WILDLANDS AND WOODLANDS STEWARDSHIP SCIENCE

Manual for Long-Term Vegetation Monitoring

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Manual for Long-Term Vegetation Monitoring

A COMPANION PAPER TO

Wildlands and Woodlands Science

Long-term Forest Measurements for Ecological and Conservation Insights

AND

Wildlands, Woodlands, Farmlands & Communities

Broadening the Vision for New England

Edward Faison, David Orwig, David Foster, Emily Silver, Brian Hall, Brian Donahue, and Audrey Barker-Plotkin

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PREFACE

The Wildlands and Woodlands (W&W) initiative is a broad, collaborative effort to conserve at least 70% of New England in forest and 7% of the region in farmland by 2060 (http://www.wildlandsandwoodlands.org/). At the heart of this initiative is the awareness that our wooded and agricultural landscapes and urban treescapes provide immeasurable natural and human/societal benefits and the conviction that we should understand these systems better, manage them wisely, and conserve them for the future. As part of W&W, Stewardship Science seeks to encourage widespread application of an accessible approach to monitoring forests, agricultural lands, and other open space that interested landowners or conservation-minded individuals can use to track changes in their woods or fields over time. Whether the motivation is carbon storage, plant diversity, wildlife habitat, management for timber, or understanding how natural communities are shaped by natural forces and human activities, anyone equipped with a notebook, tape measure, pencil, and the willingness to puzzle through a book of plant identification can readily develop a robust and valuable set of observations.

This idea is not new. For over 150 years, leading conservationists and ecological thinkers beginning with Henry Thoreau have argued that there is much to be learned through simple, long-term measurements of vegetation growth and change. These authors also stressed the scientific value of areas free from management or disturbance as critical reference areas against which to compare changes occurring in managed or disturbed areas. Yet, there are still remarkably few examples of private landowners, land trusts, forestry organizations, or conservation groups that (1) base their understanding, long-term goals and management practices on a regular system of observations and measurements and (2) establish reference areas for actively managed areas that enable comparison and understanding of the outcomes of the management. This guide is an effort to change this situation in New England.

Although this manual can be used solely to help you understand your own land, the program also provides a shared database https://harvardforest2.fas.harvard.edu/asp/hf/php/ww/ww_project.php where you can record forest data and have access to simple graphing and analysis tools, as well as to other participant datasets across New England. Thus, Stewardship Science makes monitoring simpler for the landowner but also more widely useful for understanding changes to New England's wooded and open landscape over time.

All units of measurement in this manual are metric for greater compatibility with existing monitoring programs and datasets. For additional background on the W&W Stewardship Science initiative, please see *Wildlands and Woodlands: Long-Term Forest Measurements for Ecological and Conservation Insights* at https://www.wildlandsandwoodlands.org/sites/default/files/Wildlands%20and%20Woodlands%20Science_HSHF30_June%2013_2014_0.pdf.

WHAT IS LONG-TERM VEGETATION MONITORING?

Long-term vegetation monitoring is the systematic, repeated measurement of trees and other plants in the same location over at least a 10-year span. Initial measurements are compared with subsequent measurements in order to document patterns of change (see Figure 1). Although meaningful vegetation change may be documented within a decade, longer-term monitoring generally provides greater benefits for understanding changes and trends.

WHY IS LONG-TERM MONITORING IMPORTANT?

We are living in an age of great environmental change marked by a warming climate, accelerated extinction rates, widespread species invasions, forest fragmentation from roads and development, and other environmental degradation from human activity. These changes directly affect the natural environments—from urban park to rural hill farm to expansive forests—that sustain our lives in New England. Forests mitigate climate change by sequestering and storing carbon; provide us with clean water and air, flood resilience, and wood products; shade our streets and homes; and offer places for healthy outdoor recreation and spiritual renewal. Farms provide a local food source and important habitat for plants and animals that live in treeless vegetation communities. To understand how our forests and fields are changing as a result of human activity and natural forces, and to enact thoughtful management plans that prevent undesirable changes and encourage desirable ones, we need a method of obtaining reliable information about vegetation change. Long-term monitoring, if done carefully, provides reliable knowledge and fascinating insights. Casual observation, which is often fallible, does not.

HOW IS THIS VEGETATION MONITORING PROGRAM DIFFERENT FROM OTHERS?

Although a number of excellent vegetation monitoring programs exist in New England today (see Appendix G on page 32), most are designed for and used by professional forest and grassland scientists. We have designed W&W Stewardship Science to be accessible and useful to the educated layperson. In addition, our online database provides helpful graphing and analysis tools and allows landowners to examine their forest trends in the context of other datasets across the region.

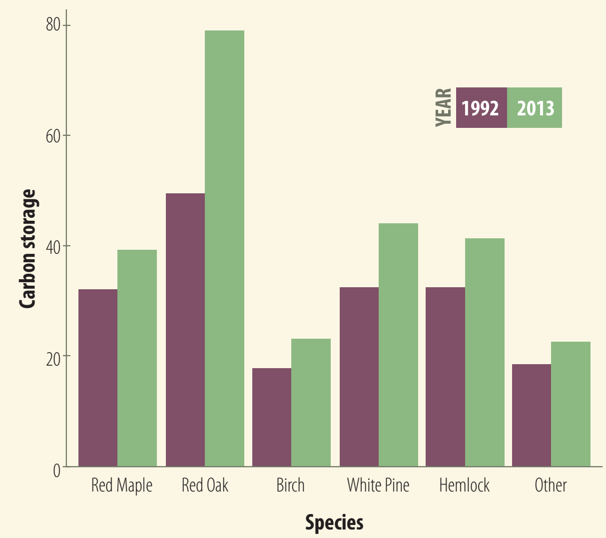
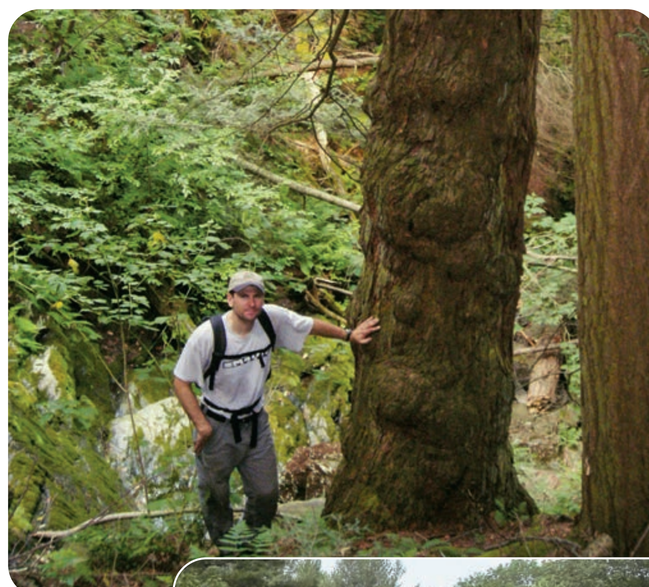


FIGURE 1. Change in carbon storage of tree species between 1992 and 2013 from 60 long-term monitoring plots in Petersham, Massachusetts. Data from the Harvard Forest.



Standing next to a 300-year-old hemlock in a long term forest plot (top) and monitoring the vegetation in a grassland (bottom).

HOW DO I BEGIN A W&W LONG-TERM MONITORING STUDY?

Before beginning a monitoring study, it will be helpful to have a basic understanding of the property on which you plan to study. At the very least this will involve examining a map and perhaps some aerial photos of the property to understand the extent of forest, field, and wetlands, followed by an informal walk of the property to take note of different vegetation types and important features (e.g., large trees, stone walls, presence of invasive species, appearance of meadow or grassland). Alternatively, a professional consultant can perform a more formal site review of your property. An informal or formal site review will enable you to delineate basic boundaries between vegetation types and management units (e.g., mowed meadow vs unmanaged forest). Obtaining soil, geological, and historical aerial photo maps will be helpful to aid in the interpretation of vegetation patterns on the property.

