer needle should move freely. Tilt the compass upward, and align the edge of the compass with the slope of terrain. Read inclination from where the inclination needle meets the declination scale.

- **Terrain Position**: circle the number that best describes the position of the plot. Refer to the topographic illustration below to determine the plot's position on the landscape, if on a slope. Use following codes:
    1. Top of slope - convex region, or flat ground on top of a plateau
    2. Upper slope - convex region near top of slope
    3. Mid-slope - uniform, fairly straight sloping region
    4. Bench - level land with slopes above and below
    5. Lower slope - concave region near bottom of slope
    6. Toe slope - the gently inclined surface at the base of a slope where it intersects with natural ground line.
    7. Bottomland - flat and low-lying; associated with drainage and flooding
    8. Flat - low elevation, but unrelated to drainage and flooding; may have minimal elevation change
    9. Various aspects (rolling)
    10. Other (describe)



Canopy Tree Measurements

Woody species in the tree canopy and subcanopy layer are sampled within two nested belt transects, centered along each transect. This is done after the quadrat sampling is completed so as to not trample the ground vegetation. A stem is counted along the edge of the plot if at least half the diameter of the stem at diameter at root color (DRC) is within the plot. If the tree has multiple stems or there are several independent trees that have grown together, but have a common base along the edge of the belt transect, treat them as separate trees. To determine which ones get measured, follow the center of each bole to the root collar. Using the criteria above, each separate bole that falls outside the belt transect is excluded.

Any transect that has no trees in the belt transect should be clearly marked as such on the datasheet, using the phrasing **sampled, no data**. If a transect is not sampled due to time constraints or safety, this is clearly marked on the datasheet using the phrasing **not sampled**. This pertains only to documentation on paper datasheets. If no trees were sampled in a transect, there is the option to note that in the electronic application.

Woody vegetation ≥ 2.5cm and < 10cm DBH: The species and diameter at breast height (DBH) of all woody plants and vines that fall within this diameter range are sampled in a 45 x 4m belt transect centered along each transect (2 m on either side; Figure 1).

Woody vegetation ≥10cm DBH: The species and DBH of all trees ≥ 10cm are recorded in a 45x10m wide belt transect centered around each transect (5 m on either side). Any evident damage from pests and pathogens or abiotic factors is noted for each tree measured (Table 1). Trees are defined as all live or 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 considered 'live' 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 live.

Dead standing trees lack any living parts (i.e., leaves, buds, cambium) at or above DBH, and lean <45 degrees from vertical, as measured along the bole. They must also meet the same DBH size requirements noted above for each belt transect, have a bole with an unbroken height of at least 1.37 m, and do not need to be self-supported. Dead trees leaning >45 degrees from vertical are considered coarse woody debris, provided they cross the transect intercept plane. (See Figures 2-3).

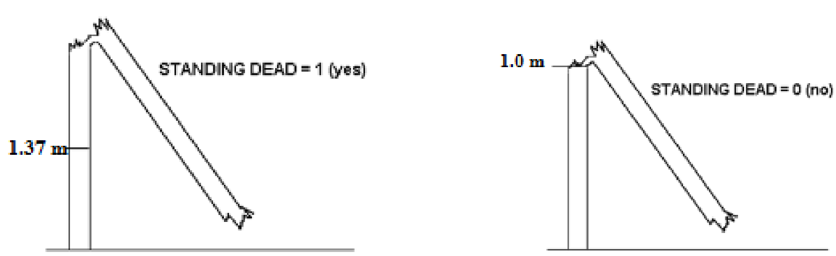


Figure 2: The tree on the left would be tallied because it is at least 1.37 m (4.5 ft) and ≥ 2.5 cm in diameter at the 1.37 m height. The tree would not be tallied because it does not have an unbroken height at 1.37 m. (adopted from USDA 2018 and Sanders et al. 2014)

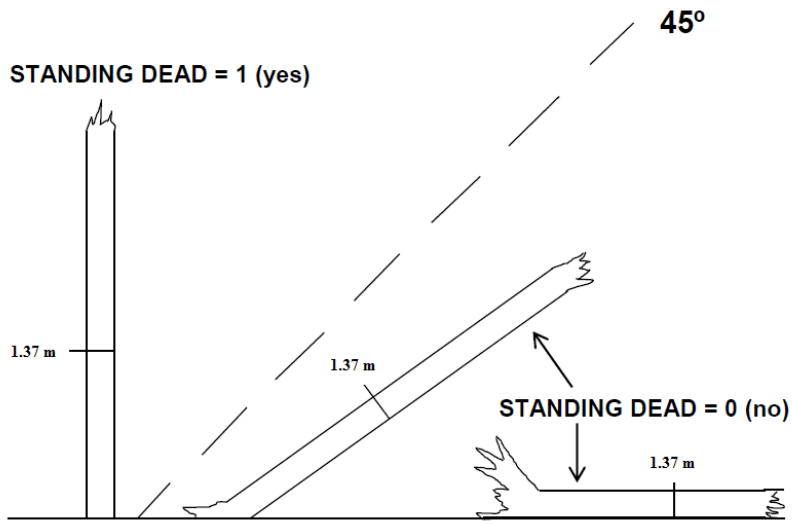


Figure 3. Other examples of dead trees. The tree on the left would be tallied since it is at least 2.5 cm in diameter at the 1.37 m height, and it has at least 1.37 m in unbroken actual height. The two trees on the right would not be tallied as standing dead trees since they are leaning at an angle ≥45˚ from vertical, although they would be counted in the CWD tally, provided they cross the transect and meet all of the other qualifications. (adopted from USDA 2018 and Sanders et al. 2014)

It is most efficient to measure species in both belt transects simultaneously using a team of three crew members, where two people are identifying species and taking DBH measurements (one on either side of the transect) and the third crew member is recording the data. Crew members measuring DBH will need to be mindful of only measuring species ≥ 2.5cm and < 10cm within the 4 m nested belt transect. However, species ≥10cm are recorded throughout the entire 10m belt transect. In order to determine whether the crew member is beyond 2m or 5m of the transect line, a Haglöf DME Ultrasonic Cruiser is used with a transponder, where the data recorder holds the receiver and the measurer holds the transponder. In this way, crew members can easily keep track of their distance without the use of a meter tape.

Do not use calipers to measure tree DBH unless it is physically impossible to use a DBH tape. If calipers are used due to some irregularity, take two measurements and average them together and note this on the datasheet. The following fields are recorded:

- **Species:** Record species of woody tree or shrub. If tree is dead and species cannot be determined, indicate whether it is a conifer or hardwood, or unknown.
- **Live/Dead**: L–Live tree; D–Standing dead tree;
- **Fragmentation class**: If standing dead tree, record fragmentation class (Figure 4):

1 = Recent snag, fine branches present

2 = Loose bark, only major limbs left

3 = Clean bole only, few branch stubs

4 = Broken stem, snapped above DBH

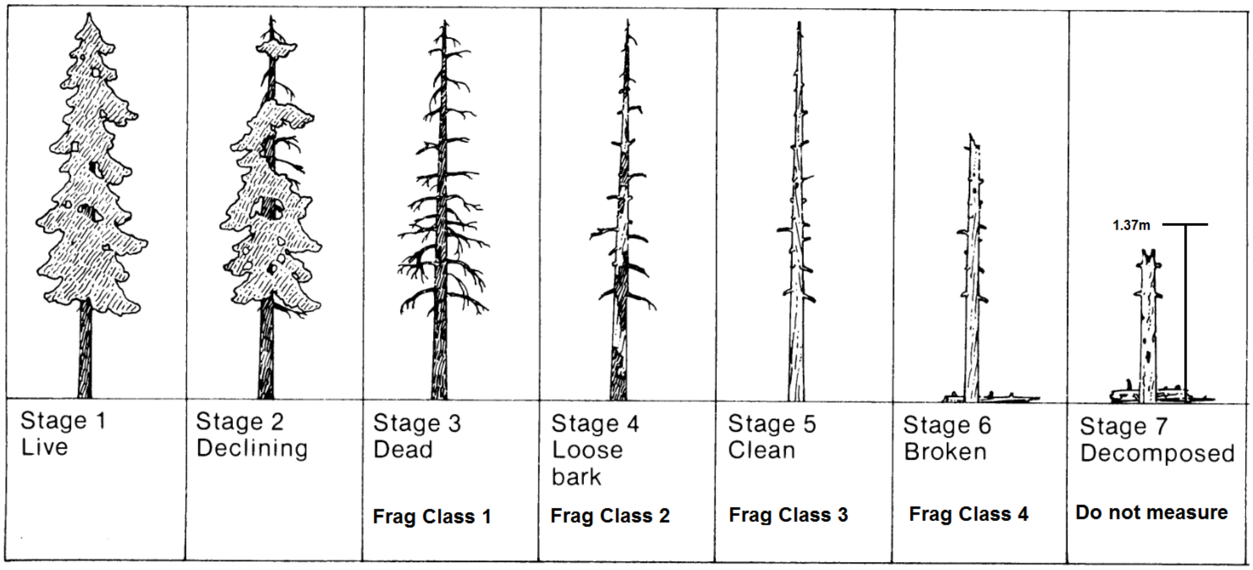


Figure 4. The different stages of standing dead trees and their corresponding fragmentation class. Adapted from Maser et al. (1979).

