Grassland and Forest Understory Vegetation Monitoring: An Introduction to Field Methods

Research Report

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Introduction

Forest tree monitoring has reached an admirable degree of precision and uniformity, but the same cannot be said for herbaceous and shrub vegetation monitoring. This is not a trivial failing. The ability to characterize and monitor herbaceous/shrub vegetation trends over the long term is essential for proper management of biodiversity, species at risk, ecological restoration, climate change effects, wildfire and prescribed fire response, invasives and grazing values. This article attempts to convey a basic understanding of the quantitative tools of grassland, wetland and forest understory monitoring. It is directed to field staff with management responsibilities for Crown lands, parks, conservancies and private holdings. Content is based on the author's three decades of field monitoring experience and on the monitoring literature. Some older methodologies no longer in common use, and qualitative assessments have been eliminated for the sake of brevity. Sampling design and statistics are beyond the scope of this article. For readers seeking greater detail on the methods described, the annotated bibliography is organized by subject area.

The author hopes to encourage more long-term monitoring of our grassland and forest understory resources. In addition, a large number of archival vegetation monitoring installations and data can be found around the Province. Relocating these installations and remonitoring them with the original or a compatible methodology provides a valuable source of long-term data and trends. Repeat monitoring over time is crucial in dry ecosystems such as grasslands and woodlands, since changes are gradual, and weather-induced variation in vegetation parameters is generally of greater magnitude than variations resulting from human intervention.

Carefully defining the objectives of a planned monitoring effort, and determining the staff time available for it, will dictate the choice of methodology. The techniques employed to monitor a specific component of the vegetation, such as a rare plant or new invasive, will differ from those used to characterize the entire plant community, and a project analyzing grazing or fire impacts might employ different methodologies yet again. Monitoring can focus on the entire plant community, just the dominant species, or just on a single species of interest. A current minor vegetation component could become significant in the future, so full plant community assessments should be chosen if time and budget are available.

The monitoring of herbaceous and shrubby vegetation falls into three overlapping categories:

Gayton, D. 2013. Grassland and forest understorey vegetation monitoring:
An introduction to field methods.
Journal of Ecosystems and Management 14(3):1–9.
Published by FORREX Forum for Research and Extension in Natural Resources.
http://jem.forrex.org/index.php/jem/article/viewFile/173/494

JEM
Vol 14, No 3
Journal of Ecosystems & Management

- Species and plant community identification, biodiversity assessments, and vegetation mapping
- Species cover, height, frequency and richness parameters
- Biomass production and removal parameters

Stratification: A first step

A crucial preliminary step for any monitoring project is site stratification. Monitoring datasets that lump different plant communities (e.g., riparian together with upland, or forest understory with open grassland) are of little value. Before establishing monitoring locations, a site reconnaissance should be performed, ideally together with local experts. Using field observations and aerial photos, the site can then be divided (stratified) into different vegetation types based on permanent features—elevation, aspect, moisture regime and soil type. The number of vegetation types defined depends on the size and variability of the site and the monitoring objectives, but three to ten types is a typical range. Intensive monitoring may only focus on one or two of the mapped vegetation types. Taking representative landscape photos and attaching a short verbal description of each vegetation type is a useful asset to future data users.

Grassland and forest understory monitoring generally consists of establishing permanent linear transects, 25-100 meters long, and making vegetation observations along that transect. Random placement of multiple monitoring transects is good scientific procedure, but many monitoring projects are flawed because randomly placed points mix data from more than one landform or vegetation type. This pitfall can be easily avoided by stratifying first and then randomly placing the monitoring points within each defined vegetation type, and recording the data separately for each type. Even if the monitoring objective is to gain an overall, landscape-level perspective, it is preferable to record data separately by vegetation type and then, if needed, merge the data for final analysis.

Wetlands and riparian areas present unique monitoring challenges, as distinct vegetation types tend to occur in very narrow bands along or around the water body. Good community stratification is essential here. Transect length may need to be shortened to ensure sampling stays within the specified bands.

Species and plant community identification

Species identification forms the basis for monitoring. Shrubs, broad-leaved herbaceous plants, grasses and grass-like (sedges and rushes) are typical categories used in grassland and forest understory monitoring. Non-vascular mosses and lichens can be included as well if they are deemed important to the monitoring objectives.

Species identification can be challenging in grass-dominated stands, more so if flowering parts have been grazed off or flowering is suppressed by grazing. Plant identification is best done at "peak phenology," i.e., the time of year when the largest number of plant species are in flower. Peak phenology varies from late May in low elevation sites close to the 49th parallel, to early August in Northeastern BC. Spring ephemeral species are notorious for completely disappearing as the season progresses, so for an exhaustive plant community assessment, the normal peak phenology field visit should be preceded by a spring visit, to capture the flush of spring ephemerals.