Gathering basic information on your property will inform and facilitate your monitoring objectives which will be the next step in developing a monitoring study. Articulating your monitoring objectives will require some thought and perhaps a few discussions with colleagues, family, or friends. Consider the topics that interest or concern you about your property and then reframe these topics as questions. For example in *forests*, which tree species and tree sizes are growing the fastest or the slowest? How has a history of timber harvesting altered the composition (the fraction of different tree types) and structure (the fraction of different tree sizes, the number of dead standing trees, and the amount of downed logs) in your forest? How quickly are your ash trees declining from the exotic emerald ash borer? In a *field* relevant questions might include: how does the presence or intensity of livestock grazing influence the composition of wildlflowers (forbs) relative to grasses? Or how does the timing and frequency of mowing influence the structure and composition of a meadow used by grassland birds?

Monitoring goals are generally limited only by the characteristics of your property, the scope of your interests, and the time and resources you can devote to your project (see Box 1 for approximate time and expense of a monitoring program). Your objectives will in turn determine the type of monitoring study you decide to pursue.

Box 1– Approximate Time and Budget Guidelines for Initiating a Forest Monitoring Project

TIME

- **Defining study questions and choosing plot locations**
  Several days to several weeks.
- **Plot sampling**
  Two people can set up and measure the vegetation in one to three plots per day. Pace depends on skill and experience of participants, commute time to field sites, difficulty of terrain, density and diversity of vegetation, and amount of data being collected.
- **Data entry**
  A few hours to a week, depending on the number of plots you are monitoring.

COST

- **Field equipment** (see Box 3 for complete list)
  - Tape measures, diameter tapes, field guides, plot markers, etc.: ~$200–300
- **Personnel**
  - Volunteers/field assistants: $0–12 per hour
  - Consulting field botanist (optional): ~$50–60 per hour

WHAT ARE THE DIFFERENT TYPES OF MONITORING STUDIES?

There are two approaches to vegetation monitoring. The first is basic, or passive, monitoring and the second is comparative, or question-driven, monitoring.

Basic monitoring involves simply measuring vegetation over time in one or more locations in your woods or fields.This approach is designed to answer questions about current conditions in your natural landscape and how your forest or field is changing but not about what is causing that change. Basic monitoring would be appropriate for addressing questions about which tree species are growing the fastest or are increasing in abundance in your forest, but not about how past timber harvesting or other disturbance affects the growth or relative abundance of these species. Although basic monitoring can provide very useful information about forest change that cannot be obtained from casual observation, its application to management is limited because the cause of change often remains unknown.

Comparative or question-driven monitoring attempts to document change and determine the cause of the change. In a forest, question-driven monitoring might compare the size of trees or the abundance of invasive plants in an area where trees have recently been cut or have been cut periodically over time to a nearby forest where trees are protected from cutting. Other question-driven studies can examine the effects of a natural disturbance (e.g., a blowdown, an insect outbreak, or ice storm) in a forest to a nearby and similar forest that is left undisturbed. Question-driven monitoring might also study the effects of human activities such as forest fragmentation. For example, you could examine tree size along a forest edge (e.g., a road or field that borders your forest) by comparing the trees near the edge to those in an interior forest (>100 meters from edge).

In a farmland or other treeless setting, a question-driven study might compare the relative abundance of wildflowers vs grasses or invasive vs native species in an area that is grazed by cattle to a reference field in which cattle are excluded. Alternatively, a question-driven study might examine how the timing and frequency of mowing influences the height, abundance, and composition of different plant groups in grasslands used by bobolinks (a grassland bird species)?

Two or more levels of the same disturbance or management (e.g., two different methods used to eliminate an invasive plant or two methods of timber harvesting) can also be studied and compared with a reference area.

HOW DO I MONITOR THE VEGETATION ON MY PROPERTY?

Stewardship Science uses 20 × 20 meter square plots to delineate a subset or sample of the forest and 10 × 10 meter square plots to sample grassland or other treeless vegetation. Inside these square plots, you will measure trees and/or other vegetation. These plots are a standard size to ensure consistency of measurement units among projects across the region. This consistency increases the value of individual monitoring efforts by effectively harnessing the collective power of citizen science.

HOW DO I CHOOSE THE LOCATION OF MY PLOTS?

Your study goals and study type will determine the location of your plots. For a basic monitoring project, you can choose the location(s) that most interest you. For a comparative study, you will need to place your plots in the disturbed or managed area and in a nearby

EXAMPLE OF A COMPARATIVE STUDY IN A FOREST. A logged hemlock forest (top) is monitored and compared with a nearby intact hemlock forest (bottom).

EXAMPLE OF A COMPARATIVE STUDY ON A FARM. A hayfield (top) is monitored and compared with a nearby field that is traditionally grazed by cattle (bottom).

reference area (see Box 2 for additional information). It is important that you place plots you are comparing in locations as similar as possible except for the disturbance you are studying. For example, if you are monitoring tree health and tree size in an oak forest on a rocky slope that has recently been harvested, you should find a similar sloping, rocky, oak forest in an unmanaged forest in which to place comparative plots (see Figure 2). You don't want to place your reference plots in a flat, red maple forest with few rocks, even if it is the nearest unmanaged forest you have access to. Such an approach mixes the effect of management with the effect of the underlying environment and will prevent you from disentangling these two causes of forest change. If your property does not have an appropriate reference forest or field you may need to collaborate with a neighboring property owner, or you may need to abandon this particular monitoring question.

HOW MANY PLOTS DO I NEED?

In general, for a comparative monitoring project, the more plots you measure the greater your ability to detect differences in vegetation over time between a disturbed and reference area. You need a minimum of two plots per treatment type (e.g., managed and unmanaged × 2 plots each = 4 plots total) to enable comparison of the two groups. However, if feasible, we recommend at least four to five plots per treatment category (e.g., harvested and unharvested × 5 plots each = 10 plots total; see Figure 2). For a basic monitoring study, you can sample as few as one plot or as many plots as you like.

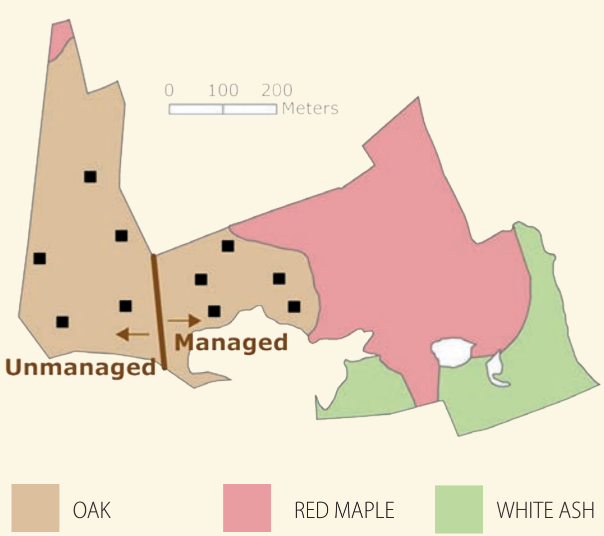


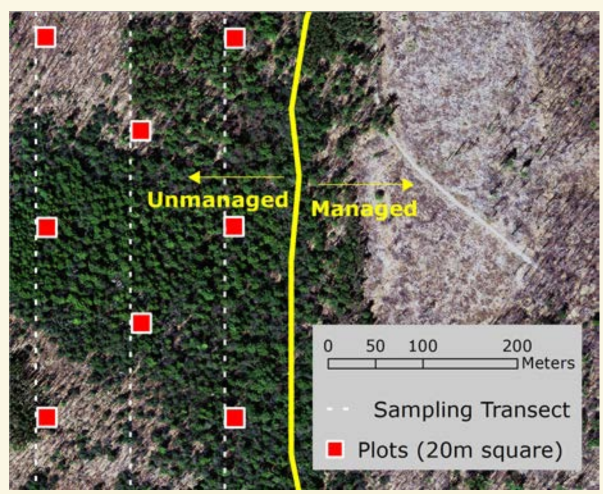
FIGURE 2. Example of plot locations in a comparative monitoring study between managed and unmanaged forest. Note that the plots are positioned in the same forest type in both the managed and unmanaged areas and are at least 50 meters apart within treatment areas and at least 50–100 meters apart between treatments.

HOW FAR APART SHOULD I PLACE MY PLOTS?

We recommend that plots be spaced at least 40-50 meters apart from plot edge to plot edge in a forest, so that data from one plot are not overly influenced by data collected from another plot. In a grassland, we recommend spacing plots at least 10-15 meters apart. Plots in disturbed and reference areas should be separated by at least 50–100 meters in forests and by at least 20 meters in grasslands to prevent the effects of management or disturbance from influencing the plots in the reference area. Ideally, plots should also be positioned at least 50-100 meters from roads and other vegetation edges (unless, of course, you are studying the effects of edge) and abutting properties of different land use, all of which could influence your results.

