Draft Invasive Plant Species
Vegetation Sampling

> ***NOTE****: While this section draws from all of the resources listed at the end of this section, the PRIMARY source is* ***Field Methods in Vegetation Science.***
> ***Mark V. Wlison (Oregon State University)*** *and you are encouraged to refer to it for full details on the material presented below.*

This document describes:

- Vegetation Attributes
  - Occurrence
  - Frequency
  - Cover

- Sampling designs
  - Optimal
    - Random
    - Stratified Random
    - Gradient-oriented Transects
  - Flawed
    - Preferential
    - Systematic

- Study Area and Sampling Plot Size

- Sampling Plot Shapes/Configurations
  - Quadrats
    - Rectangular
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    - Nested
  - Transects
    - Line-intercept transect
    - Point-intercept transect
    - Belt transect

- Locating Sampling Plots Within the Study Site
  - Locating quadrats using the coordinate system
  - Simple random sampling by area for non-rectangular study areas
  - Using GPS to locate quadrats
  - Locating quadrats using the grid system
  - Locating lines for line-intercept measurements of cover

See also ***Vegetation Sampling Design Checkilst***

You may wish to refer to:
Using Random Numbers for Locating Sample Subplots
How To Make A Rectangular Frame
Hints On Using A Compass

Random Sampling Learning Activity

Introduction

Sometimes, the entire population is sufficiently small that every member can be counted. However, it is more usual that the population is too large for every plant to be accounted for. A small, but carefully chosen sample can be used to represent the entire population. The design of the sampling program will be influenced by what is being sampled and why.

Vegetation Attributes to be Sampled

Plants may be quantified in several different ways:
Occurrence – whether or not a given species is present or absent. This (1) results in a species list for a plot; (2) can be used to measure biodiversity; and (3) is relatively simple to collect. Usually, individual plants are counted only if they are rooted within a quadrat.

Frequency - the proportion of unit area (quadrat) in which a species is present. The prime requirement in estimating frequency is to use as large a sample size as possible. The frequency of a species is defined as the probability of finding it within a plot when the plot is placed on the ground. Frequency values can vary from 0% to 100%. Frequency reflects both a species' abundance and how much it is spread over a community. Usually, a species is counted as present if a plant of that species occurs anywhere within the quadrat, whether or not it is rooted within the quadrat. Frequency depends on quadrat size. As a consequence, frequency cannot be compared from community to community, from study to study, or from year to year unless the quadrat size is the same.

Cover - is the proportion of the ground (quadrat) obscured by a species' above ground leaves and stems (and flowers). The most common way to measure cover is the visual estimation method. Visual estimation is popular because it is fast, requires no specialized equipment, and can be adapted to plants of various growth forms. A disadvantage of visual estimation is its subjectivity, making it hard to maintain consistent and accurate measurements. Not only do you have to estimate plant cover, you have to be able to identify plants to species and find all cover of each species within the quadrat. The leaves of different species often overlap which means that you have to look beneath other species when recording cover.

Cover can be expressed in the following ways:

- ***Total cover*** is the cover of all plants, ignoring what leaf belongs to which species. Total cover can take values of 0% to 100%.
- ***Combined cover*** is the sum of the cover values for different plant species or groups. Because different species or groups can have leaves that overlap, combined cover can take values that exceed 100%.
- ***Overall cover*** is cover across the entire study area, usually estimated by the average of individual cover values taken from quadrats, lines, etc. For example, total cover in three quadrats might be 60%, 100%, and 50%, leading you to estimate overall total cover as 70%.

The following recommendations are made when estimating plant cover:
Be systematic. Plants within a quadrat will vary in size, shape, and color, making it hard to search for all of them simultaneously. First identify what species are in the quadrat (species list). Once you have established what plants are there, estimate their cover.

Use calibration templates. A good way to keep cover estimates calibrated is to use templates of known size. You can construct sturdy templates from thick paperboard, adding plastic lamination to make them sturdy enough for field work. The most important part is to make sure that you cut the templates to exact measurements. Templates representing 1%, 5%, and 10% cover work well in a variety of vegetation types.

Don't force yourself to round. Estimating cover is subjective, even imprecise. Many people think it is easier to round (up or down) but nothing is gained from this. What is lost is accuracy. If 32% is your best guess, forcing yourself to round to 30% adds an *error* of 2.