- **Unusual DBH:** indicate yes/no when measurement is moved due to an irregularity at DBH (swelling, bump, branch, fork, etc.) and describe in the notes field where the location of the DBH was recorded instead and why it was moved.
- **Pest/Pathogen signs**: If any damage is evident, use the diagnostic key for tree pest detection to pinpoint the area and type of damage (Sanders et al. 2014). Examine the bark as well as any branches, leaves/needles, and buds that are accessible and/or observable from the ground. Only list damage on dead trees if the causal agent is obvious (this will be rare). Table 1 lists the primary and secondary pest and pathogen signs, as well as the shortcut abbreviation used for recording evidence of pests or pathogens on the datasheet.

  Table 1 has been adopted from the National Park Service's GLKN forest vegetation monitoring program, which uses an evidence-based approach where only signs of disease presence (e.g., cankers, mycelial fans) or damage (e.g., insect exit holes, leaf mining) are observed and noted. Using this method does not require that a field crew actually identify the causal agent (e.g., anthracnose, emerald ash borer), unless the crew member is completely certain as to the source or cause. With instances of repeated and/or widespread disease or damage, samples will be collected and submitted to experts for confirmation of the causal agent.

Table 1. Primary and secondary pest and pathogen signs to look for using the diagnostic key (Adapted from Sanders et al. 2014).

1° Pest/Pathogen Sign	2° Pest/Pathogen Sign	Abbreviation to record
Dieback	>10%, but not pervasive	Die - >10%
Dieback	pervasive, throughout the crown	Die - pervasive
Epicormic sprouts	on bole (not root collar)	Epi sprouts
Wilted foliage	partial crown	W – partial crown
Wilted foliage	whole crown	W – whole crown
Environmental	frost cracks	Env – frost cracks
Environmental	lightning strike	Env – lightning
Environmental	hail injury	Env – hail
Environmental	sunscald	Env - sunscald
Environmental	broken branches	Env – broken branches
Environmental	flooding	Env – flooding
Environmental	drought/poor soil	Env – drought
Environmental	cedar bark splitting	Env – cedar splitting
Environmental	Fire scar or cambial damage due to fire.	Env – fire
Environmental	other	Env – other
Human-caused Stress	topping/poor pruning	Stress – topping
Human-caused Stress	poor or restricted planting/mulching	Stress – restricted planting
Human-caused Stress	wounding of woody tissues	Stress – wounding
Human-caused Stress	salt/chemicals	Stress – salt
Human-caused Stress	Other, such as axe marks, embedded nails or fence wire.	Stress – other
Defoliation	defoliation > 10% foliage, but not pervasive	Def - > 10%
Defoliation	defoliation pervasive throughout crown	Def - pervasive
Defoliation	leaf mining, > 10% of foliage, but not pervasive	Def – leaf mining >10%
Defoliation	leaf mining, pervasive throughout crown	Def – leaf mining, pervasive
Defoliation	chewing of the mid-rib only (any level)	Def – midrib only
Discolored Foliage	mottling, spots, or blotches	DF – mottling/spots
Discolored Foliage	marginal scorching of leaves	DF – marginal scorching
Discolored Foliage	interveinal scorching of leaves	DF – interveinal scorching
Discolored Foliage	white coating	DF – white coating
Discolored Foliage	black coating (often sticky)	DF – black coating
Discolored Foliage	complete browning/bronzing of needles	DF – browning/bronzing
Discolored Foliage	complete yellowing of leaves or needles	DF – yellowing
Discolored Foliage	stippling	DF – stippling
Discolored Foliage	yellow/orange/white pustules	DF – pustules
Abnormal Foliage	foliage/twigs distorted or galls	AF - distorted/galls
Abnormal Foliage	witches' brooms	AF – witches' brooms
Insect Signs - foliage & twigs	caterpillars/sawflies feeding throughout crown	ISFT – caterpillars feeding
Insect Signs - foliage & twigs	beetles feeding throughout the crown	ISFT – beetles feeding
Insect Signs - foliage & twigs	aphids/white cotton pervasive throughout crown	ISFT – aphids/white cotton
Insect Signs - foliage & twigs	bags pervasive throughout the crown	ISFT – bags
Insect Signs - foliage & twigs	scales pervasive throughout the crown	ISFT – scales
Insect Signs - foliage & twigs	tents/webbing on more than one branch	ISFT – tents/webbing
Foliage dieback Affected	> 10% but less than 30%	Fol - > 10%
Foliage dieback Affected	>30% but not the whole crown	Fol - > 30%
Foliage dieback Affected	whole crown	Fol – whole crown
Insect Signs - branches & bole	frass only	ISBB – frass
Insect Signs - branches & bole	sawdust	ISBB – sawdust
Insect Signs - branches & bole	pitch/resin exudation	ISBB – pitch/resin
Insect Signs - branches & bole	D-shaped exit holes	ISBB – D-shaped
Insect Signs - branches & bole	pencil round or oval exit holes (≥2mm)	ISBB – round/oval
Insect Signs - branches & bole	shot holes (< 2mm)	ISBB – shot holes
Insect Signs - branches & bole	other holes	ISBB – other holes
Insect Presence	caterpillars	IP – caterpillars
Insect Presence	beetles	IP – beetles
Insect Presence	aphids	IP – aphids
Insect Presence	scale	IP – scale
Insect Presence	carpenter ants	IP – carpenter ants
Disease Signs	decay	DS – decay
Disease Signs	conks	DS – conks
Disease Signs	fleshy mushrooms	DS – mushrooms
Disease Signs	cankers	DS – cankers
Disease Signs	bleeding/slime flux	DS – bleeding
Disease Signs	resinosis/gummosis	DS – resinosis
Disease Signs	woody galls or burls	DS –galls or burls
Problem Location	branches	PL - branches
Problem Location	bole and/or root collar	PL – bole
Problem Location	both branches and bole	PL – branches & bole
Loose Bark	loose bark only	LB – loose bark only

Loose Bark	rhizomorphs present	LB – rhizomorphs
Loose Bark	mycelial fans or pads present	LB – mycelial fans/pads
Loose Bark	insect boring or galleries causing loose bark	LB – insect boring
Bark Damage	Bird damage such as woodpecker or sapsucker holes	BIRD
Bark Damage	Mammal rubbing such that bark is severely damaged	MAMMAL

Special DBH situations:

1. Forked tree: Trees which fork at or above breast height (1.37 m) are measured as one tree. Diameter should be measured below the point at which forking affects DBH (Figure 5). Note: **Fork does not have to be live to be considered a fork.** When forks occur, the limiting distance for whether a tree is counted in a belt transect is the same for all forks--they are either all in or all out --and it is determined by the central stump.

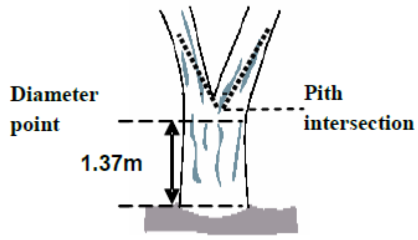


Figure 5. One tree.

2. For trees that fork below breast height (1.37 m), each trunk ≥2.5 cm is measured as a separate tree. Use the following rules to measure the DBH of forked trees:

   <u>Trees forked between ground and 30 cm</u>. Trees forked in this region are treated as distinctly separate trees (Figure 6). Distances are measured individually to the center of each stem where it splits from the base of the tree.

   <u>Trees forked between 30 cm and 1.37 m</u>. Trees forked in this region are also counted as separate trees (Figure 7), but the DBH of each fork is measured at a point approximately 1.07 m (3.5 feet) above the pith intersection (Figure 8F).

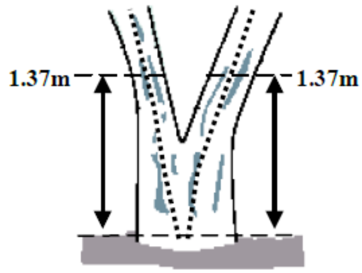


Figure 6. Forked below 30cm.

3. <u>Stump Sprouts:</u> Stump sprouts that originate between ground level and 1.37 m on the boles of trees are handled the same as forked trees, provided they are ≥2.5cm. 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 discussed in the forked tree rules above.

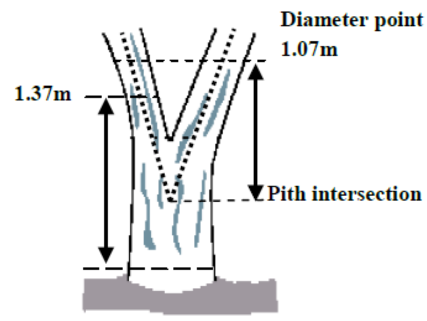


Figure 7. Forked between 30cm – 1.37.