Box 2– Random Plots

In strict scientific terms, plots should be placed randomly in the woods in accordance with your study objectives. For practical purposes, this is often unnecessary in basic monitoring studies, as change can be measured in subjectively placed plots over time.



For comparative studies, selecting plots randomly is more important in order to avoid biased results. One relatively easy method for selecting random plot locations is to run a tape measure with aid of compass out along one to several lines spaced at consistent intervals and then choose plot locations at predetermined and consistent intervals along each line (e.g., 200 meters; see above). This method would be used for selecting plot locations in both unmanaged and managed areas.

WHAT TIME OF YEAR SHOULD I MONITOR MY PLOTS?

It depends to some extent on what plants you are interested in studying. The presence and abundance of some herbaceous plant species (as well as their ease of identification) may change considerably throughout the growing season, so it may make sense, depending on your goals and focal species, to sample either earlier or later in the growing season. For instance, many spring "ephemeral" wildflowers emerge and bloom in April prior to tree leaf out.

However, for many vegetation studies, late spring to mid-summer (June-August) will suffice. The key to documenting long-term change is to resample your plots at approximately the same time from year to year to ensure that you are recording inter-annual changes rather than seasonal variation within a single year.

HOW FREQUENTLY SHOULD I MONITOR MY PLOTS?

Monitoring intervals will vary depending on the goals of your study and the type of vegetation you are monitoring; however, a re-measurement interval of five to 10 years in a forest is reasonable for many projects. If you participate in a Current Use program, your forestlands may already be monitored every 10 years by a consulting forester. If so, you may wish to remeasure the vegetation more frequently and capture details not measured by the forester. For example, if you are monitoring a recently harvested woodland or a forest struck by a windstorm, rapid changes in the vegetation will occur during the first few years after the disturbance. If you are examining the effects of different timing and frequencies of grazing and mowing on the vegetation or bird populations in a grassland, you may wish to monitor changes every year in order to make the appropriate decision about management in the grassland. In general the longer the duration of the monitoring study, the more valuable it will be for understanding trends.

Grassland in Chilmark, Massachusetts

Box 3– Field Equipment for Forest Monitoring

- Data sheets (use waterproof paper such as Rite in the Rain on wet days)
- Backpack
- Measuring tapes (four to five) in metric units; at least two 50-meter tapes and two 30-meter tapes are best
- Stakes or chaining pins (five to eight) to anchor tapes at corners
- DBH (diameter at breast height) tape to measure tree diameters
- Iron, rebar, or PVC pipes to permanently mark plot corners (four per plot)
- Pencils
- Clipboard, preferably with storage compartment to protect data sheets in the field
- Compass (one per person)
- Hammer or mallet for pounding stakes/rebar
- Plant identification field guides (optional)
- Railroad chalk to mark trees (optional)
- Tree tags (optional)
- Tree calipers for measuring downed woody debris (optional)
- Plastic-coated wire for tree tags on small trees (optional)
- Aluminum nails for tagging trees (optional)
- GPS unit for identifying plot latitude and longitude coordinates and relocating plots in future (optional)

You can purchase most, if not all, of this field equipment online at Forestry Suppliers (http://www.forestry-suppliers.com/)

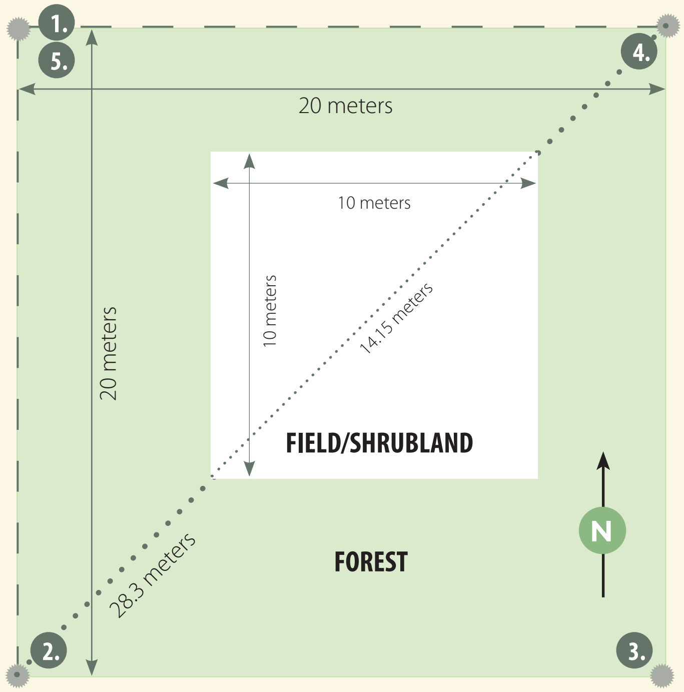


FIGURE 3. Plot layout

Forest:

1. Secure the end of a 50-meter tape (tape #1) at one corner (e.g., NW) with a stake or chaining pin. Walk south 20 meters, unwinding the tape behind you.
2. Secure tape #1 at 20 meters (SW corner) with a chaining pin, turn 90 degrees, and walk east 20 meters unwinding tape # 1 behind you until it reaches 40 meters (SE corner).
3. Secure the end of a second 50-meter tape (tape #2) at SE corner with a stake or chaining pin. Turn 90 degrees and walk north 20 meters, unwinding the tape behind you.
4. Secure tape #2 at 20 meters (NE corner) with a chaining pin, turn 90 degrees, and walk west 20 meters, unwinding tape #2 until you reach the starting point (NW corner).
5. Tape #2 should be at or close to 40 meters (i.e., between 39.8 and 40.2 meters) when you return to the starting corner. (You can also lay out a plot with 30-meter tapes instead of two 50-meter tapes.)
6. Double check the accuracy of your square plot by measuring the diagonals, which should be ~28.3 meters.

Field/Shrubland: Use the same approach as above, but use 10 meters for each side of the plot and 14.15 meters for the diagonal distance. If two people are present, one person can stand at a corner with a compass and guide the other person running out the tape.

HOW DO I LAY OUT MY PLOT?

Once you have selected a location for your plot, place a stake (metal or PVC pipe) at a starting corner of your choice. Use a compass and tape measures to follow the steps shown in Figure 3.

When you are finished and satisfied that your plot is a 20 × 20 meter square in a forest or a 10 × 10 meter square in a field or shrubland (i.e., a permanently shrubby area, not a young, regenerating forest dominated by trees), mark four corners with iron rebar or PVC pipes. Mark at least one corner post with the plot identification number or name and cardinal direction of the corner either on a tag or on the post itself. You also may want to flag or spray-paint your corner posts to help find them again. It is important to weigh the benefits of being able to relocate the plots in the future against the aesthetic drawbacks and vandalism risks of making them conspicuous. Risk of vandalism will vary, of course, depending on the location and size of your property.

Using compass for plot layout (top left); Laying out the plot (bottom left) and one side of a grassland plot (above).

WHAT SHOULD I DO AFTER I SET UP AND MARK MY PLOT(S)?

Leave the measuring tapes laid out while you gather your measurements, so the plot boundaries are clearly visible. Start by recording general identification and location information about the plot on the field data sheet, including latitude and longitude coordinates (a GPS unit or smartphone will provide them), the plot name/number, and the date (see Appendix A, the Forest data sheet, on page 18 and Appendix F, the Grassland or Shrubland data sheet on page 31). This basic plot information will be required when submitting your data to the W&W Stewardship Science online database.

Although optional, additional information about the plot's topography, proximity to an edge, evidence of past land use, disturbances, and wildlife sign will help you interpret the vegetation in your plot, as well as forest change over time (see Appendix B on page 20 and Appendix C on page 26 for more information). For comparative studies, describing the topographical features will help you determine how similar your comparative plots are.

HOW DO I MEASURE THE TREES IN MY PLOT?

To be an official participant in the W&W Stewardship Science Forest Monitoring Project, you will need at a minimum to identify the species and measure the diameter of each of the trees in your 20 × 20 meter plot.