Don't use cover classes. Cover class systems divide possible cover values into a few categories, i.e., 0%-10%, 10%-30%, 30%-60%, and 60%-100%. However, cover classes have several drawbacks: (1) means and standard deviations across your quadrats cannot be calculated; and (2) slight errors at the margins of cover classes can lead to huge differences. For example, if you estimate the cover to be 61% when it is really 59%, it is no big deal if you are using absolute numbers. But if you are using the cover class system, choosing between the 30%-60% cover class and the 60%-100% cover class introduces considerable error into your data.

Work in pairs or teams. Better cover estimates can be made when there is more than one person making observations. Each person looks at the quadrat from a different angle, seeing plants and their cover that might be overlooked from a single vantage point. Team members should estimate cover independently and then compare their estimates with the others. The separate estimates should then be resolved into a final, consensus value. One team member can be a data recorder while the others focus exclusively on the vegetation.

Sampling Designs

A good sampling design accommodates: replication, independence, randomness, representative-ness, and interspersion.

- **Replication** is the repetition of equivalent measurements. Replicated measurements are *representative* if they are *independent* of each other and *interspersed* across the community.

- ***Independence*** means that the location of one sample does not affect the location of another. The best way to assure independence is to locate your samples *random*ly.

- **Interspersion***,* the distribution of samples across the community, is another way to make your measurements representative. By definition, any simple random selection of samples is equally likely.

<u>Optimal Sampling Design</u>

- **Random sampling** is the purest form of probability sampling. Each spatial point in the landscape is given an equal probability of being sampled. Random methods are most conductive to statistical analysis.

- **Stratified Random Sampling** is formal way to ensure interspersion. In this method, you first divide the study area into strata. Then, you use simple random sampling to place sampling locations within each stratum.

- **Gradient-Oriented Transect (Gradsect) Sampling** is a variant of stratified random sampling schemes. This approach is based on the distribution of patterns along environmental gradients where transects that contain the strongest environmental gradients in a region are selected. The rationale of the gradsect method is that sampling (transects) oriented along the steepest environmental gradient should detect the maximum number of species in an area. This is best done in conjunction with topographic information of the study site.

<u>Flawed Sampling Design</u>

There are many flawed sampling designs. Two of the most common are:

- **Preferential sampling** simply refers to the place you prefer to place your samples; there is no scientific reason to it. The advantage is that it is quick and easy, important considerations in field work. The disadvantage is that it is not representative of the community.

- **Systematic sampling** refers to a sampling scheme in which a pattern of sampling is imposed on the landscape, i.e., 1 m by 1 m subplots placed 5 meters apart. The problem is that systematic sampling scheme may under sample a preexisting pattern in the vegetation cover that might not be obvious. Completely systematic designs are not replicated, sample points are not randomly located and independent, and the design can be unrepresentative of the whole community.

Study Area and Sampling Plot Sizes

The general site size should be large enough to capture a representative sample of the area to be described. The subplot sizes within the site should be large enough to include significant numbers of individuals, but small enough so that plants can be identified without duplication or omission of individuals.

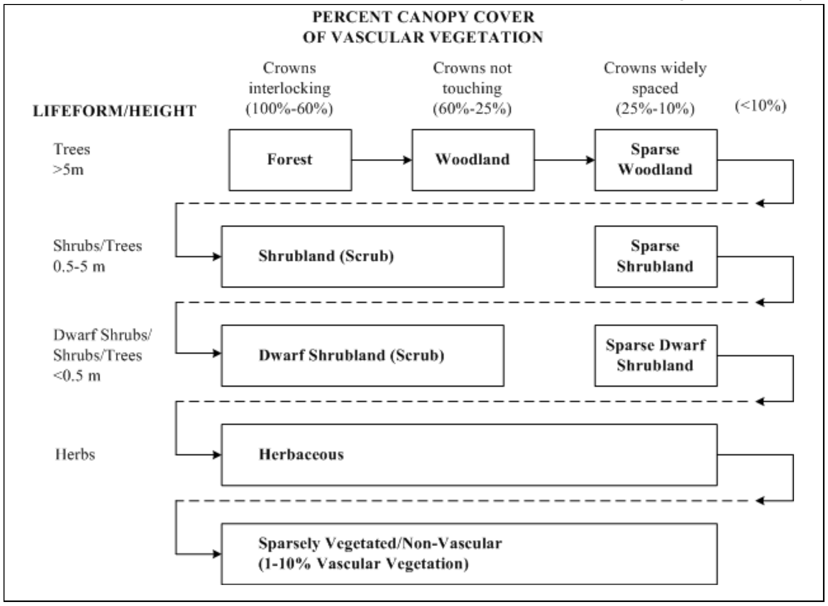
According to the USA National Phenology Network, the size of your total ***study area*** will depend on the scale of your landscape. It is best to choose a site size that allows your students to make a sufficient number of observations across the site with the time you have available. However, the goal is to select a minimum area that will fully represent the species composition of the community. Your monitoring locations should be divided into different sites if their habitats are obviously different. A site should be no larger than 15 acres (6 hectares or 250 x 250 meters). A site can certainly be smaller than this, and larger properties can be divided into multiple sites.