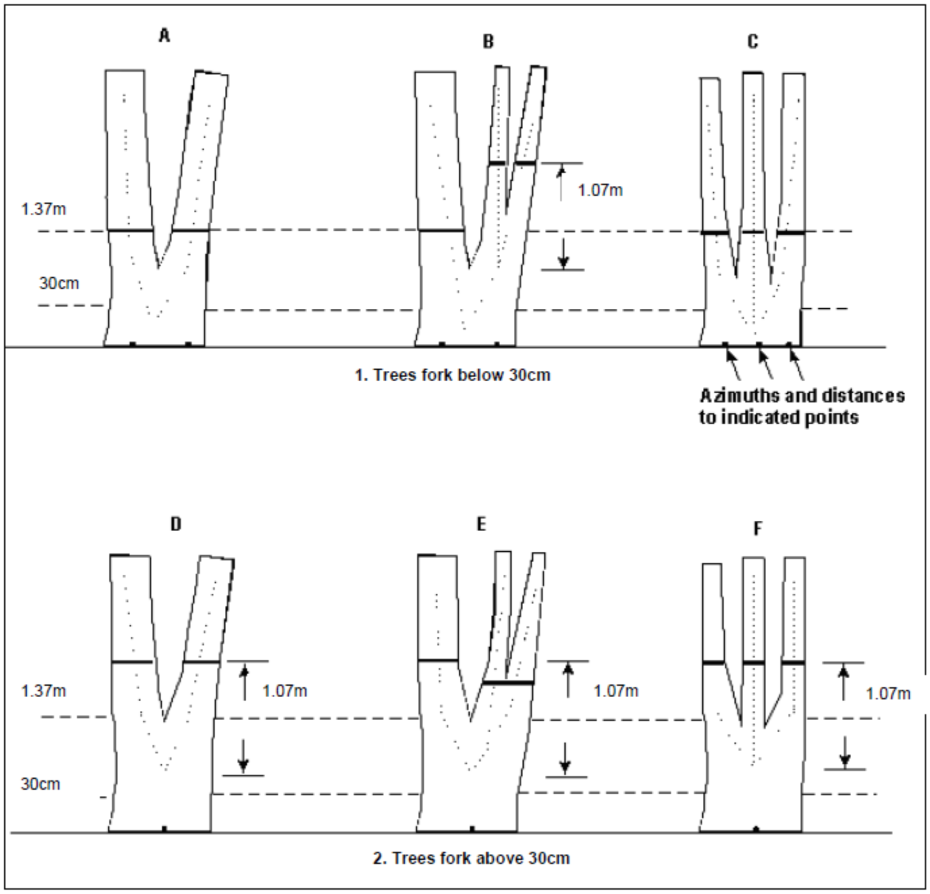


Figure 8. Summary of where to measure DBH on forked trees. (adapted from Sanders et al. 2014)

4. <u>Tree with butt-swell or bottleneck:</u> 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 9).

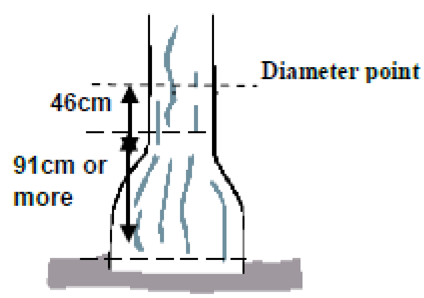


Figure 9. Bottleneck tree.

5. <u>Tree with irregularities at DBH:</u> On trees with swellings (Figure 10a), bumps, depressions, or branches (Figure 10b) at DBH, measure the diameter immediately above the irregularity at the place it ceases to affect normal stem form. Note on the form where you took DBH and the irregularity.

Note: *If a normal diameter cannot be obtained at or above 1.37 m, it is valid to measure diameter just beneath any swelling that would inflate DBH and note at what height you measured DBH on field form.*

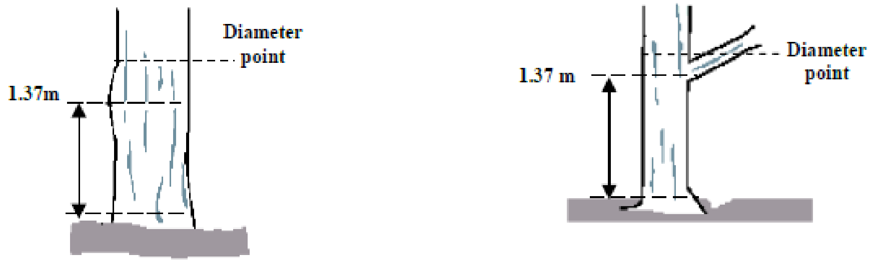


Figure 10. a) Tree with swelling b) tree with branch.

6. <u>Tree on slope:</u> Measure diameter at 1.37 m above the ground on the uphill side of the tree (Figure 11).

7. <u>Leaning tree:</u> Measure diameter at 1.37 m from the ground, measured along the underside face of the bole (Figure 12).

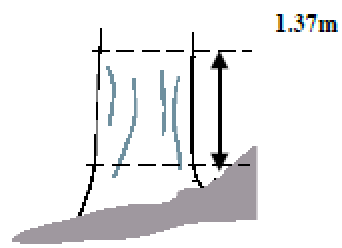


Figure 11. Tree on slope

8. <u>Independent trees that grow together</u>: 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 using a caliper.

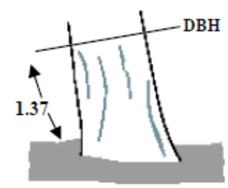


Figure 12. Leaning tree

9. <u>Missing wood or bark:</u> Do not reconstruct the DBH of a tree that is missing wood or bark 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 or missing part of main bole (or gouge, depression, etc.) at the point of DBH, apply the procedure described for trees with irregularities at DBH (Figure 10).

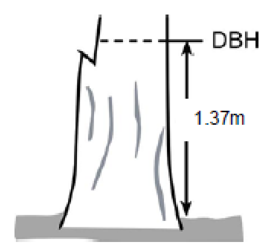


Figure 13. Tree with part of stem missing.

10. <u>Live windthrown tree</u>: Measure from the top of the root collar along the length to 1.37 m (Figure 14). Note that this only applies to **live, rooted trees**. The angle of the tree from the vertical does not matter as long as the tree is **alive**.

11. <u>Down live tree with tree-like branches growing vertical from</u> main bole. When a down live tree that is touching the ground has vertical (less than 45 degrees from vertical) tree-like branches coming off the main bole, first determine whether or not if the pith of the main (downed) bole 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, where if the 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 cm above the pith intersection for both the main bole and the tree-like branch (Figure 15).

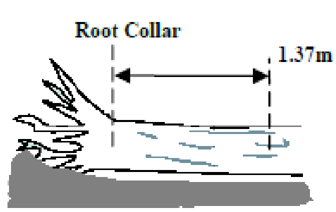


Figure 14. Tree on the ground.

- If the intersection between the main down bole and the tree-like branch occurs beyond the 1.37 m point from the stump along the main bole, treat that branch as part of the main down bole (i.e., do not tally it; Figure 15).

- 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. 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).

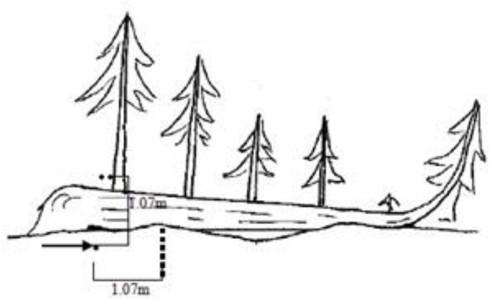


Figure 15. Down tree above duff.

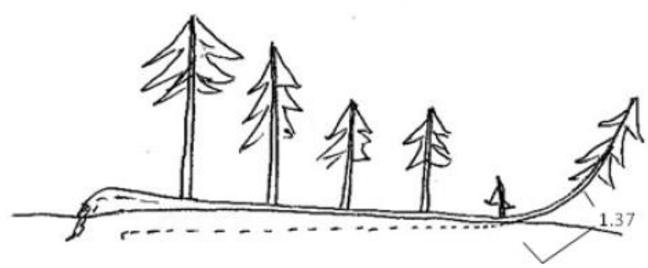


Figure 16. Down tree below duff.

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

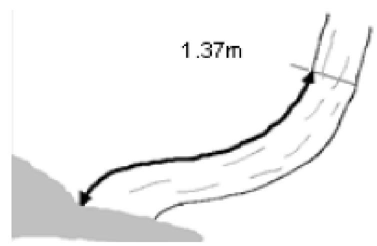


Figure 17. Tree with curved bole (pistol butt tree).

13. Trees growing on objects: When trees are growing on objects, such as rocks or logs, measure diameter at 1.37 m above the root crown rather than from the forest floor (Figure 18).

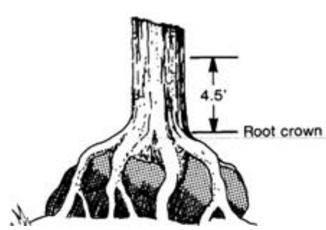


Figure 18. Tree growing over objects, measure starting at root crown.

Ground Layer Quadrat Measurements

Herbaceous plants and woody species including shrubs and vines < 2m in height and less than 2.5cm DBH are assessed within the 1 × 1 meter ground layer quadrats, placed every 5 meters (Figure 1). Each of these 1m^2 plots contain a smaller 0.1m^2 nested plot in the corner adjacent to the transect, where all species that occur within this area are first marked as present in the nested. Additional species that occur outside the nested plot are then listed before recording cover for the entire 1m^2 area. Cover class categories to be used are **1**=<2%; **2**=2–10%; **3**=10–25%; **4**=25–50%; **5**=50–75%; **6**=75–100% (Figure 19).