Measuring tree diameters. Identify a spot on your body that is 1.4 meters above the ground (often referred to as breast height among forest researchers). It may be helpful to use a pole that is marked at 1.4 meters to assure measurement consistency. Using a diameter at breast height (DBH) tape, measure the diameter of all standing trees and shrubs at least 2.5 centimeters in diameter inside the plot at 1.4 meters above each tree's base. (DBH tapes generally have a diameter side and a circumference side, so make sure you use the diameter side of the tape when measuring the tree). Record the species, diameter, and condition (alive or dead) of each tree on the data sheet (see Appendix A or download it separately here).

Measuring trees on a slope. Measure diameters at 1.4 meters from the *uphill* base of the tree.

Taking notes in a meadow plot with the rare purple milkweed in the foreground.

Measuring the diameter of a tree with aid of a 1.4 meter pole.

Measuring trees that have a deformity 1.4 meters above the base. If the tree has a deformity that juts out at the measuring height of 1.4 meters, simply measure the diameter just above or below the deformity and note on the data sheet where the measurement was made for future reference.

Measuring trees with multiple trunks. Some trees have two or more trunks emerging from one base. Measure the trunks as separate trees if trunks split below 1.4 meters; measure as one diameter if trunks split above 1.4 meters.

Identifying the tree. There are many tree identification guides available, but two especially popular ones are *Tree Finder: A Manual for the Identification of Trees by Their Leaves (Eastern US)* by May Theilgaard Watts (1991) and *Bark: A Field Guide to Trees of the Northeast* by Michael Wojtech (2011). The Native Plant Trust also has an excellent and simple online key: http://gobotany.newenglandwild.org/simple/. You might also consider enlisting knowledgeable volunteers from the community to assist with identification.

Avoiding double-counting or missing some trees. Divide the plot into four 10 × 10 meter squares with your tape measures and/or use chalk to mark the trees as you move about the plot. You may also wish to tag the trees in your plot (see next point).

Keeping track of individual trees for future monitoring. You don't have to do this, but tagging trees enables you to track the growth of individual trees in the plot over time and be certain that only the originally measured trees are remeasured in the future. The disadvantages of tree tags are that they are aesthetically unpleasing to some, particularly in an unmanaged nature preserve, and they require some maintenance (see description below).

Nail an aluminum tree tag into each tree greater than 8 centimeters in diameter and record the tag number next to diameter and species information for each tree on the data sheet. The nail should be inserted about 1 meter high on the trunk, at an upward angle, and only slightly into the wood, to allow the tag to hang away from the tree. For smaller trees, 2.5–8.0 centimeters in diameter, tree tags should be strung loosely to the trunk with wire to avoid cracking the trunk with the nail. As the trees grow, nails and wires will need to be adjusted to avoid having the tree envelop the tag.

WHAT WILL I LEARN FROM MEASURING TREE DIAMETERS?

Measuring tree diameters will enable you to calculate the carbon stored in the trees, the cross-sectional 'basal area' of each species, and the range of tree sizes in your plot. With these measurements, you can then calculate tree growth rates, changes in tree composition, mortality of trees over time, and the rate of carbon uptake in your trees.

Knowing the species, diameter, and presence of dead standing trees will also inform you about the habitat your forest is providing for wildlife species.

Measuring a multi-trunked chestnut oak tree. Each stem is measured as a separate tree because they split below 1.4 meters.

Tree tags nailed into large tree (left) and hung with wire on small tree (right).

Large trees provide important nesting and denning sites for many species of wildlife. Larger crowns also provide an abundant seed source for many animals. Smaller diameter trees, when growing densely together in a regrowing forest, will provide habitat for certain species that specialize in young, shrubby vegetation found in forest gaps including timber harvests.

OTHER FOREST MEASUREMENTS

Depending on your interests, objectives, and study type, there are a number of additional but optional measurements you can make on shrubs and herbs, tree seedlings, stumps, and downed woody debris

Shrubs and herbaceous plants. Shrubs are typically multi-stemmed woody plants shorter than 10 meters in height that provide important habitat for forest birds and mammals and influence the growth of herbs and tree seedlings through competition for growing space. Many of the region's invasive plants are shrubs and are spreading rapidly. Herbaceous plants include grasses/ sedges, ferns, and wildflowers; can be either annual or perennial; and have nonwoody stems. Herbs are the source of most of the plant diversity in a forest and comprise most of the rare plant species in New England.

Record all species growing in the plot (see Appendix D for data sheets); some plants may be identifiable only to genus. Grasses, sedges, and rushes (collectively known as graminoids) are notoriously difficult to identify even for seasoned ecologists and can be a drain on time and resources to identify to species, so you may wish to lump them into a single category. However, graminoids comprise a susbstantial fraction of the species diversity in some woodlands, and Japanese stilt grass (Microstegium vimineum) is a common invasive species. Thus, depending on your goals, a more precise identification of these plants may be desirable. The Native Plant Trust's Go Botany Key is a helpful resource https://gobotany.nativeplanttrust.org/simple/.

Additionally, there are several excellent new plant identification apps that can offer help in the field. These include *Picture This*, *Seek, iNaturalist*, *PlantNet*, and *PlantSnap*. Although helpful, these apps are not 100% accurate and should not be fully relied upon to identify the vegetation.

If you cannot identify a species, you may wish to take a picture of it or mark its location in the plot so somebody else can identify it.

Monitoring the herbaceous layer in a forest.

Red maple seedling

Estimate the percentage of cover of each species according to six cover classes:

1 = <1%	4 = 26–50%
2 = 1–5%	5 = 51–75%
3 = 6–25%	6 = 76–100%

Then estimate the abundance of each species that is <= 5% cover (cover class 1 or 2):

m = many individuals (>20)
f = few individuals (2-20)
r = rare (1 individual)

We define 'percentage cover' as the percentage of the plot covered by the outermost perimeter of foliage of each plant (as opposed to 'foliar cover' — the percentage of the plot covered by the stem and foliage of each plant, not including the gaps between stems and leaves). When estimating percent cover, it is helpful to divide the 20 × 20 m plot into four 10 × 10 m subplots by laying out two cross tapes and then visualize what the percent cover classes look like in terms of the area of a 400 square meter plot: 1% = a 2 × 2 meter area; 5% = a 5 × 4 meter area; 25% = a 10 × 10 meter area; 50% = a 10 × 20 meter area. Then, to narrow down possible cover classes, ask whether all of the individual plants of species X distributed across the plot fit within a 2 × 2 meter area, a 5 × 4 meter area, and so on.

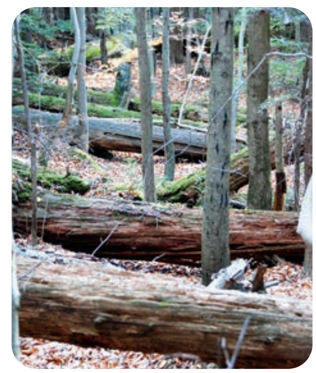
Tree seedlings and saplings. Seedlings and saplings are the smallest and youngest category of trees and therefore represent the future forest. Seedling and sapling species and numbers will vary tremendously depending on forest age, forest type, the level of disturbance and size of openings in the canopy, and the level of deer browsing in the forest. Seedlings and saplings are single tree stems that originate from the ground, the base of a cut stump, or standing tree within the plot. Individual sprouts in a clump will therefore be counted as separate stems, according to the above rules. Select two corners of the plot at random, and lay out a 5 × 5 meter subplot in each. Corners can be selected randomly by writing NW, SW, NE, SE on four strips of paper, shuffling them, and blindly choosing two of the strips of paper. Count and identify all tree seedlings (at least 30 centimeters but less than 1.4 meters in height) and saplings (at least 1.4 meters in height and less than 2.5 centimeters in DBH) in the two 5 × 5 meter areas (see Appendix D for an example of a data sheet).

Cut stumps. If your woodland has been harvested in the recent past, it is informative to record the stumps in your plots. Doing so will reveal the number, size, and species (if identifiable) of the trees that were harvested. Data on stumps will help you interpret vegetation change over time as the forest grows back and will also help you establish appropriate reference plots in unlogged forests (i.e., with trees of similar species and diameter as the stumps in the logged plots).

Measure the diameter and record species (if possible) of all cut stumps in the plot, that is, only those stumps with a smooth plane that have been cut as opposed to the rough and jagged stumps of naturally fallen trees. Record whether the wood of the stumps is hard (recent) or soft (old) as an index of the relative age of the timber harvest (see Appendix D on page 28 for an example of a data sheet).