The table below summarizes the recommended study site sizes for various land cover used by the United States Geological Survey (USGS). Note that the maximum size of the forest and woodland sites exceeds the value recommended by the National Phenology Network. This is because wooded sites should generally be larger in order to be able to include a representative number of trees which are usually spaced further apart than shrubs and herbaceous plants. The accompanying figure explains the land cover types.

Land Cover Type	Area of Total Site (m^2)	Dimensions of Sampling Subplots (m)
Forest	100 - 1,000	10x10 - 20x50
Woodland	100 - 1,000	10x10 - 20x50
Sparse Woodland	25 - 1,000	5x5 - 20x50
Shrubland	25 - 400	5x5 - 20x20
Sparse Shrubland	25 - 400	5x5 - 20x20
Dwarf shrubland	25 - 400	5x5 -20x20
Sparse dwarf shrubland	25 - 400	5x5 - 20x20
Herbaceous	25 - 400	5x5 - 20x20
Nonvascular	1 - 25	1x1 - 5x5

(Source: http://biology.usgs.gov/npsveg/fieldmethods/sect5.html)

Landcover



(Source: http://biology.usgs.gov/npsveg/classification/sect5.html#5.1)

Sampling plot size may change depending on species measured. Plot size should be 1 to 2 times as large as mean area of most common species. If you are sampling a forest understory, the rule of thumb is that the subplot size should be at least twice as large as the average canopy of the largest tree species. Cain and Castro (1959) suggest the following sampling sizes:

Vegetation Layer	Sampling size (m^2)
Trees	100
Tall shrubs and low trees	16
Tall herbs and low shrubs	4
Herb layer	1 - 2
Moss layer	0.01 – 0.1

Sampling Plot Shapes/Configurations

Quadrats

Sampling with quadrats (subplots of a standard size) can be used for most plant communities. A quadrat delimits an area in which vegetation cover can be estimated, plants counted, or species listed. Quadrats should be located randomly within a study site. Large quadrats with many plants may require two or more people to obtain an accurate census, while one person may be sufficient for smaller plots or those with sparse vegetation.

Rectangular quadrats

Small rectangular quadrat frames can be fabricated before going into the field. Using these frames insures that the sample sizes will be the same from sample area to sample area and from one sampling day to another. See *Appendix XX* for instructions on how to make a sampling frame.

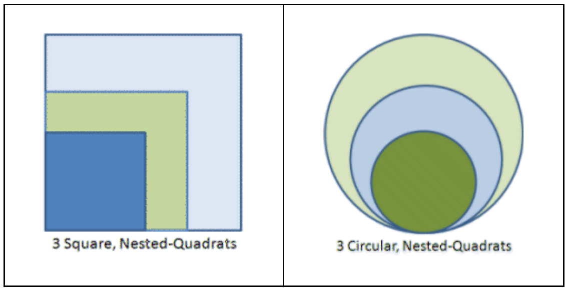
Frames don't work well with quadrats of large size. In these cases, rudimentary surveying is needed to mark the quadrat boundary. First mark the initial quadrat corner with a stake. Then run a meter tape from the plot corner. At the distance corresponding to the first side of the quadrat, place a second stake to mark the second corner. Then sight a 90-degree corner with a compass and run the tape out in that direction for a distance corresponding to the quadrat's second side (See *Appendix XX* for tips on how to use a compass.). Mark this as the third quadrat corner. Continue like this until you get to the fourth corner, which should be where you started.

Circular quadrats

Circular frames are nearly impossible to construct yourself. However, you can also define a circular quadrat with a radius cord. Measure a cord to correspond to the area you want to measure. For example, a 25 m^2 circular quadrat has a radius of 2.82 m. Running the cord from the fixed quadrat center (stake or flag) defines the perimeter of the quadrat. Although circular quadrats work well for measuring density, frequency, and biomass, it is difficult to estimate cover inside a space defined by curved sides.