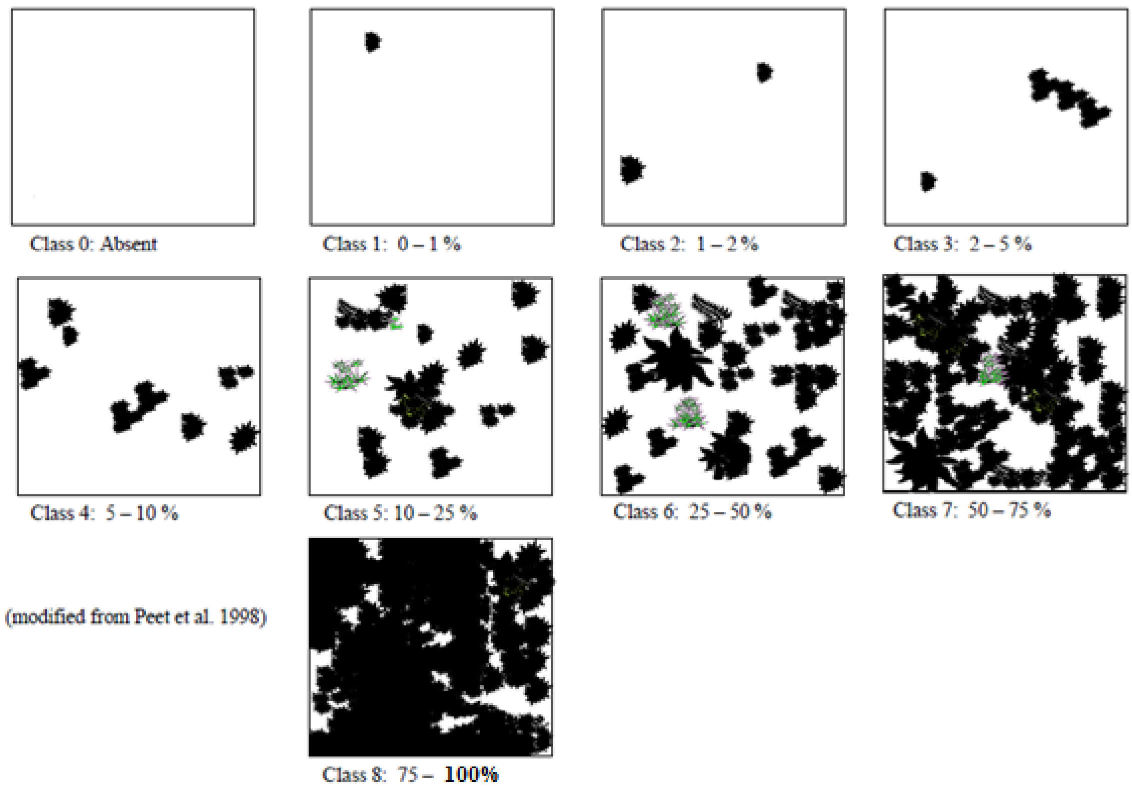


Figure 19. Illustration of ground layer cover classes to be assigned for quadrats (Modified from Peet et al. 1998).

Notice the exact percentage breakpoints can be in two different classes (e.g., 10-25% and 25-50%). This is not a mistake and a choice regarding the cover class will be either that it is less (as in 10-25%) or slightly more (as in 25-50%) if it is close to 25%. The most suitable class should be assessed and recorded as rapidly as possible while maintaining accuracy.

Begin each quadrat first by assessing non-vascular cover using the cover classes shown below under *Foliar Cover*.

- **Non-vascular cover**: Estimate cover within the 1m^2 quadrat for *Sphagnum* and non-*Sphagnum* bryophytes. Non-vascular moss on coarse woody debris that is suspended above the ground are not included. However, if there are rocks or decaying course woody debis that has cover of moss such that is grows continuously from the soil and over these features on the ground, consider this bryophyte cover to be counted as it is part of the ground layer. Bryophytes growing on tree trunks are not included since the trunk is vertical.

After completing the non-vascular cover categories, move down to the vascular plant fields, where the bulk of the data will be recorded:

- **Vascular species frequency** is first recorded in the nested plot (0.1m^2), where a check mark is recorded to indicate a species is present and rooted in the smaller quadrat. The observer then moves to the larger 1m^2 quadrat, recording any additional species not previously encountered in the nested plot, followed by assessing cover for all species within the 1m^2 plot.

- **Foliar Cover** is recorded for each individual vascular plant that has cover under 2m in height using the appropriate cover class in the 1m^2 quadrat. The total for all species in each quadrat can be less than 100%, if portions of the quadrat are un-vegetated. The total can also exceed 100% if vegetation is dense and overlapping. However, overlap of vegetation of the same species is ignored. There will often be overlap of plants of different species and this does need to be considered. Therefore, the total cover for a quadrat may exceed 100%.

  Vegetation cover is assessed for the entire 1m^2 quadrat, and only for individuals that are rooted in the quadrat. In other words, plants rooted in, but that are bent over so their cover is mostly outside the quadrat, will only be given a cover value based on the foliage that covers the quadrat where it lies naturally. Species that are rooted outside the quadrat but have cover overhanging the plot are not included. Imagine the percent cover of each plant as a shadow on the ground if the sun were directly overhead.

  Bare twigs or branches, dead woody species without foliage and woody vines without foliage do not count towards cover (e.g. large grape vines without foliage in the quadrat).

  All foliage or vegetation that was recently alive during the current growing season is included in the cover estimates. For example, species in the Liliaceae Family tend to senesce in early August so an estimate of its recent cover should be attempted. Thus, if the leaves were clearly recently alive, consider it as such and adjust cover estimates accordingly. Aerial cover from recently broken fern fronds (e.g., broken or bent fronds of bracken fern) and stems are also included if it is clear they were recently growing and green, unless completely detached and dead. Bracken fern (*Pteridium aquilinum*) is often easily broken while setting up transects, thus minimizing trampling impacts to this species is especially important. However, in the event the stems are broken, lift the top frond to an upright position and adjust cover estimates to the best of your ability.

Additionally, rhizomatous or stoloniferous species such as *Fragaria virginiana* that have runners that cross or drape over or through the quadrat area are not counted. Thus, if runners are not rooted and without leaves, these species are not considered as growing in the quadrat and are not recorded or considered to have cover. Other species with similar growth are *Vaccinium oxycoccos, Rubus pubescens, Linnaea borealis,* and *Carex assiniboinensis,* to name a few.

- **Recording uncertainty:** Record your level of confidence in the species identification for each plant where there is uncertainty at any taxonomic level. Recording your confidence in the identification is important. Use the following codes to record uncertainty level, particularly for uncollected individuals. See Appendix A for a list of accepted groups.

#	**Uncertainty/reliability desc.**
3	species group
4	species uncertain
5	only genus is certain
6	Genus is uncertain
7	unknown
8	only the family is certain

- **Tree seedling and sapling tallies**: Count number of tree seedlings that are less than <2.5cm DBH. Qualifying tree seedlings must also be at least 5 cm tall or exhibit signs of second-year growth, such as previous years' bud scars. Seedlings experience high mortality due to high mast years, weather and predation. Thus, if a seedling is present, but does not have second year's growth and it is not counted in the tally, then record 0 to acknowledge that the seedlings were zero and the count was simply not forgotten.

  If there are numerous seedlings at the base of a tree, but they are growing from the ground, they are counted. If you can clearly see that the sprouts are growing from the trunk of a tree, do not count them, thus do not tally any seedlings that sprout from a live tally tree.

  Do not count "layers" of branches if they are clearly still connected to that of another main stem and only shallowly rooted under leaf litter or moss substrate. In the case of *Thuja occidentalis* or *Picea mariana*, which roots and produces ramets from downed trees or moss-covered lower branches, count the number of ramets rooted within the ground layer quad only if the pith of the downed tree bole from which they are growing lies below the duff or moss layer. Vegetative regeneration through layering is an important means of reproduction in black spruce swamps and bogs in Minnesota. For example, if moss-covered, lower branches from an adjacent *Picea mariana* appear to have advanced growth, such that these branches have transitioned toward having a primary leader and the branch can no longer easily be pulled above the upper moss layer, then count this as an individual seedling or sapling.

Do <u>not</u> include these species in seedlings tallies, as they are not considered canopy trees:

- *Crataegus* spp.
- *Salix* spp. (see below for exceptions)
- *Amelanchier* spp.
- *Alnus* spp.
- *Prunus virginiana*
- *Acer spicatum*
- *Prunus pensylvanica*
- *Sorbus americana*

Do include these understory tree species in the tallies of seedlings:

- *Carpinus caroliniana*
- *Ostrya virginiana*
- *Prunus nigra*
- *Prunus americana*
- *Juniperus virginiana*
- *Sorbus decora*
- *Prunus serotina*
- *Salix nigra*
- *Salix amygdaloides*
- *Salix fragilis* (non-native canopy tree willow)
- *Salix x rubens* (non-native canopy tree willow)

When there is no data or quadrats cannot be sampled

If there are no plants in a quadrat, the quadrat is considered sampled, but with no data. A quadrat landing on a dirt trail with no living plants is considered sampled with no data because there is potential for vegetation to grow there. A quadrat comprised of mud, a pile of coarse woody debris, or a large tree trunk with no visible vegetation growing should also be considered as sampled, no data. Clearly write in transect notes which quadrats were sampled, but with no data.

Similarly, if a quadrat is not sampled, due to a safety concern or a transect was cut short as it was under water one year, clearly write in transect notes which quadrats were not sampled. Some examples where using this would be applicable would be when a quadrat lands completely on paved area or large boulder or rock slab where there are no plants, and they are unable to ever grow there. Additionally, a quadrat may be skipped due to a ground hive or other safety issue, or any quadrat with water deep enough that you cannot tell if vegetation is growing or not should also be noted as not sampled.