Large downed wood. Large pieces of downed wood on the forest floor (technically known as coarse woody debris) are a good indicator of the relative age of the

Measuring tree saplings in a recent timber harvest.



Recent downed wood from autumn snowstorm (left) and older downed wood (right).

forest, whether it has been harvested in the recent past, and past natural disturbances to the canopy from wind, ice or insect/pathogen outbreaks.

With tree calipers and tape measure, measure pieces of downed wood that are greater than 1.5 meters long and greater than 10 centimeters in diameter within the plot. Identify each piece to species whenever possible, or note hardwood as opposed to conifer. Measure piece length and the diameters of both ends (see Appendix D for an example of a data sheet) and record the level of decay of the downed wood using the following decay classes: (adapted from Fraver et al. (2002):

1) Wood is sound and cannot be penetrated with thumbnail; bark is intact; smaller to medium sized branches are present; and log is often suspended by its own branches.

(2) Wood is sound to somewhat rotten; bark may or may not be attached; branch stubs are firmly attached; log retains round shape and lies on duff.

(3) Wood is substantially to mostly rotten; thumbnail penetrates readily; wood texture is soft; bole partly to substantially buried in duff.

PHOTOGRAPHING YOUR PLOT

Photomonitoring provides an invaluable visual record of vegetation changes in your study plots over time.

Photograph each study plot from an established plot corner or from two corners in plots with dense vegetation.

Be sure to take pictures from the same location, at the same height (1.5 m fence posts are a helpful guide), the same time of year, and with the same camera settings each time the plot is rephotographed.

For the most accurate picture comparison, insert a permanent fence post with a visible marker in the middle of the plot. Position the marker on the fencepost in the center of the camera's field of view each time you take a picture from the plot corner.

Record the photo ID on a datasheet.

HOW DO I MEASURE THE VEGETATION IN A FIELD OR SHRUBLAND?

Once you have set up a 10 x 10 m plot in a field or other treeless site, you will determine the percentage of the plot that is covered by four different plant groups including (1) graminoids (i.e., grasses, sedges, or rushes that have narrow leaves), (2) forbs (i.e., flowering plants with broad leaves), (3) ferns, and (4) shrubs. You will estimate the abundance of each of these "functional" groups using the same percentage cover classes outlined for forests on page 55 and listed below. Additionally, it will be helpful to estimate the percentage of the plot with no vegetation at all (i.e., bare ground). For each of the plant groups, measure the height (in meters) of the tallest individual in each group (see Appendix F, the Grassland and Shrubland Data Sheet on page 31).

Additionally, if you have the expertise to identify individual plants to species, you may wish to do so and estimate their individual percent covers. Alternatively, If there is a particular focal species or set of species that you are interested in studying (e.g., a species that may impact overall forage quality of a meadow like smooth bedstraw, a rare native species like purple milkweed, a nuisance species like poison ivy, or an invasive exotic species like the common thistle) you can also estimate the individual percent covers for just those species.

Estimate the percentage of cover of each plant group (and individual species if desired) according to six cover classes:

1 = <1%	4 = 26–50%
2 = 1–5%	5 = 51–75%
3 = 6–25%	6 = 76–100%

To facilitate estimating percentage cover in the plot, it helps to divide the 10 x 10 m plot into four 5 x 5 m subplots by laying out two cross tapes. When deciding between different cover classes, ask yourself whether all of the individual plants of plant group X distributed across the plot fit within a 1 × 1 meter area (1%), a 2 × 2.5 meter area (5%), a 5 × 5 meter area (25%) and so on.

WHAT WILL I LEARN FROM ESTIMATING PLANT GROUPS AND SPECIES IN A FIELD OR SHRUBLAND?

Estimating the abundance of different plant groups in a field or shrubland will enable you to determine the composition and structure of the vegetation, which is important for determining habitat quality for certain grassland bird species or rare species like the New England Cottontail. It will also inform you of the outcomes of different grazing or mowing regimes on field vegetation if you are attempting to manage for a particular composition of the grassland.

Bobolink in a meadow.

Estimating plant abundance in a meadow.

Hilltop meadow at the Highland Foundation in Redding, Connecticut.

HOW DO I SUBMIT MY DATA TO W&W STEWARDSHIP SCIENCE?

At this time, the W&W Stewardship Science online database is only set up to accept tree data in a forest. Please go to http://harvardforest2.fas.harvard.edu/asp/hf/php/ww/ww_project.php for instructions on how to upload data into the online database.

WHAT ARE THE ADVANTAGES TO SUBMITTING MY DATA TO THE W&W ONLINE DATABASE?

Submitting your data to our online database provides you with access to some basic graphing and analysis tools, as well as to other participant datasets across New England. You will also have the satisfaction of contributing to a broader effort to understand and manage the region's forests using science. Moreover, your data will be safely stored if for some reason you were to lose it from your home or office computer.

AM I REQUIRED TO SUBMIT MY DATA TO W&W STEWARDSHIP SCIENCE?

No. Although we encourage you to submit your data, you are free to use the information from this manual to monitor your forest independently.

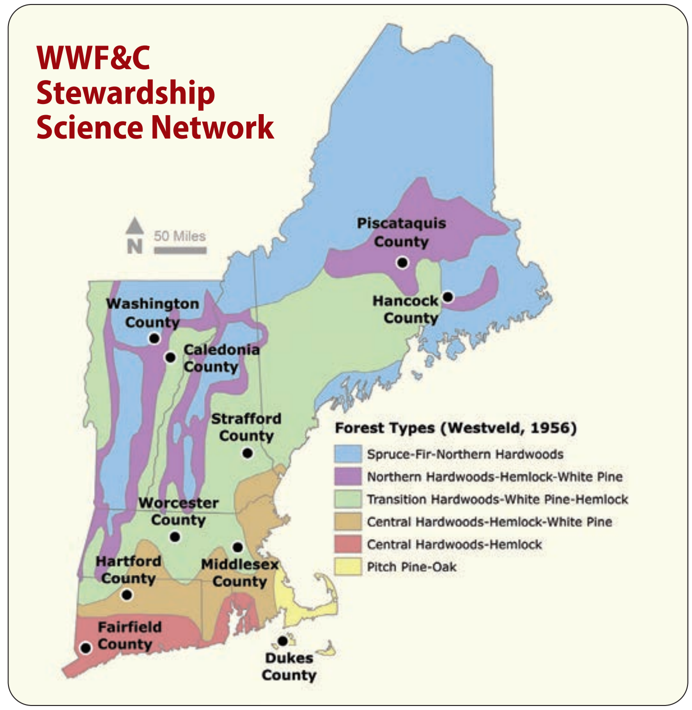


FIGURE 4. Locations of organizations, agencies, and landowners across New England that are part of the Wildlands and Woodlands Stewardship Science Network.

Large standing dead trees (snags) in old forest.

APPENDIX A: FOREST DATA SHEET

WILDLANDS AND WOODLANDS STEWARDSHIP SCIENCE FOREST DATA SHEET

General:
Plot Unique ID ______________________

Observers: ____ Date: ____/____/_____

Time Start: ___________________________ Time End: ___________________________

Plot Location: Town: ____________________ County: __________________ State: ______

Coordinates: Lat ____________________ Long ____________________

Additional Directions to Plot: ____

Trees and Shrubs: Record all stems ≥2.5 cm DBH in 400 m^2 plot.

Species	DBH (cm)	Condition Class	Tag Number
		1 = tree alive 0 = tree dead	(optional)

APPENDIX A: FOREST DATA SHEET, CONTINUED

WILDLANDS AND WOODLANDS STEWARDSHIP SCIENCE FOREST DATA SHEET, PAGE 2

Species	DBH (cm)	Condition Class	Tag Number
		1 = tree alive 0 = tree dead	(optional)

TOPOGRAPHICAL AND PHYSICAL FEATURES

Topographical and physical features of the plot have a strong influence on forest vegetation by affecting soil moisture, soil depth, soil nutrient levels, microclimate, and growing space for trees.