The vehicle for recording species identification is the floristic list, which documents all species encountered onsite by location, date, common name, scientific name, previous scientific names (if any), vegetation category (i.e., shrub, grass, etc.) and the name of the person collecting/identifying the plant. A single field visit is unlikely to capture all species, so the floristic list for a particular site should remain as a living document, to be added to over time. Floristic assessments are best done prior to the commencement of monitoring, so personnel doing the actual monitoring have the convenience of a known list of species to work from. Even very intensive cover or frequency monitoring is unlikely to capture all species on a site, so the floristic list is important for identifying uncommon or rare species, and newly arrived invasives.

Renewing a monitoring site's floristic list periodically provides the raw material for assessing changes in site biodiversity over time.

Intensive floristic assessments involve collecting, drying, mounting and identifying plant specimens, for external verification and future reference. Photographing individual plants is now of little value, since the advent of online floras such as e-Flora and the USDA Plants Database, which include a range of good quality plant photos.

Vegetation cover

Vegetation cover estimation is the most widely used method of characterizing herbaceous and shrub vegetation. Cover (the 2-dimensional area occupied by a species) is used as a proxy for the relative dominance of that species within a plant community. The three common variants of cover analysis are visual estimates, point intercept and line intercept.

Visual cover estimates

This method involves placing an observation frame just above the vegetation and visually estimating the two-dimensional cover of each plant species found within the frame. The frame can be rectangular, square or circular, typically enclosing an observation space of between 0.1 meter^2 and 2 meters^2. In doing visual estimation, the space inside the frame is taken as 100 percent, and the cover of each plant of each species within the frame is mentally aggregated into a single percentage value for that species in that frame. To visualize this process, imagine taking a two-dimensional photograph of the vegetation within the frame and then cutting up the photo and aggregating all the pieces representing species A, then species B, and so on. The total area of all species, plus the area occupied by plant litter, bare soil, rock, etc. is made to equal one hundred percent. In dense, multilayered stands, plant cover can exceed one hundred percent.

Typically vegetation monitoring is done along permanently marked linear transects, with observations (also referred to as plots, or quadrats) spaced at regular or random intervals along each transect. With all methods, maintaining a reasonable spacing between transects and observation points is important so that spatial autocorrelation (vegetation in adjacent observation points close enough that they influence each other) is avoided.

Visual cover monitoring has many variations and details, and that is wherein the devil lies. If the project involves re-monitoring of an existing site, it is best to replicate the original methodology. If switching to a different methodology, some portion of the original installation can be monitored using both the original and the new methodology and a conversion ("crosswalk") factor developed to put old and new data on the same footing.

If a new visual cover project is contemplated, the following points should be considered.

Monitoring frame size

Visual assessment of cover works best when all the vegetation within the monitoring frame can be seen, identified and assessed from a single vantage point above the frame. The traditional 20cm x 50cm Daubenmire frame size was selected based on the viewer being able to see the entire frame without having to move his/her head. If the vegetation being monitored contains a fairly continuous cover of large plants (a sagebrush flat, for instance), then a larger frame of one or two meters squared may be selected. Beyond this frame size, however, it becomes very difficult to accurately identify and assess the vegetative cover of smaller plants (particularly grasses) unless the vegetation is unusually sparse.

Canopy vs. Foliar assessment

The visual assessment of cover falls into one of these categories. Foliar assessment just counts the area of actual leaves, stems and branches. Canopy assessment includes the air spaces in between: the observer in effect draws a mental line around the periphery of an individual plant, and estimates the area inside that periphery. Foliar assessment is the more precise and repeatable of the two approaches.

Monitoring the substrate

Monitoring may also include the non-living components: litter, bare soil, rock, feces, etc. Litter is a challenging component to monitor, due to variations in size (from fine leaves to tree branches) and degree of weathering. Measuring the amount of bare ground can give some measure of the potential erodibility of the site. Including the substrate in vegetation monitoring creates an additional time requirement, both in the field and at data entry.

Cover classes

The original Daubenmire frame methodology, and subsequent modifications to it, recorded data by cover classes (e.g., 1-5%, 6-25% and so on), and then used the midpoint of each class for summary calculations. Current practice has moved away from cover classes for statistical reasons, in favor of estimating to the percent.