Nested quadrats

Matching quadrat size to plant size makes sense if all the plants are the same size. But many vegetation studies look at plants of many sizes, from herbs and bryophytes to trees. A solution to the problem of which quadrat size to select is to use a series of nested quadrats of different sizes. For example, for any sampling point, you could use a 30-cm by 30-cm quadrat for measuring small herbs and bryophytes, a 1-m by 1-m quadrat for measuring large herbs and tree seedlings, a 10-m by 10-m quadrat for measuring shrubs, and a still larger quadrat for measuring large trees. The added complexity of nested measurements is outweighed by the greater efficiency of using the right quadrat size for the right plants.



Transects:

One of two methods can be used to lay out the transect line. Either a random starting point and direction are obtained or the topographic gradient for the study site is determined and the transect line is oriented along this gradient.

Line-intercept Transects

Once the transect has been laid out, the species touching the line may be recorded along the whole length of the line. This can include the presence/absence of species or species cover.

The line-intercept species cover method works best for plants with distinct crowns. The method works by measuring the proportion of the line being intercepted by the species being measured. Walking along the transect, record where the plants intercept the tape (i.e., 3.27 m to 3.45 m). These points of interception are typically called "starts" (when enter into a plant's cover) and "stops" (when you emerge from cover). This includes not only vegetation that comes in direct contact with the transect line, but also any species that may lie above or below the vertical plane of the transect line. It does not include vegetation that extends beyond the end of the tape. To determine the plant cover calculate the total length of cover on the tape and divide by the total length of tape.

In another line-transect sampling scenario, a series of points along this baseline are selected using a random or stratified random procedure. These points serve as starting points for transects throughout the area, (i.e., transect lines extend out at right angles from the baseline for some distance, see example below).

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Point-intercept Transects

A point-intercept transect is used to estimate plant frequency. Plant presence/ablsence is recorded at set point along the line.

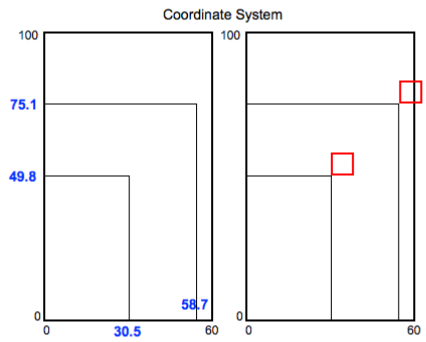
Belt Transects

The belt transect provides information on abundance as well as presence/absence of species. It may be considered as a widening of the line-transect to form a continuous belt (continuous quadrats), or series of quadrats. In this method, the transect line is laid out across the area to be surveyed. Then the plant survey can take place in one of two ways: either a continuous survey can be done a pre-determined distance on both sides (or one side) of the tape or quadrats can be placed (random or stratified) and assess at intervals along the tape.

Locating Sampling Plots Within the Study Site

Locating quadrats using the coordinate system

The coordinate system is most easily explained if we assume that the study area is a rectangle. In this example, the study area is 100 m by 60 m: every point in 100 m by 60 m rectangle corresponds to a pair of Cartesian coordinates. Here, the 60 m side is the X-axis and the 100 m Y-axis. By picking a pair of random numbers, one between 0 and 60 and the other between 0 and 100, you can identify a random location within your study area (see *Using Random Numbers for Locating Sample Subplots*). The figure shows two such locations where X = 30.5 and Y = 49.8 in one pair and X = 58.7 and Y = 75.1 in the other.



The most efficient way for determine the location of the sampling subplots in the field is to create one axis of this coordinate system by placing a meter tape along one side of the study area, with the zero end of the tape at one corner. To locate your plot, go to the point on this axis corresponding to the first number in your random number pair. Then run a second tape out at right angles for a distance corresponding to the second number in your random number pair. Repeat this process for each quadrat location. Note that it is more efficient to select the series of random numbers first and rearrange the sequence of quadrats into an efficient order.