Landscape Position. The location of the plot relative to surrounding landscape features.
Choose one of the six to describe your plot:

> **Ridgetop/hilltop –** The plot is generally level and the surrounding land is level and/or slopes downhill in at least two different directions.
> **Hillside upper –** The plot and the surrounding land are sloping; most of the hillside is downslope from the plot.
> **Hillside lower –** The plot and the surrounding land are sloping; most of the hillside is upslope from the plot.
> **Dry flat –** The plot is on a level plateau but not in a wet basin; the surrounding land may be level, above, or below the elevation of the plot.
> **Wet flat –** The plot is level and in a wet, mucky basin or bottomland, often near a water source; the surrounding land is either level or a higher elevation than the plot.
> **Rolling upland –** The plot is generally sloping or uneven; the surrounding land neither ascends nor descends consistently but undulates.

Slope. The steepness of the incline of the slope.
Locate the center of the plot. Estimate the incline of the slope in one of four categories (none (0%), slight (1-4%), moderate (5-15%), steep (>15%).

Aspect. The direction the slope faces.
From the center of plot, orient your compass in the direction that the land is sloping and record the bearing in degrees. (A good way to think about aspect is to ask yourself, "In what direction would water flow down the hill?") If the plot slopes in two different directions, record two aspects; if plot is on level ground, record the aspect as N/A.

Rock Cover. An index of the depth of the soil and area of growing space for trees.
Estimate the percentage of the plot surface covered by rock in one of six broad categories (<1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%).

Water. Note the presence of small streams, pools, and flooded areas in the plot.

Rocky ridgetop forest with mountain laurel in bloom.

Wet flat with skunk cabbage covering the forest floor.

EVIDENCE OF HUMAN AND NATURAL DISTURBANCES

Pests and Pathogens. Many pests and pathogens are exotic and invasive, and many are expanding their ranges and becoming more deadly to trees with a warming climate. Documenting their presence helps explain current and future tree death in your plot and provides data on pests that are newly arriving and/or actively spreading.

Observe the trees in the plot for the following pests/pathogens and check all that occur:

Ash yellows/decline – Thinning/dying canopy on ash trees without sign of emerald ash borer.

Asian long-horned beetle – Large (3–4 centimeters) black beetle with white spots and long, banded antennae; prefers maples, but infests many hardwoods such as birch, elm, and poplar. Makes smooth, round "bullet" exit holes (1 centimeter in diameter). Known only in the immediate surroundings of Worcester, Massachusetts.

Balsam woolly adelgid – An insect that produces white, woolly spots on trunks of fir trees, swollen twigs.

Beech bark disease – Recognized by a white, waxy coating of beech scale insect on the oftentimes cracked and fissured bark and/or tiny red Nectria fungus emerging from cracks. Oozing "tarry" spot is also diagnostic.

Beech leaf disease – Curling, leathery texture, and striping on leaves of American beech trees.

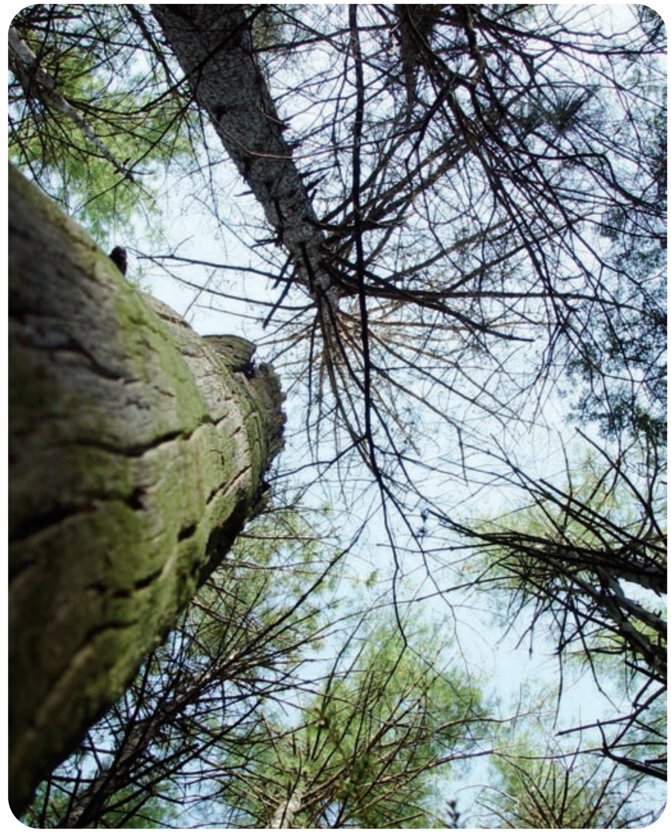
Butternut canker – Black, "sooty" cankers on trunk and dying canopy.

Chestnut blight – Orange-brown canker and accompanying trunk death.

Emerald ash borer – Bright, metallic green beetle (1-1.5 centimeters). D-shaped boreholes on trunk of ash trees from emerging adult beetles, and orange-colored trunks, resulting from extensive bark removal by woodpeckers foraging on larvae in ash tree are diagnostic.

Hemlock woolly adelgid – White, woolly coatings of insect beneath hemlock needles; thinning canopy is also diagnostic (see photos, right).

Spongy moth ***(Formerly called Gyspy moth)* –** Caterpillar has five pairs of raised blue spots followed by six pairs of raised red spots along back; does not build silken tents. Prefers oaks.



Thinning canopy (top) and white woolly masses on hemlock needles (bottom): telltale signs of hemlock woolly adelgid.

Spruce budworm – Prefers balsam fir; look for severed needles, giving tree a scorched look.

White pine blister rust – Red-needled, dying branch is diagnostic; damage more severe in northern New England.

Winter moth – Defoliates deciduous trees primarily in coastal regions of southern New England. Look for light green caterpillars about one inch in length.

Current and Past Human Activity. Past and current land use is often critical to understanding the vegetation growing in the plot. For example, a plot with stone walls nearby and dominated by white pine typically means the area was formerly an agricultural field that, when abandoned, provided the soil conditions and open growing conditions favorable for pine.

Check all of the following features that occur in or near the plot and identify whether inside the plot (I) or outside the plot (O) and estimate how far outside the plot. Be sure to check "none" if no sign of disturbance is observed.

Cut stumps – (recent logging): Note only stumps with smooth-cut surfaces from a saw; do not include uneven or jagged-surface stumps resulting from natural treefall, including those blown down by storms.

Logging scar on tree

Woods cabin

Residential house

Large building complex

Footpath

Skid trail – (a rough, unmaintained vehicle path through a recently logged forest)

Forest road – (a maintained dirt/grassy road for large vehicles)

Trash

Paved road – (a small side road)

Highway – (a major paved road)

Open field

Stone wall – (a human-made rock wall, not a naturally formed rock outcrop)

Barbed wire – (denotes historic grazing by livestock)

Cellar hole – (an old stone foundation to a former house)

Multiple-trunked trees – (denotes historic logging and possibly fire)

Dead oak trees on Martha's Vineyard killed by fall cankerworm and other insects. Nearby surviving trees are American beech.

Evidence of current land use: forest road.

Large, open-grown pasture trees – (denotes historically open conditions)

Abiotic Natural Disturbances. Natural disturbances influence light levels, growing space, species invasions, germination of dormant seeds in the soil, and sprouting on the base of damaged trees. Documenting disturbances helps explain changes in tree density, growth rates of trees, species diversity and composition, and tree regeneration over time.

Check all of the following features that occur in or near the plot:

Uprooted trees – (wind, snow/ice)

Snapped trees – (wind, snow/ice)

Large downed branches – (snow/ice)

Burn scar with charcoal (fire) **–** Look for charcoal pieces in the soil beneath the scar to differentiate a burn scar from other scars.

River deposits (flooding) **–** Search for signs of water encroachment into the plot, such as mud deposits or flattened grasses.

Deformed/broken canopy – (snow and ice)

Pit and mound topography (wind) **–** Look for depressions and adjacent mounds on the forest floor. The mound is formed by the decayed root mass of an old blown down tree; the pit is formed by the former roots being lifted out of the ground as the tree fell.

Wildlife Sign. Wildlife activity can influence vegetation structure, composition, and diversity. Woodpecker drill holes, for example, can signify the presence of insect pests in the trees. At the same time, changes in forest structure and composition from disturbance and natural succession influence what species of wildlife use your forest.

Moose browsing on young trees in a recent timber harvest in Northwestern Connecticut.

Evidence of past land use: stone wall.

Evidence of natural disturbance: root mass from old uprooted tree.