The following applies to recording on paper datasheets only. For **sampled no data** or **not sampled**, draw a line through the column for the specific quadrat number and at the top of the column write **ND or NS**, respectively.

Unknown species

If a plant cannot be identified to species quickly and confidently by crew members in the field, record genus or family, if possible, and choose appropriate taxonomic uncertainty level.

When collecting voucher specimens for later identification, try to remove the root as well as the aboveground portion of the plant. All field crews will carry a trowel with them for this purpose. Soil should be knocked free from the roots to the extent possible without damaging them. An unknown plant tag should then be attached and labeled with the plot number, quadrat(s) it is associated with as well as transect(s). In the event that a woody plant species cannot be identified, portions of these plants may be cut and removed from the field for later identification. All crews carry pruning shears for this purpose.

When collecting plants, an attempt must first be made to locate individuals of the same species outside of the outer boundary of the plot. If this is not possible, collections should at least be made outside of the quadrats. If this is not possible, then either take a photo of the plant from different angles and/or consult with the field lead on the best way to extract the minimum amount of material needed for identification. If reproductive structures are present (i.e., viable seeds, fruit, decaying acorns), be sure to collect enough material to aid in later identification. However, only the minimum amount needed should be collected.

Collected specimens are then placed in a plastic bag for later identification. Keep the specimens in as cool and dark of a place as possible while you continue to work, and do not allow it to be crushed.

Follow these guidelines to determine whether and how to collect a specimen for subsequent identification:

- Exercise caution when removing plants for voucher specimens. Do not collect the entire plant, including the roots, if any unknown is represented by 5 or fewer individuals (i.e., locally sparse) in the general vicinity of the plot. Consider taking only a small portion of the plant that will aid in identification. If an unknown plant is not locally rare, it can be collected from inside the plot, but outside the quadrats.
- Do not remove entire plants (including roots) from within the quadrats. If the plant occupies greater than 2 % cover and is sufficiently robust, a portion of the plant may be removed from within the quadrat such that the overall cover of the plant within the quadrat is not significantly affected.
- Anytime it is not possible to collect a specimen, take a photograph. Place a ruler in the photograph for scale, and allow the camera to automatically select the appropriate aperture for the given light conditions. Use the Macro setting to take detailed close up photographs of smaller plants.

When back at the vehicle or that same evening, press bagged/collected specimens in provided pressing materials and plant press. On each individual specimen sheet, transcribe what was written on the attached plant labels: transect(s), quadrat(s), and plot ID plant is associated with as well as the date and any other information that will be helpful to correctly connect the unknown plant with all quadrats where it was recorded at a later date, once it is identified.

Coarse Woody Material

Coarse woody materials are also assessed along each of these three transects, whereby data are collected on all downed wood which intersects the transect plane, with a diameter ≥ 7.5 cm (following FIA standards) at the point of intersection. Data on coarse woody material will be collected along each of the three parallel 45 m horizontal distances using the planar intercept method. Tally rules follow below. For all pieces of coarse woody material tallied, the parameters recorded are: species, diameter at plane intercept, distance along transect, and decay class.

- **Transect**: record transect number.
- **Species** – Record each piece of coarse woody material if it is possible to identify which is ≥7.5cm and > 1m in length that crosses the plane of the transect. Because this is a planar transect, the tree is counted whether it is on the ground, or at any height above it. If species cannot be determined, record either **Unknown conifer; Unknown hardwood; or Unknown**.
- **Distance**: record distance where CWD intersects
- **CWD length**: Record only woody pieces that are ≥1m
- **Diameter at intersection**: Record the diameter (in centimeters) at the point of intercept. This diameter is measured perpendicular to the length of the log, regardless of the orientation of the piece to the transect plane. Record the measurement to the tenth of a centimeter, rounding down, rather than to the nearest tenth. For example, a reading of 12.78 cm is recorded as 12.7 cm.
- **Decay class**: Record the decay class of the piece using the rules outlined in Table 2. Because decay conditions may vary along a piece, record the decay class that predominates (Table 2)

Table 2. 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; all bark intact; hard when kicked	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; some bark missing; hard when kicked	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; most of the bark is missing; piece supports its own weight; still hard when kicked	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, and most of the branches < 1" missing
4	heartwood rotten; piece does not support its own weight, but maintains its shape; sounds hollow when kicked and you can remove wood from outside with boot	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; easy to kick apart	soft; powdery when dry	red-brown to dark brown	throughout	branch stubs and pitch pockets have usually rotted down

Tally Rules for Coarse Woody Material Sampling:

1. Tally dead and down trees whose central longitudinal axes intersect the transect plane (Figure 20). This includes all unrooted dead trees and their branches regardless of the angle at which they are leaning away from vertical. Some parameters may have to be estimated, depending whether part or all of the piece is elevated.

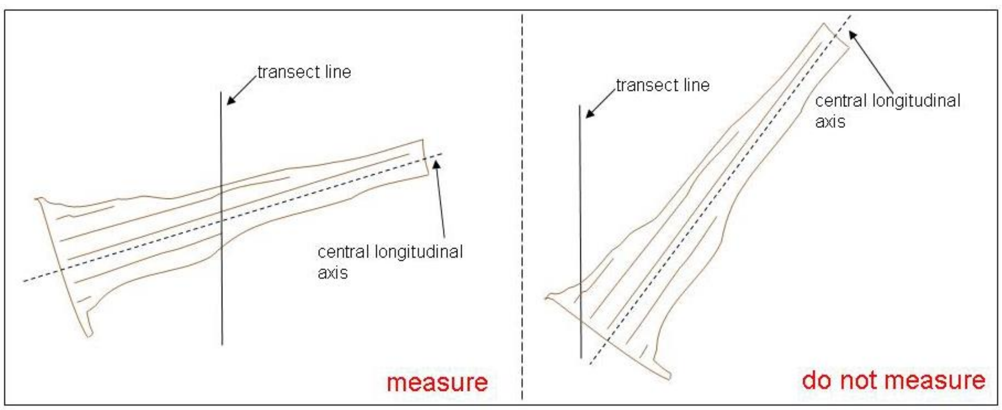


Figure 20. Do not tally any CWM piece whose central longitudinal axis does not cross the transect plane. (Adapted from USDA 2018 and Sanders 2014).

2. Tally dead trees and stumps that are leaning ≥45˚ from vertical. (Do not tally live trees or standing dead trees and stumps that are still upright and leaning <45˚ from vertical. See section “Tree Data” above.)

3. The minimum length of any tally piece is 1 m for decay classes 1 through 4.

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 ≥7.5 cm in diameter at the point of intersection with the transect plane. The piece must also be ≥1 m in length and ≥7.5 cm (3 in) in diameter along that length.
   - **For decay class 5**: tally a piece if it is ≥10 cm in diameter at the point of intersection with the transect. The piece must also be ≥1.5 m in length and ≥10 cm 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. If coarse woody debris was created by human activities, such as logging or cutting, tally these as well, but only if it has been left scattered across the site. Do not tally if it has been left in a pile.

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 plane, tally the piece each time it is intersected. This is an uncommon situation. (Figure 21).

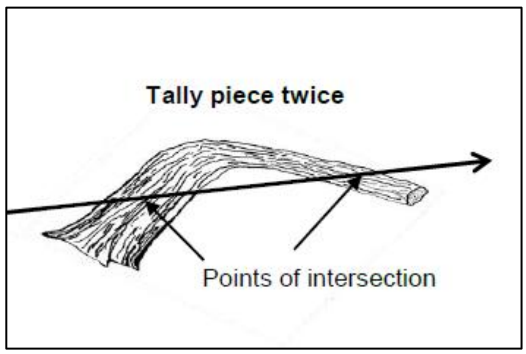


Figure 21. If the central longitudinal axis crosses a transect twice, then tally the piece twice. (adapted from USDA 2018)

8. 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. Tally only the piece intersected by the transect plane. If judged that it would not pull apart, tally as one piece.

9. Do not tally a piece if it intersects the transect plane on the root side of the root collar (see right side of Figure 20). Do not tally roots. Stumps that are rooted in the ground are also not recorded.

10. When the transect crosses a down tree bole that is forked, or a large branch connected to a down tree, tally each qualifying piece separately (Figure 22). To be tallied, each individual piece must meet the minimum diameter and length requirements.

11. 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 22).

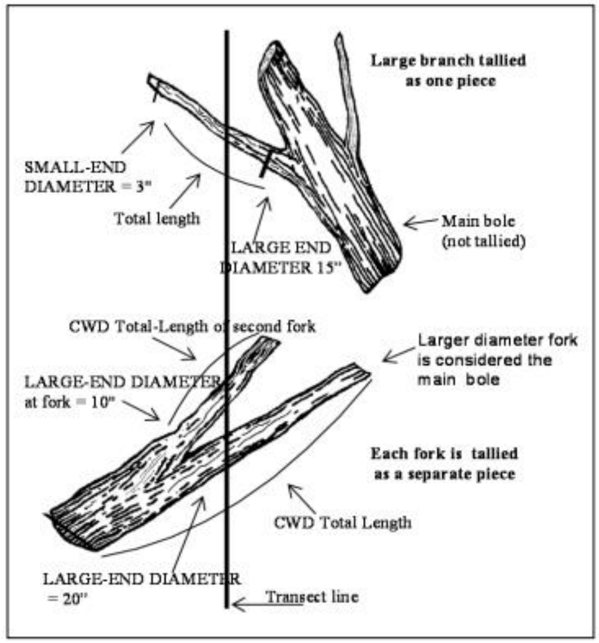


Figure 22. CWM tally rules for forked trees. (adapted from USDA 2018)

12. For pieces that cannot be taped and are not round in cross-section because of missing chunks of wood or "settling" due to decay, measure the diameter in two directions and take an average. Estimate the longest and shortest axis of the cross-section ("A" and "B" in figure), and enter the average in the diameter field (Figure 23).