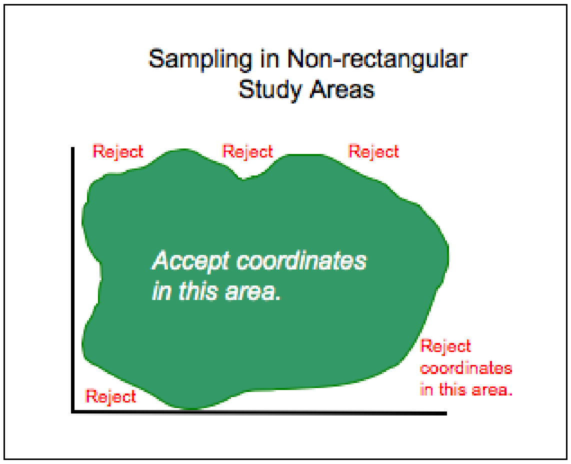
Once you have your random location for the quadrat, you need a system for actually placing the quadrat on the ground. When using the coordinate system, you need to decide if the selected coordinates designate the center of the quadrat or one of its corners. In the example above, the lower, left-hand corner of the quadrat is defined by the coordinates (small red box). The point of the system is to eliminate any subconscious bias in placing the quadrat frame.

The coordinate system has problems along the boundaries. If the random placement results in part of the quadrat being *outside* the sampling area, don't use it. In the figure above, the red "quadrat" at the far right (lower left corner defined by 58.7, 75.1) would be eliminated. In addition, drop any random locations that produce overlapping quadrats.

The axes in the coordinate system represent continuous numbers from 0 to the end of the axis. When picking random numbers you have to determine how many digits of resolution to use in locating your quadrats. We recommend a resolution of 0.01m (1 cm) since most meter measuring tapes are marked down to this interval.

Simple random sampling by area for non-rectangular study areas

Many study sites are not rectangular. You can still use the *coordinate system*, but there is some extra work involved. Pick random coordinates as before but discard any locations that fall outside your sampling site. This process is a lot easier if you have a map of the area boundary so you can select random locations in the classroom. The *grid system* for selecting sample locations does not work well for non-rectangular study areas because the study area usually cannot be broken up into equal-sized rectangles.



Using GPS to locate quadrats

The Global Positioning System (GPS) provides an efficient way to locate points in the field. Modern, affordable GPS units can take you to a defined location within 2-5 meters. GPS can save a lot of effort for *locating sites* or for locating *large sampling plots*. GPS is usually too coarse for quadrats less than 200 m^2 in area and you need to stick with measuring tapes. A good procedure is to use a GPS unit to establish the boundaries of your study area, then use measuring tapes and stakes to locate sampling quadrats.

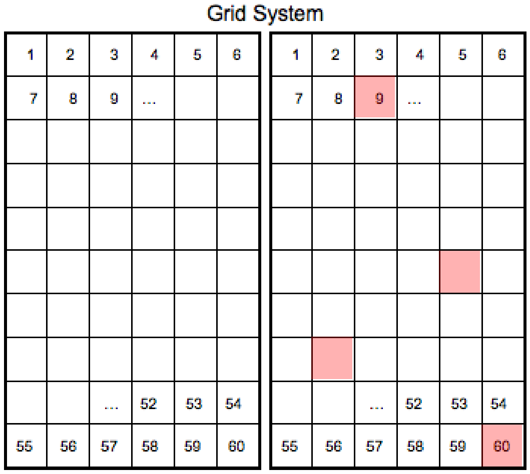
Tips on using GPS in vegetation science:

- Use a GPS unit with a high precision (at least within 5 m).
- Be wary of GPS units that drift rapidly, that is, the readings change before your eyes. Drift occurs because the unit has not locked onto enough satellites or does not have good enough software.
- If you have any drift, create a rule for knowing when you have reached your location, otherwise your subjective judgment will creep in and the sampling will no longer be random. A good rule is to stop the first time the GPS unit says that you have reached your destination. That is, do not wait for the unit to "settle down."
- Once you have stopped, have a rule for locating the plot itself, i.e., mid-point between the toes of your boots.

Locating quadrats using the grid system

In the grid system, divide up your study area into non-overlapping quadrat-sized rectangles. See the figure below for what this looks like. These rectangles make up a grid for your study area. Each rectangle segment of the resulting grid is a potential location for a quadrat. Number all the grid rectangles. Pick your quadrat locations by selecting from their numbers at random (if the number is small, you could pick the numbers out of a container without replacement). To actually find these quadrat locations in the field, use the procedure described for the grid system (*see Using Random Numbers for Locating Sample Subplots*).