Check all of the following signs that occur in the plot:

Deer/moose browsing – Torn and rough stem tips that look to have been ripped off; moose browse up to 3 meters high; deer up to about 1.8 meters.

Porcupine browsing – 45-degree-angle cuts on twigs and stems up to 2.5 centimeters in diameter with incisor marks; often near rock outcrops. Porcupines climb trees, so browsing can occur at all heights; tops of hemlock can be damaged.

Rabbit/hare browsing – Clean, knifelike, 45-degree angle cuts on low, woody twigs less than 1 centimeter in diameter.

Bark stripping (moose and deer; see photo) **–** Look for incisor mark generally on red maple, mountain maple, witch hazel, hemlock, trembling aspen, balsam poplar, mountain ash, and pin cherry 3–25 centimeters in diameter.

Antler rubbing (deer and moose) **–** Generally on trees 2.5–10 centimeters in diameter; prefer red maple, alder, cherry, red cedar, white pine, and witch hazel. Look for places where the bark has been removed in a long, oval shape.

Claw marks on beech (black bear) **–** Generally on beech trees at least 20 centimeters in diameter (those that are large enough to produce nuts and support the weight of the animal).

Felled trees (beaver; see photo) **–** Base of trees gnawed and cut in hourglass pattern, generally within 100–150 meters of water source; trees cut can range from small saplings to stems larger than 60 centimeters in diameter.

Woodpecker holes (see photo) – Range from large rectangular holes left by pileated woodpecker to very smallhorizontal rows of holes made by yellow-bellied sapsucker.

Deer pellet piles – Variable; generally less than 2.5 centimeters long and 1 centimeter in diameter.

Moose pellet piles – At least 2.5 centimeters long and thicker than deer pellets.

Bark-stripping by moose on red maple tree

Beaver-cut ash tree in wet flat

Bark flecking and holes made by woodpecker feeding on emerald ash borer larvae beneath the bark of ash tree.

Examples of canopy cover percentage classes.

≤25%

26–50%

51–75%

76–100%

FOREST STRUCTURAL CHARACTERISTICS

The percent canopy cover of the plot indicates the amount of sky blocked by the tops of trees over the plot and provides information about recent canopy disturbance and the amount of light reaching the forest understory.

From the center of the plot, look up and estimate the percentage of sky above the plot covered by canopy foliage in one of four categories: <=25%, 26–50%, 51–75%, 76–100% (see examples, above). Do not include the foliage from shrubs and small trees less than 25 centimeters in diameter in the canopy cover estimate unless these smaller woody plants make up the uppermost canopy (i.e., in a young regenerating forest). Look to the highest level of tree growth and estimate percent canopy cover using that layer only.

View of an oak forest canopy. Note low foliage from witch hazel shrub in upper part of picture.

Old forest on the slopes of Mount Wachusett, Machusetts

APPENDIX C. FOREST PLOT DESCRIPTION DATA SHEET

Topography and Physical Features

Landscape position. Check one.

❑ ridge/hilltop ❑ hillside upper ❑ hillside lower ❑ dry flat ❑ wet flat ❑ rolling upland

Slope. Check one.

❑ none (0%) ❑ slight (1–4%) ❑ moderate (5–15%) ❑ steep (>15%)

Aspect° ___________

Rock cover. Check one.

❑ <1% ❑ 1–5% ❑ 6–25% ❑ 26–50% ❑ 51–75% ❑ >75%

Water. Check one or more.

❑ small stream ❑ seasonal stream ❑ flooded area ❑ vernal pool ❑ none

Additional notes on topography: ____

Evidence of Disturbance

Pests and pathogens. Check one or more.

❑ ash yellows/decline
❑ Asian long-horned beetle
❑ balsam wooly adelgid
❑ beech bark disease
❑ butternut canker
❑ chestnut blight
❑ emerald ash borer
❑ gypsy moth
❑ hemlock woolly adelgid
❑ spruce budworm
❑ white pine blister rust
❑ winter moth
❑ other________
❑ none

Current and past human activity. Check one or more and designate either I = inside plot; or O = outside plot.

❑ cut stumps _____
❑ woods cabin _____
❑ footpath _____
❑ paved road _____
❑ barbed wire _____
❑ multiple-trunked trees _____
❑ logging scar on tree _____
❑ residential house _____
❑ skid trail _____
❑ highway _____
❑ cellar hole _____
❑ other _____
❑ stone wall _____
❑ large building complex _____
❑ forest road _____
❑ open field _____
❑ large, open-grown pasture trees _____
❑ none _____

Weather and other nonliving natural disturbances. Check one or more and designate either I = inside plot or O = outside plot.

❑ uprooted trees _____
❑ burn scar w/charcoal _____
❑ deformed/broken canopy _____
❑ snapped trees _____
❑ river deposits _____
❑ other _____
❑ large downed branches _____
❑ pit and mound topography _____
❑ none _____

Wildlife sign in plot. Check one or more.

- ❑ deer/moose browsing
- ❑ hare/rabbit browsing
- ❑ porcupine browsing
- ❑ bark -stripping (moose or deer)
- ❑ antler rubbing (deer or moose)
- ❑ claw marks on beech (bear)
- ❑ felled trees (beaver)
- ❑ woodpecker holes
- ❑ deer pellet piles
- ❑ moose pellet piles
- ❑ none
- ❑ did not assess
- ❑ other ______________________________

Forest Structural Characteristics

Canopy closure estimate. Check one.

❑ <=25% ❑ 26–50% ❑ 51–75% ❑ 76–100%

Additional notes on disturbance:

APPENDIX D. DATA SHEETS FOR ADDITIONAL FOREST MEASUREMENTS

Depending on your goals, you may wish to modify these sheets.

SHRUBS AND HERBS Record all species and estimate % cover class in 400 m^2 plot.			**TREE SEEDLINGS/SAPLINGS** Record all stems ≥30 cm high and <2.5 cm DBH in two 5 × 5 m subplots.			
Species	**Cover Class** 1 = <1% 2 = 1–5% 3 = 6–25% 4 = 26–50% 5 = 51–75% 6 = 76–100%	**Abundance Class** **m.** <=5% cover, many individuals (>20) **f.** <=5% cover, few individuals (2-20) **r.** <=5% cover, rare (1 individual)	**Species**	**Size Class** 1 = 30 cm–1.3 m 2 = 1.4 m–2.4 cm DBH	**Plot Corner** NW, NE, SE, SW	**Browsed by Moose or Deer?** 0 = no 1 = yes

Depending on your goals, you may wish to modify these sheets.

STUMPS Identify and record all cut stumps in 400 m^2 plot and measure diameter of each.			**DOWNED WOOD** Measure with tree calipers and tape measure all large pieces of downed wood that are greater than 1.5 m long and greater than 10 cm in diameter.				
Species or Genus (if species not discernible, label as "unknown"; if no stumps in plot enter "none")	**Diameter** (cm)	**Condition** 1 = Wood hard 2 = Wood soft	**Species (if known)**	**Length** (m)	**Diameter** 1 (cm)	**Diameter** 2 (cm)	**Condition** 1 = Wood is sound and cannot be penetrated with thumbnail; bark is intact; small to medium sized branches present 2 = Wood is sound to somewhat rotten; bark may or may not be attached; log retains round shape and lies on duff. 3 = Wood is substantially to mostly rotten; thumbnail penetrates readily; bole partly to mostly buried in duff.