Shrubs and trees

Woodlands (a mix of grasses, forbs and trees) and shrublands present unique monitoring problems. Vegetation that is more than 1.5 meters in height is not suited to traditional frame-based visual cover assessment. A common solution to the dilemma of woodlands and shrublands is to perform a dual vegetation assessment. Transects are established and a conventional cover assessment is done for the herbaceous vegetation. This is followed by a separate assessment (using the same transects) of the tall woody vegetation, using the line intercept method. If the shrub canopy is less than 1.5m, a large frame (e.g., 1x2m) can also be employed, to do visual cover estimates of the shrubs.

Line intercept

Line intercept involves laying a measuring tape down along a permanent transect, and recording the point at which a shrub or tree first intersects the plane of the tape, and again when it last intersects it. The observer will look down over the tape in the case of shrubs or, in the case of trees, look up and use a “mental plumbob” approach to determine the start and stop point (usually estimated to the nearest 1/10th meter) of each shrub or tree whose canopy intersects the tape. These values are then summed for each species to determine cover. Line intercept can also be used for herbaceous vegetation, but is a much more time consuming method than cover or point intercept.

Belt transect

The belt transect is also used for shrubs, tree seedlings, or herbaceous vegetation that grows in separate, spaced clumps. The observer walks a traditional transect while holding a horizontal reference stick of specific length, with its midpoint directly over the transect. Every species of interest that falls under the plane of the reference stick is noted and assigned to a pre-determined size (two-dimensional area) class. This method is less accurate than line intercept, but substantially increases the area sampled with little increase in field time. With a five-meter reference stick and a 20-meter transect, for instance, the sampled area becomes 100 meters^2.

Point intercept

This method (sometimes referred to as line-point intercept) involves projecting a sharp metal point vertically downward into the vegetation canopy and identifying and recording each species that the point contacts in its passage through the canopy. This is done multiple times over the length of a transect. Large, sharpened pins may be used, or a horizontal frame laced with crossed strings to create observation points. Other variants use a laser or a visual device with crosshairs. The observer simply records “hits” for various species, making it a less subjective method than cover estimation. The disadvantages of point intercept are: the equipment tends to be cumbersome; leaf movement in wind can make the method less definitive, and with vertically-oriented vegetation such as bunchgrasses, it can be difficult to determine if a hit has occurred or not. Since the actual area sampled is far smaller than a cover analysis, fewer species will be recorded for the same amount of sampling effort. Repeatability is important in all monitoring procedures, but is critical to point intercept because of the small area measured. Transect and observation plot relocation and monitoring technique must be precise for point intercept repeat monitoring data to be valid.

Basal cover

This method measures the 2-dimensional area of the plant right at the soil surface. Basal cover can be measured using either the visual cover, point intercept or line intercept method. The logic behind monitoring only the plant’s basal area is that it experiences less weather-induced seasonal and annual variation than the aerial parts of the plant. The basal cover method only works with vegetation that grows in large, defined clumps. A stand of cheatgrass, for instance, would not lend itself to basal cover measurement.

Frequency

Simply stated, frequency is the percentage of times a particular species is encountered during a series of random placements of a monitoring frame. Frequency has some advantages over cover or intercept analysis; it generally requires less field time, is more objective and is more sensitive to changes in the plant community. A disadvantage is that it does not provide an accurate assessment of relative species dominance. For instance, a tiny annual “understory” plant growing beneath the sward of a bunchgrass-dominated grassland may be recorded more often than the bunchgrass species, but has much less significance to the plant community than the bunchgrass. Frequency can be done using a standard sized monitoring frame, or a series of nested frames. Because of its limitations, frequency should be done in combination with other methodologies. Frequency values can also be derived from visual cover estimates.

Height monitoring

Vegetation height, particularly shrub height, is an important parameter for certain birds and mammals. Sward heights can also be used as a measure of the forage removed after grazing events. Height can be incorporated along with cover or frequency monitoring by measuring the height of the tallest plant in each observation plot. The Robel pole is another device for measuring sward height. A graduated pole is viewed from a specific distance and height, and the last graduation visible above the sward is recorded. Multi-layered stand structure can also be assessed using height measurements.

Density

Density is the number of individuals of a particular species in a plot of a given area, irrespective of their size. Density is a metric that is now infrequently used in operational monitoring.

Species richness

Species richness (or alpha biodiversity) is the total number of species found in an area of defined size. Richness data can be inferred from cover, point or line intercept data, but a more intensive methodology, the Modified Whittaker Plot, is now commonly used for richness assessments. It is based on a 10x30m macroplot, with microplots of varying sizes placed inside.