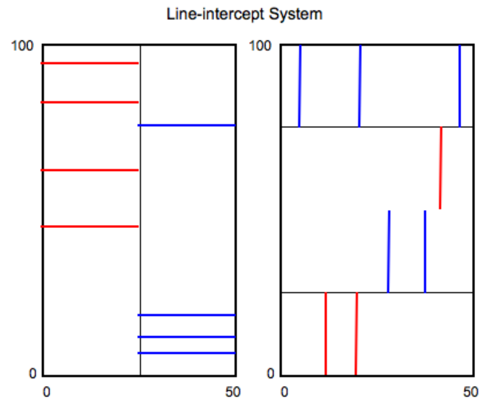
Grid System



Locating lines for line-intercept measurements of cover

The process of locating lines involves selecting a starting point and a direction. The coordinate system described for locating quadrats also works for locating random starting points. You can then pick a random direction by, for example, picking a random number between 1 and 360 and going in that compass direction. This system has boundaries problems because lines are long and are more likely to extend beyond the edge of the study area.

If you have a rectangular study area, a modified method can be employed. In the examples below, the study area measures 50 m by 100 m. Assume that you want to locate 8 lines that are 25 m long within this study area. In the example on the left, a line starting at the 25 m mark along the 50 m side is run the full length of the study area (100 m) thereby bisecting the site. Random points are chosen along this “center” line and eight 25 m sampling lines are run out perpendicular to it. The direction of each sampling line the can be chosen by flipping a coin - left (shown in red) or right (shown in blue).



In the example on the right, two 50 m lines are run out across the study area along the 100 m side at 25 m and 75 m. Four 25 m sampling lines are located at random points along each line with their direction determined by flipping a coin. This is valid simple random sampling, because every part of the study area is equally likely to be sampled and the location of one sampling line does not affect the location of any other line.

Vegetation Sampling

Cain, S.A. and G.M. DE O. Castro. 1959. Manual of Vegetation analysis. Harper, NY pp. 325.

Determining Optimum Quadrat Size and Shape: An Introduction http://www.afrc.uamont.edu/whited/Optimum%20quadrat%20size%20and%20shape.pdf

Ecological Sampling Methods http://www.countrysideinfo.co.uk/biol_sampl_cont.htm

Experimental design considerations for plot-based monitoring; a discussion paper – Environment Canada http://www.eman-rese.ca/eman/ecotools/studydesign/plotbased-monitoring.html

Field Methods in Vegetation Science. Mark V. Wlison (Oregon State University) http://oregonstate.edu/instruct/bot440/wilsomar/Content/Index.htm

Forest Biometry – General Vegetation Surveys and Measures of Biodiversity (Forest and Wildlife Ecology, University of Wisconsin - Madison) http://forest.wisc.edu/facstaff/Radeloff/No10_vegetation_biodiversity.pdf

Forest Biometry – Plot types and fixed area plots (Forest and Wildlife Ecology, University of Wisconsin - Madison) http://forest.wisc.edu/facstaff/Radeloff/No8_fixed_area_plots.pdf

Guidelines for Surveying Soil and Land Resources – Vegetation (Australian Commonwealth Scientific and Research Organization – CSIRO) http://www.publish.csiro.au/samples/Guidelines.pdf

Herbaceous Vegetation Sampling http://spectrum.troy.edu/~diamond/General%20Ecology/sampling.html

Hill, D.A., et al. 2005. Handbook of biodiversity methods.

Methods for Palnt Sampling (Restoration in the Colorado Desert: Management Notes) http://www.sci.sdsu.edu/SERG/techniques/mfps.html

National Phenolgy Network – USA (Frequently Asked Quesitons) http://www.usanpn.org/?q=plant_faq#rep_location

Principles of Vegetation Measurement and Assessement, Univeristy of Idaho, College of Natural Resources http://www.cnr.uidaho.edu/veg_measure/schedule.htm

Terrestrial Vegetation Biodiversity Monitoring Protocols – Environment Canada http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/vegetation/introduction.html

USGS: Biology – Field Sampling Theory http://biology.usgs.gov/npsveg/fieldmethods/sect2.html

USGS: Biology – Field Method http://biology.usgs.gov/npsveg/fieldmethods/sect5.html

Vegetation Analysis: Plotless Sampling Techniques http://ecophys.biology.utah.edu/public/Biology_5465/xprotected/red_butte/Vegetation_sampling_(Cox).pdf