APPENDIX E. FOREST MONITORING STEP-BY-STEP FIELD CHECKLIST

1. Locate site of forest plot.
2. Lay out a 20 × 20 meter plot and mark the corner posts with PVC pipe or rebar. If two people are present, one person can stand at a corner with a compass and guide the other person running out the tape.
   (a) Secure the end of a 50-meter tape (tape #1) at one corner (e.g., NW) with a chaining pin. Walk south 20 meters, unwinding the tape behind you.
   (b) Secure tape #1 at 20 meters (SW corner) with a chaining pin, turn 90 degrees, and walk east 20 meters, unwinding tape #1 behind you until it extends 40 meters (SE corner).
   (c) Secure the end of a second 50-meter tape (tape #2) at the SE corner with a stake or chaining pin. Turn 90 degrees and walk north 20 meters, unwinding the tape behind you.
   (d) Secure tape #2 at 20 meters (NE corner) with a chaining pin, turn 90 degrees, and walk west 20 meters, unwinding tape #2 until you reach the starting point (NW corner).
   (e) Tape #2 should be at or close to 40 meters (i.e., between 39.7 and 40.3 meters) when you return to the starting corner.
3. Identify a spot on your body that is 1.4 meters above the ground (a pole that is marked or cut to that length may be helpful).
4. Measure (with DBH tape) the diameter at 1.4 meters above the base of all standing trees or shrubs (at least 2.5 centimeters in diameter) that are growing inside the 20 × 20 meter plot.
   - If the tree is on a slope, measure the diameter at 1.4 meters from the uphill base of the tree.
   - If the tree has a deformity 1.4 meters above the base, measure the diameter just above or below the deformity and note where the measurement was made for future measurements.
   - If the tree has at least two trunks emerging from the base, measure the trunks as separate trees if the trunks split below 1.4 meters; measure as one diameter if they split above 1.4 meters.
5. Record the species, diameter, and condition (alive or dead) of each tree.
6. To avoid double-counting or missing trees, you may wish to divide the plot into four 10 × 10 meter squares with two additional tape measures and/or use chalk to mark the trees as you move about the plot.
7. If you wish to track individual trees in the plot, nail an aluminum tree tag into each tree greater than 8 centimeters in diameter and record the tag number next to the diameter and species information on the data sheet. The nail should be inserted about 1 meter high on the trunk, at an upward angle, and only slightly into the wood to allow the tag to hang away from the tree. For smaller trees, 2.5–8.0 centimeters in diameter, tree tags should be strung loosely to the trunk with wire to avoid cracking the trunk with the nail.

APPENDIX F. GRASSLAND OR SHRUBLAND DATA SHEET

General:

Plot Unique ID: ______________________

Observers: ______________ *Date:* / /

Time Start: ______________________ *Time End:* ______________________

Plot Location: *County:* ________________ *State:* _____ **Coordinates:** *Lat* ________ *Lon* ________

Additional Directions to Plot

PLANT GROUPS Estimate % cover class for each plant group in 100 m^2 plot	**COVER CLASS** 1 = <1% 2 = 1-5% 3 = 6-25% 4 = 26-50% 5 = 51-75% 6 = 76-100%	**MAXIMUM HEIGHT (METERS)**
Graminoids		
Forbs		
Ferns		
Woody Plants		
Bare Ground		

PLANT SPECIES (OPTIONAL) Record all species and estimate % cover class in 100 m^2 plot	**COVER CLASS** 1 = <1% 2 = 1-5% 3 = 6-25% 4 = 26-50% 5 = 51-75% 6 = 76-100%	**MAXIMUM HEIGHT (METERS)**

APPENDIX G. RESOURCES AND REFERENCES

OTHER FOREST AND GRASSLAND MONITORING PROJECTS IN NEW ENGLAND

Maine Baxter State Park Continuous Forest Inventory,
https://www.uvm.edu/femc/data/archive/project/baxter_park_sfma_cfi/dataset
Maine Ecological Reserve Monitoring,
https://www.maine.gov/dacf/parks/publications_maps/docs/Ecological_Reserve_Update_spring2005.pdf
Massachusetts Continuous Forest Monitoring Program,
https://www.mass.gov/files/documents/2016/08/pz/cfi-manual-2014-t.pdf
National Park Service Northeast Temperate Network Inventory and Monitoring,
https://www.nps.gov/im/netn/index.htm
USDA Forest Service Northeastern Forest Inventory and Analysis,
https://www.fia.fs.usda.gov/
Vermont Monitoring Cooperative,
http://www.uvm.edu/rsenr/wkeeton/pubpdfs/SleeperetalVMCForestHealthSynthesisReport.pdf
Vermont State Lands Continuous Forest Inventory,
https://www.uvm.edu/femc/data/archive/project/continuous-forest-inventory
Sandplain Grassland Network,
http://sandplaingrassland.net/

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WEBSITES AND ONLINE RESOURCES

Organizations

Brandeis University's Suburban Ecology Project, http://www.brandeis.edu/programs/environmental/sep/about.html
Harvard University's Harvard Forest, http://harvardforest.fas.harvard.edu/
Highstead Foundation, https://highstead.net/what-we-do/we-steward-land/stewardship-science/
Sandplain Grassland Network, http://sandplaingrassland.net/sandplain-grassland-network/
Wildlands and Woodlands, http://www.wildlandsandwoodlands.org/science-initiatives/stewardship-science

Plant Identification
Native Plant Trust, https://gobotany.nativeplanttrust.org/
Northern forest atlas, https://northernforestatlas.org/2016/01/22/woody-plant-photographic-guide/

Rare and Threatened Plant Species
Native Plant Trust. Saving Imperiled Plants https://www.nativeplanttrust.org/conservation/rare-and-endangered/

Invasive Plant Species
Invasive Plant Atlas of New England (IPANE), http://www.eddmaps.org/ipane/

Stump Identification
Basic Guide to Identification of Hardwoods and Softwoods Using Anatomical Characteristics, https://extension.msstate.edu/sites/default/files/publications/publications/p2606.pdf

Forest Pests and Pathogens
Ash yellows/decline, https://ag.umass.edu/landscape/fact-sheets/ash-yellows
Asian long-horned beetle, https://www.aphis.usda.gov/publications/plant_health/2016/book-alb.pdf
Balsam woolly adelgid, http://www.maine.gov/dacf/mfs/forest_health/insects/balsam_woolly_adelgid.htm
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Chestnut blight, http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Cryphonectria_parasitica htm
Emerald ash borer, https://www.dnr.state.mn.us/invasives/terrestrialanimals/eab/index.html
Moth, https://www.dec.ny.gov/animals/83118.html
Hemlock woolly adelgid, https://ag.umass.edu/landscape/fact-sheets/hemlock-woolly-adelgid
Spruce budworm, https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_042853.pdf
White pine blister rust, https://extension.unh.edu/resources/files/Resource000413_Rep435.pdf
Winter moth, https://ag.umass.edu/landscape/fact-sheets/winter-moth-identification-management

Field Equipment Suppliers
Forestry Suppliers, http://www.forestry-suppliers.com/

The Harvard Farm in Petersham, Massachusetts

AUTHOR PROFILES

Audrey Barker-Plotkin is senior scientist and site & research manager at Harvard Forest, Harvard University
https://harvardforest.fas.harvard.edu/audrey-barker-plotkin

Brian Donahue is professor emeritus of American environmental studies at Brandeis University
https://www.brandeis.edu/facultyguide/person.html?emplid=795028f17a5a7228b030635491bae0067583a037

Edward Faison is senior ecologist at the Highstead Foundation
https://highstead.net/who-we-are/our-people/ed-faison/

David Foster is director emeritus of the Harvard Forest, Harvard University
https://harvardforest.fas.harvard.edu/david-r-foster

Brian Hall is GIS specialist at Harvard Forest, Harvard University
https://harvardforest2.fas.harvard.edu/asp/hf/php/researcher_profile1.php?id=33

David Orwig is senior forest ecologist at Harvard Forest, Harvard University
https://harvardforest2.fas.harvard.edu/asp/hf/php/researcher_profile1.php?id=59

Emily Huff is Associate Professor, Human Dimensions of Forestry, Michigan State University
https://www.canr.msu.edu/people/emily_huff

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Tom Clark
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Anthony D'Amato
Dave DeFusco
Stephen DeStefano
Elaine Doughty
Geordie Elkins
Aaron Ellison
Sarah Ganong
Clarisse Hart
Matthew Kelty
Kathleen Kitka
Dave Kittredge
Bill Labich
George Lovejoy
John McLeran
Bill Moorhead
Glenn Motzkin
Julie Pallant
Alex Petzke
Elaine Shiramizu
Jes Siart
Pamela Snow
Jonathan Thompson
Rick Van de Poll

HIGHSTEAD, established in 1982, is a non-profit organization based in Redding, Connecticut, that works to conserve the natural landscape of New England through science, sound stewardship, and as a leader in the Wildlands and Woodlands Initiative

THE HARVARD FOREST, established in 1907, is Harvard University's 3500 acre laboratory & classroom located in Petersham, Massachusetts. Since 1988, it has also served as a National Science Foundation Long Term Ecological Research Site.

For ADDITIONAL Information, contact efaison@highstead.net

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