Biomass monitoring

Biomass measurements are used to monitor foraging and browsing, and in primary productivity studies. Typical plot size is one-half to one meter squared; all vegetation inside the plot can be clipped off at 2 or 2.5cm at ground level (or at a specific height above ground level), bagged, dried and weighed. Vegetation components may be separated into grasses/grasslike, forbs and shrubs. Unless the plant community is very simple, separating plants to the species level for biomass estimation can be very time consuming.

Shrubs present a biomass monitoring challenge because they are typically composed of annual leaves, current-year shoots and perennial woody stems. The particular shrub type being monitored will dictate a protocol for collecting only the current-year biomass production.

Assessing forage and browse removal by wild or domestic ungulates is done using temporary cages that exclude foraging and browsing for a growing season. Clipping and weighing the biomass produced inside the cages at the end of the growing season represents the total annual productivity. Equivalent paired clips on uncaged vegetation quantifies the residual biomass, and the difference between the two values represents the amount of forage removed. If desired, forage samples can be tested for crude protein and digestibility values.

Combined methods

A number of hybrid methods have been developed over the years:

- Cover/biomass or height/biomass correlations, mainly for range management work
- Relative dominance indices: the cover of a particular species as a percentage of the total cover of all species.
- Floristic richness and evenness assessments
- Rangeland health assessments, which combine cover estimates with a number of other vegetation and soils parameters

Plot marking and documentation

No matter which methodology is used, permanent and relocatable plot or transect markers are essential for precise repeat monitoring. Wooden markers eventually rot and break off. Metal markers are best, but should not protrude any distance above the ground, to avoid injury to people, animals and vehicles. With the advent of inexpensive GPS units, it is now possible to drive a metal marker in flush with the ground and relocate it years later. The author uses 50-60cm lengths of rebar with the top 10-15cm bent into a crook. A small piece of orange plastic barrier fencing is attached to the crook, and the rebar is driven into the ground vertically so the crook is just above the soil surface. The swatch of barrier fencing is durable, and provides a visual clue to the location of the marker for many years. For convenience, wire survey flags can be placed next to each plot marker during installation and monitoring, and removed when the project is complete. Good quality survey tapes should be used, so tape stretch does not skew remeasurements.

Transects were traditionally established along a baseline, which in turn was linked to an identifiable tie point, for relocation purposes. GPS units have made baselines and tie points unnecessary. However, a detailed plot map should accompany the GPS data. Clear, precise description of the methodology used in new monitoring installations is crucial. Details that seem intuitive and not worth noting down at the time can nullify the value of remonitoring results years later. Common omissions are not indicating which end of the transect is the start point for measurements and which side of the transect is being monitored. If a rectangular cover frame is used, indicate whether the short or the long side is parallel to the transect, and which corner of the frame (front or rear) is placed adjacent to the assigned meter point on the transect. For visual cover estimates, define whether it is done by the foliar or canopy method, and define the "in-out rules" for quantifying plants rooted outside the monitoring frame but leaning in, and those rooted in but leaning outside the frame. For line intercept, a "gap size threshold" must be specified, so the operator knows to ignore canopy gaps below a certain minimum length.

When developing the documentation for a new monitoring installation, one must assume that future remonitoring will be done by personnel with no previous familiarity with the site, the original researcher or the methodology, and that the current data entry software will be obsolete.

Field training in the chosen methodology is always recommended. If more than one person is involved in monitoring, group "calibration" sessions in the field will ensure consistent application of the methodology. Visual cover estimating ability can be sharpened in an office exercise: take pieces of paper that represent different percentages of the frame size, cut them up into irregular shapes and distribute them under the frame. Operators then have the opportunity to compare their estimates to actual values. Estimating accuracy has been shown to be lowest at small cover values, so the paper exercise can emphasize the 1% through 15% cover range.

Summary

Given the scarcity of good long-term studies, we often resort to "substituting space for time," i.e., choosing a series of similar sites that represent a chronosequence since the imposition of a common treatment. While this approach provides quick results, it also introduces new variables based on subtle biotic and abiotic differences between sites. Repeat monitoring at the same site or sites over time requires patience and institutional persistence, but in the end yields the most reliable data.

The level of vegetation monitoring rigor can range from the subjective "windshield tour" to a fully replicated, research-grade installation, and all levels in between. The methods outlined above can be used for either operational monitoring or research-grade monitoring; the difference would be the degree of replication and statistics applied.

There are as many monitoring methodology variants as there are workers in the field. Methodologies vary by region, by institution, and over time. Making an informed choice of methodology is important, but equally important is the detailed documentation of the chosen methodology, to guide future users of the original data. The culmination of this painstaking work will be a greater understanding of the functioning and deep mechanics of British Columbia's treasured ecosystems.

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