13. Any transect that has no CWD is marked as "**Sampled with no data**." If a transect was not sampled due to time constraints or safety, write "**not sampled"** in the notes section.

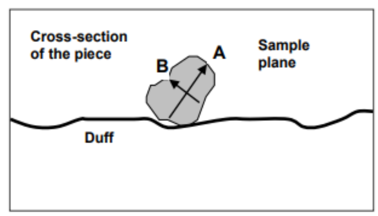


Figure 23. Estimating the diameter of pieces that are not round in cross-section.

Direct Browse and Shrub Frequency

For each direct browse sampling circle (Figure 24), record the presence of all woody species that have foliar cover below 2 m in height (defining the ''molar zone''). In addition to species presence, evidence of ungulate browse on each species in the sampling circle is recorded. Impact on woody species where all twigs are higher than 2 m are not recorded, as these shrubs or trees are considered to have grown out of the reach of deer. Attempt to document browsing evidence only for twigs browsed by deer, which is characterized by ragged ends of twigs unlike the sharp, 45° cut typical of rabbit and hare *(Sylvilagus* spp., *Lepus americanus*) browsing (Figure 25). Observations of browse should also attempt to focus on current year's browse, where twig ends are more ragged and often still green; previous year's browsing is characterized by a length of dead, discolored twig between the browse point and current year's growth. However, it is recognized that this is sometimes difficult to determine if the browse occurred during the winter months. In light of this, err on the side it being browsed. We will also use the presence data from the direct browse assessment to obtain shrub frequencies.

Unlike the quadrat data, note that for both presence and browse, it does not matter whether a tree or shrub is rooted within the 1m radius cylinder; presence and browse are recorded as long as any part of a tree or shrub falls within the cylinder and if any part within the cylinder is browsed. For example, browse is noted on a tree rooted outside of the cylinder that has branches extending into the cylinder, where it is browsed. Conversely, a tree that is rooted within the cylinder is marked as present, but if the browsed portion is outside of the cylinder, it is not be marked as such.

It is possible there will be no shrubs or saplings within the sampling circle; in these instances, no direct browse is assessed for those sampling circles. These browse circles are considered sampled, but with no data. Clearly write in transect notes which quadrats were sampled, but with no data. If an entire transect has no woody species present, be sure to indicate this in the transect notes.

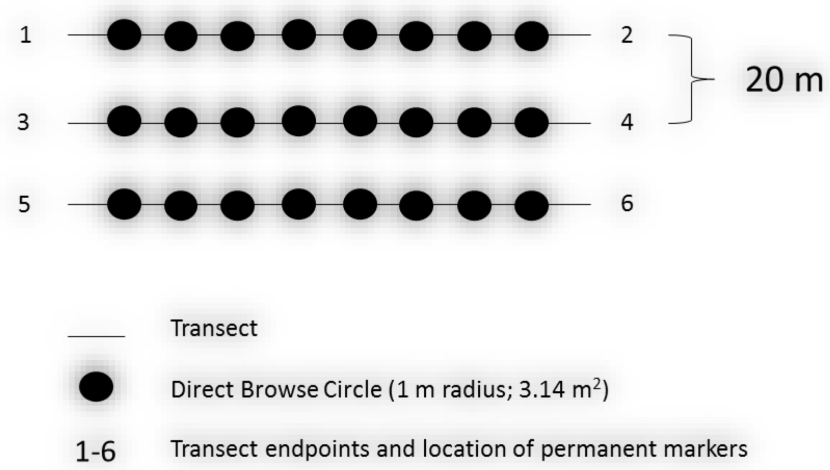


Figure 24. Direct browse sampling circles every 5m in plot.

The following applies to recording on paper datasheets only. Clearly write **ND** to represent **sampled, no data** in the appropriate column for the browse circle represented. If an entire transect has no woody species present, be sure to write this on the datasheet so that it is clear to others doing data entry in the future that this data was simply not forgotten.

Figure 25. Left twig shows ragged tear reflecting deer browse. On the right is hare browse that is a clean, 45 degree angle. Source: http://extensionpublications.unl.edu

Additional Species Walkthrough Datasheet

Prior to completing the plot, a ≤ 30 minute (depending on the habitat) time-delimited walkthrough is conducted to determine the complete list of species that are present in each plot. The area to be searched is delimited by the outer transect lines; thus 40m x 45m for wooded systems and 20m x 45m for open systems. Any species that have already been accounted for in the ground layer, shrub or tree sampling areas are not recorded again. During the 30 minutes, focus the time finding species that are truly being missed by the quadrats, not species that shows up a single time, a single grass species that has no diagnostic parts for identification, or is rare and not indicative of the community.

Earthworm Assessment Datasheet

Earthworm assessments will occur in all upland forested plots. Two, 1m^2 earthworm assessment sites will be selected by the field crew either within, or adjacent, to the plot to look for evidence of earthworms (Figure 26). Plots will be selected subjectively in order to characterize the plot and surrounding area. Earthworm monitoring will be limited to two goals: determine whether or not there is evidence of earthworms present and to what extent, and determine the depth of layers of the upper soil surface as an additional explanatory variable. The earthworm and soil assessments are designed to address two key questions:

- Are upper soil organic layers changing over time? Earthworms can change organic soil properties that may drive consequent changes in plant growth (e.g., richness, diversity). As such, we will measure organic layer depth (litter, duff, and humus) and test for associations between organic layer depth and vegetative indices.
- Is there evidence of earthworms at vegetation monitoring plots? We will use visual cues on the forest floor as indicators of earthworm presence.

The earthworm assessments are not performed on trails or old roads, as the soil horizons in these areas will be compacted. Also, low-lying wet depressions should be avoided, unless the majority of the plot is a wet depression.

It is also helpful to also look around the larger plot area for exposed root crowns of trees and record this in the Earthworm Assessment notes, regardless of the forest floor ranking. We will only determine the presence of earthworm signs; no attempt will be made to quantify, collect, or identify earthworms during this sampling.

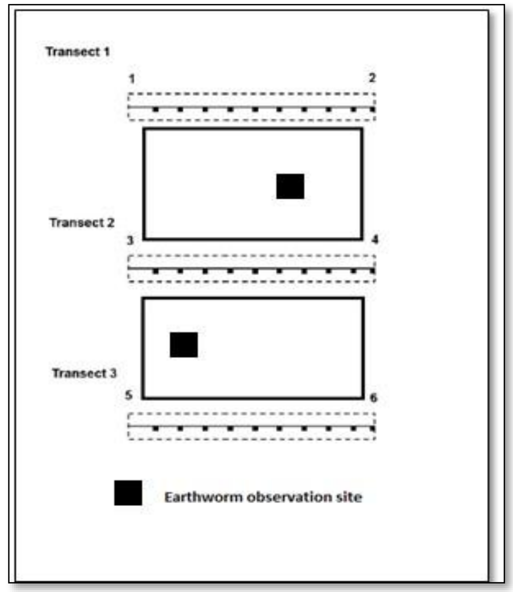


Figure 26. Example earthworm assessment areas.

Earthworm assessment plots

To begin, find two 1m^2 areas within the plot to assess the litter layer and record one of the following: 1) intact, layered forest floor in which fresh litter, fragmented and decaying litter, and humus are present (see below description of Oi, Oe, and Oa horizons); 2) litter layer partially fragmented, but containing litter from more than one year (Oi and Oe horizons); or 3) no intact litter, only freshly fallen leaves from the previous year (Oi horizon only). See Table 4 below for further help in selecting the assessment rankings and the description of organic layers.

O Horizon: organic layer of fresh and decaying residue at the surface. May be separated into three layers (but all three are not always present).

> **Oi** = fresh litter, often complete or nearly complete leaves readily distinguishable and even identifiable to species. Often layered or matted. If this layer is dry and fluffy and yielding an unreliable measure of thickness, compress the leaves to simulate what it would be if "layered" and then measure the thickness.
> **Oe** = relatively undecomposed organic material that is fragmented so that it is difficult to identify as to its specific type or species. Peat-like and generally not blackened in color.
> **Oa** = humified or decomposed organic material with less than 50% mineral soil component (as estimated by visual inspection). May be very black and mixed with worm cast material, but still maintains network of roots (dead or alive) and recognizable organic material.

1. Using a ruler, measure the depth of the litter layer (Oi) in a number of places in the 1 m^2 assessment area. If the fresh litter on the forest floor has a lot of air space, compress it to get an estimate of the thickness.
2. Using the measured values, calculate an average litter layer depth.
3. Calculate the average depth of the duff, or fragmented litter, layer (Oe).
4. Calculate the average depth of the humus layer (Oa). Note that measuring the depth of the humus layer is sometimes more easily accomplished using a soil knife or other digging tool.
5. Brush away the litter layer and look for castings and middens (Figure 27a and b), classifying both as absent, present, or abundant.
6. For the castings, absent means you did not find any; present means there are some casts but you really need to look for them; and abundant means that the castings are very obvious to see as you move the leaf litter away.
7. For the middens, absent means you did not find any; present means there are some middens present (typically less than four); and abundant means there is a high density of middens. Middens are about 1-5 cm in diameter and 1-3 cm in height with a burrow hole

Figure 27. a) Earthworm castings. b) Earthworm middens.
(Source: http://www.greatlakeswormwatch.org)

(2-4 mm in diameter) near the center. The burrow entrances of middens also often have large numbers of leaf petioles or fragments of leaves sticking out of them.
8. Determine the forest floor ranking on the scale of 1-to-5, as described below in Table 4 (Loss et al. 2013).

Table 4. Earthworm assessment ranking descriptions.

Rank Descriptions	What to look for
Rank 1, Earthworm free 1) Forest floor and humus fully intact and layered (Oi, Oe, and Oa horizons present) 2) Roots present in humus (Oa) and leaf fragments (Oe) 3) Forest floor coherent when picked up, with intact recognizable layers 4) No earthworms or earthworm sign present 5) Distinct and rapid transition from forest floor to mineral soil horizon (E horizon, A horizon largely absent)	Result: Plant community remains very diverse, dominated by native species, no expansion of Carex spp.
Rank 2, Minimally invaded 1) Humus present in patches (Oa horizon), may be slightly mixed with mineral soil; the rest of the forest floor is intact and layered (large and small fragmented leaves) 2) Some roots in the forest floor, but not thick 3) Small earthworms or cast material found in the forest floor 4) In mineral soil, earthworm castings present or absent, but not abundant 5) Lumbricus terrestris middens absent	Result: Plant community remains somewhat diverse, dominated by native species, minimal expansion of Carex spp.
Rank 3, Moderately invaded 1) Minimal forest floor present; larger, mostly intact leaves from the previous litter-fall present (Oi horizon) 2) Also, includes mostly intact, partially decayed leaves from more than one year (Oe horizon) 3) Plant roots absent or sparse in the thin forest floor 4) No humus present (Oa horizon) 5) Mineral soil and earthworm castings present, but not abundant 6) Small leaf fragments present under intact leaves 7) Lumbricus terrestris middens absent or rare	Result: Plant community may be somewhat diverse, with native species and/or with broken patches of Carex spp.
Rank 4, Substantially invaded 1) No forest floor; larger, mostly intact leaves from the previous litter-fall present (Oi horizon) 2) Sometimes includes mostly intact, partially decayed leaves from more than one year (Oe horizon) 2) No humus present (Oa horizon) 3) Mineral soil and earthworm castings abundant 4) Lumbricus terrestris middens present 5) Plant roots absent in forest floor.	Result: Plant community may be sparse OR be dominated by exotic species such as garlic mustard and European buckthorn OR have a broken-to-unbroken carpet of Carex spp.
Rank 5, Heavily invaded 1) No forest floor; only larger, mostly intact leaves from the previous fall present (Oi horizon) 2) No small leaf fragments from more than one year present (Oe horizon) 3) No humus present (Oa horizon) 4) Mineral soil and earthworm castings abundant 5) Lumbricus terrestris middens abundant 6) Plant roots absent in forest floor.	Result: Plant community may be sparse OR be dominated by exotic species such as garlic mustard and European buckthorn OR have a broken-to-unbroken carpet of Carex spp.

Grassland Criteria and Plot Establishment

Grassland sampling criteria includes:

- Grassland canopy tree cover is <10%. Transects are placed 10m apart where the minimum area of suitable area for sampling is 1500m^2, e.g., 50m x 30m. If >10% cover of trees is present, then consider it a wooded or forested plot and place transects 20m apart.
- Grasslands currently managed (e.g., mowing, grazing, prescribed fire, etc.) at a relatively low intensity.
- Formerly grazed or currently lightly grazed pastures or fields are acceptable provided native plants are the dominant cover (have >50% cover) and the vegetation present is identifiable if it is currently being grazed.
- Overgrown or infrequently mowed rights-of-way are acceptable, provided native plants consist of >50% cover and there is suitable area.

Sites that will not be considered include:

- Grasslands recently planted in monocultures are not accepted, even if it's a native species such as big bluestem *(Andropogon gerardii).* Additionally, areas planted in alfalfa or clover, especially if plantings comprise >50% cover, such that it is considered a planted monoculture.
- Prairie reconstructions on previously plowed land are not included. This will need to be assessed in the field and may be difficult to detect if plantings were done some time ago.
- Fields or pastures heavily grazed (based on assessment in the field) or grazed at time of data collection such that species identification would be difficult.
- Grasslands, hayfields, etc. that are mowed frequently.
- Agricultural fields that are fallow, where evidence of recent tilling observed and non-native species dominate.
- Conservation Reserve Program (CRP) grasslands. These lands are typically planted old fields that were formerly cropland.
- Manicured grasslands, such as golf courses, mowed cemeteries, city parks, or airfields.

Grassland Response Design and Data Collection

The primary sample unit for grassland community composition and structure monitoring consists of three 45 m, permanent transects (Figure 1), spaced 10 m apart. In savannas or other semi-forested systems, ideally, transects should be spaced 20 meters apart to allow adequate spacing for the tree belt transects.

If there is a sufficient amount of suitable habitat for sampling, the field crew proceeds to establish three transects parallel to elevation contours, if topography is present (see *General Criteria for establishing sampling sites in the field*). Similar to forests, distinct differences will exist in native prairie ecotones according to slope and aspect position. Additionally, the only remaining native grassland present is often on hillslopes. Cultivation is typically present (or historically occurred) in the valley bottoms or upper slopes and hilltops, with hillsides left unplowed. Therefore if any gradient is present, attempt to keep the plot within similar soils and community type, according to aspect. For example, avoid running the transects from native prairie midslope to a valley bottom with an old field, or crossing from a dry prairie into a wet prairie.

If there is no topographic gradient present, then position the transects to run in an east-west direction to limit plot establishment bias similar to forested plots, with the GRTS random plot point representing the northwest corner. If there is not sufficient habitat for this placement, then orient the plot to fit within the space that exists where the transect ends have at least a 15 meter buffer from the edge of the prairie, or edge of disturbance or change in habitat.

Similar to forested systems, data on groundlayer ($\leq$ 2 m height) height and foliar cover are collected in 24 nested quadrats (0.1 m^2 and 1 m^2, 8 per transect) placed systematically (every 5 m) along each transect. Understory composition and abundance within 1m^2 quadrats will be recorded to yield information describing species composition, including presence of non-native species. If present, trees and tall shrubs will be assessed in belt transects where each tree $\geq$2.5 cm diameter-at-breast-height (DBH) will be measured for status (live/dead), size (DBH) and condition. Tree seedlings will be quantified by species <2.5 DBH within quadrats in order to evaluate any encroachment of trees in grassland systems over time.

See Forested Plot methods for details on data collection. Earthworm Assessment data will not be collected in grassland systems. However, Visual Obstruction Readings will be recorded at two locations per transect. The Visual Obstruction Method, commonly referred to as the Robel Pole Method, can be used to estimate the amount of standing biomass, particularly when certain management activities are being employed such as grazing or fire. Using this method, height and vertical density of standing vegetation can be monitored. It can be used in both upland and riparian areas where vegetation is less than 4 feet tall.

Visual Obstruction Reading

VOR observation points are conducted at the 15m and 30m marks of each transect. The sampling process involves taking a set of VOR readings from the four cardinal directions (N, E, S, W) using a VOR (Robel) pole. The VOR pole has alternating decimeters clearly marked along the length of the pole (Robel et al. 1970). The observer will take VORs at a height of 1 m and a distance of 4 m from the pole. Record the lowest half-decimeter mark visible on the pole (i.e., not completely obscured by vegetation). Once the three transects have been established, it is recommended that you record VOR before doing anything else, so that there is minimal disturbance to the vegetation structure.

Tree Measurements (if applicable)

If canopy tree species are present that consist of >10% canopy cover, and there are woody species $\geq$2.5cm cm DBH present in the plot, transects should be spaced 20 m apart. Otherwise, if trees are present, but <10% cover, proceed with belt transects with the transects 10 m apart, measuring trees according to forested methods, see sampling details in that section.

Quadrat Measurements

See Forest Methods.

Direct Browse and Shrub Frequency

See Forested Methods. Despite there being minimal deer browse impacts in grassland areas, data collected on shrubs and other woody species will be used to assess woody species frequency.

Coarse Woody Material (if applicable)

See Forested methods.

Additional Species Walkthrough

See Forested methods.

Open Wetland Criteria and Plot Establishment

Wetland sampling criteria:

- The minimum area of suitable habitat is site dependent. Transects can be modified to fit narrow wetland zones (ensuring that there are ≥15 quadrats total), but an attempt should be made to avoid this scenario. Spacing of transects is 10 m apart, similar to grasslands.
- Sites with monocultures of *Phragmites* or *Typha* are allowed if there are still native species present in the mix and have >20% cover. These areas are typically not directly affected by anthropogenic degradation, but rather indirectly. However, these sites may require field assessment to decide whether they were formerly plowed or planted sites to decide if they qualify.
- Temporarily or lightly grazed wetlands where native vegetation is still dominant and tussock forming sedges have not been destroyed.

Sites that will not be considered include:

- Currently (or formerly) cultivated, or frequently hayed.
- Sites being grazed during the sampling season.
- Artificially constructed wetlands.
- Sites in ditches or immediately adjacent to one.
- Artificially constructed wetlands.

- Areas within or adjacent to impoundments, where there is very little terrestrial vegetation present and water fluctuations are high.
- Areas too narrow or small to accommodate transect length (stream channels, small basin).
- Aquatic systems or permanent, deep-water habitats where there is > 1-2 ft of perennially standing water and/or there is <30% terrestrial vegetation present and floating, emergent and submerged aquatic vegetation dominates.
- Areas where the majority of the plot is too deep to sample safely, even if temporarily due to flooding. If some team members can effectively walk through deeper water, the rest of the crew should not be placed in an uncomfortable situation if they are not okay with working in this situation.

Wetland Response Design and Data Collection

Similar to the other methods above, vegetation will be surveyed in 1 m^2 quadrats at regular intervals along transects for a total of 24 quadrats per plot. Sampling will occur along the same three transects as in other habitats. If plot occurs in a wetland basin where vegetation shows a gradient of vegetation zonation according to increasing water depth, then transects will instead be placed perpendicular to this gradient (i.e., perpendicular to topographic contours), emanating from the wetland basin margin nearest the GRTS random point (Figure 28).

In many cases, establishing transects perpendicular to the wetland margin will not be necessary and the transects should be established in the normal east-west pattern to eliminate bias. For example, situations where transects will likely not require adjustments to the transects are wetlands that do not have distinct vegetation zonation from margin to interior, such as a large shrub swamp with mostly homogenous vegetation throughout or large peatlands that are either entirely bogs or fens. In most situations, these decisions about plot configuration are determined prior to field visit, as the wetland size and homogeneity (more or less) can be determined from an aerial photo.

Transects are terminated if they reach open water with less than 30% plant cover, when water becomes too deep to sample safely, or when the opposite end of the wetland is encountered. Transects are placed at least 10 m apart in open habitats (when there are no trees). However, if there is space to accommodate it, semi-forested systems such as forested bogs with stunted black spruce, should have 20 meters distance between transects to allow room for the tree belt transects.

In smaller basins, the transects will be established approximately 5m from the edge of suitable habitat to minimize shrub margins or open water moats along the edge (Figure 28). If a plot cannot be established according to these configurations, then sampling will not be conducted and the next site that meets sampling criteria should be chosen.

See Forested Plot methods for details on data collection. Visual Obstruction Reading and Earthworm Assessment data will not be collected in open wetland systems. Instead, Surface Water Chemistry Data will be recorded at up to four locations within or adjacent to the plot. See information outlined below.

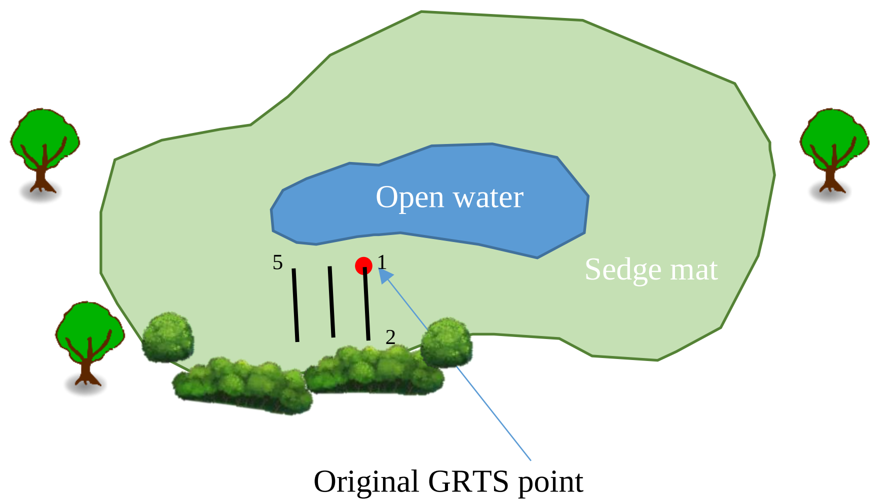


Figure 28. Potential configuration (not to scale) of transects in irregular shaped wetlands with wet meadow vegetation surrounding open water. Transects here are rotated from the typical east-west configuration so that they run perpendicular to the contours of the basin, avoiding distinctly different shrub zone margins, if present, or open water moats or interior pools.

Surface Water Chemistry Sampling

There is generally a close relationship between the chemical composition of the peat and the water filling the pore spaces in the peat, and both have been used to assess chemistry and nutrient gradients. Water chemistry is more subject to the variations of precipitation and drought than is peat water chemistry – the ion concentrations become higher as the amount of water decreases in a dry period. On the other hand there are differences between hummock, lawn, and carpet peat and groundwater is a good integrator to characterize a site as a whole. Peat waters can be sampled from surface waters or pools within the peatland, which are subject to variation with time since last rain, or from a specific depth. Make sure the meter has been calibrated prior to going in the field, according to the multi-probe manual specific to the instrument being used.

Take up to 4 samples throughout the plot in order to capture a variety of measurements and microtopography, if it exists, throughout the plot. For example record data from a pool or peat hollow, from a more contiguous sedge mat lawn, and from an area adjacent to a peat hummock. You will find that the measurement are often slightly different.

1. Put on nitrile gloves, if not already wearing them, to avoid contaminating the water sample with hand oils, lotions or other substances.
2. Record data on pH, conductivity and temperature from at least two and up to four areas within the plot – ideally two sample spots between transect 1 and 2 and two sample spots between 2 and 3. It may be necessary to gently cut through the peat mat with a knife or

push down on the upper surface of peat with a piece of PVC pipe to allow enough water to pool into the surface for sampling. Do this gently as to not stir up a lot of muck and debris in the process and to limit the amount of aeration. Sampling deeper within the upper peat surface using a cylinder with small holes drilled in the bottom (as opposed to only from surface pools) will provide a more accurate reading.

3. Do not sample water that has accumulated in surface hollows or pools. This water is typically closer to neutral, as it often related to a rainfall event and/or has been exposed to ambient temperature and oxygen. Significant variation has been found in pH measurements related to the degree of aeration of samples, time of day, and fine-scale vertical and horizontal gradients in surface pools (Tahvanainen and Tuomaala 2003). Thus, attempt to sample further down within the peat profile.
4. Note if precipitation has occurred within the last 48 hours.

Tree Measurements (if applicable)

If canopy tree species are present that consist of >10% canopy cover, and there are woody species ≥2.5cm cm DBH present in the plot, establish transects 20 m apart. See forested methods for sampling details. Otherwise, if trees are present, but <10% cover, proceed with belt transects with the transects 10 m apart, measuring trees according to forested methods, see sampling details in that section.

Quadrat Measurements

See Forested Methods.

Direct Browse and Shrub Frequency

See Forested Methods. Despite there being minimal deer browse impacts in wetland areas, data collected on shrubs and other woody species will be used to assess woody species frequency.

Coarse Woody Material (if applicable)

See Forested methods.

Additional Species Walkthrough

See Forested methods.

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Appendix A. Accepted list of complex species groups for the field

Genus	combined species	abbr	Notes
Amelanchier	laevis/interior	laev-int	
Amelanchier	sanguinea/spicata	sang-spic	
Antennaria	neglecta/howellii	neg-how	
Asclepias	speciosa/syriaca	spec-syria	Without flowers, can be difficult
Carex	brevior/bicknellii		Prairies
Carex	gracillima/arctata	grac-arct	Northern forests
Carex	sect. Ovales		
Carex	tetanica/meadii		Ecotones b/w wet and dry prairies
Epilobium	ciliatum/coloratum/glandulosum	cil-col	Wide-leaved
Epilobium	leptophyllum/palustre/strictum	lept-pal	Narrow leaved
Equisetum	laevigatum/hyemale	leav-hym	
Galium	trifidum/tinctorium		
Helianthus	giganteus/grosseserratus/nuttallii	gig-gross-nutt	
Melilotus	alba/officinalis	alba-off	
Packera	aurea/pseudaurea	aurea complx	
Pilea	fontana/pumila	font-pum	
Rosa	acicularis/blanda/woodsii	Rosa complx	
Rubus	allegheniensis/rosa/canadensis, etc.	blackberries	canes are thick and heavy, often 6+ ft. Generally growing upright but tend to lean. Prickles when present have a broad base and a sharp tip shaped like a cat's claw that can easily tear skin.
Rubus	idaeus/occidentalis	raspberries	silvery-colored leaf backs, both occur in southern MN
Rubus	ithacanus/satis/ferrofluvius/steelei, etc.	dewberries	canes can be very long, nearly 10ft, arcing. Tip-rooting defines this group. Prickles tend to be sharp and hard but smaller than highbush blackberries and lacking a broad base. Flower in june.
Rubus	regionalis/semisetosus/uniformis/vermontanus, etc	bristleberries	short canes that stand more or less upright with no tip-rooting, mostly flowering in July, some spp. have prickles like the dewberries, but mostly they are just strong bristles that do not tear skin
Sonchus	arvensis/asper/oleraceus	Sonchus grp	
Viola	heart-leaved group		
Viola	macloskeyi/renifolia	mack-reni	