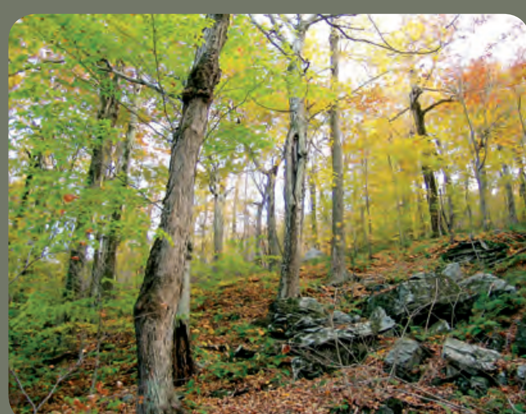
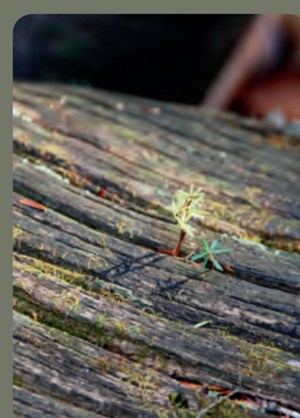
WILDLANDS AND WOODLANDS STEWARDSHIP SCIENCE

Manual for Long-Term Forest Monitoring




WILDLANDS AND WOODLANDS STEWARDSHIP SCIENCE

Manual for Long-Term Forest Monitoring

A COMPANION PAPER TO

Wildlands and Woodlands Science

Long-term Forest Measurements for Ecological and Conservation Insights

AND

Wildlands and Woodlands:
A Vision for the New England Landscape

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Highstead Foundation
Harvard Forest, Harvard University

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PREFACE

The Wildlands and Woodlands (W&W) initiative is a broad, collaborative effort to protect 70% of New England in forest over the next 50 years (http://www.wildlandsandwoodlands.org/). At the heart of this initiative is the awareness that our wooded landscapes provide immeasurable economic, environmental, and cultural 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 that interested landowners or conservation-minded individuals can use to track changes in their woods over time. Whether the motivation is active management for timber, understanding how forests are being shaped by factors ranging from climate change and ice storms to insect pests, or simple pleasure in observing nature's dynamics, anyone equipped with a notebook, tape measure, pencil, and the willingness to puzzle through a book of tree 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 David Thoreau have argued that there is much to be learned through simple, long-term measurements of forest growth and change. Yet there are still remarkably few examples of private landowners, land trusts, timber companies, or conservation organizations that base their understanding and management practices on a regular system of observations and measurements. Because the vast majority of forestland in New England is privately owned, most of these lands remain unmonitored, and management plans are often drawn up from casual rather than systematic observation. This guide is an effort to change this situation in New England.

The benefits of W&W Stewardship Science are twofold. Although this manual can be used solely to help you understand your own land, the program also provides a shared database where you can record 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 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.*

WHAT IS LONG-TERM FOREST MONITORING?

Long-term forest 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 forest change (see Figure 1). Although meaningful forest change may be documented within a decade, longer-term monitoring generally provides greater benefits for understanding forest 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 wooded environments—from urban park to expansive forests—that sustain our lives in New England. Forests provide us with clean water and flood resilience, shade our streets, mitigate global warming by sequestering carbon, fuel our economies, and offer places for healthy outdoor recreation and spiritual renewal. To understand how our woodlands 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 forest change. Long-term monitoring, if done carefully, provides reliable knowledge and fascinating insights. Casual observation, which is often fallible, does not.

HOW IS THIS FOREST MONITORING PROGRAM DIFFERENT FROM OTHERS?

Although a number of excellent forest monitoring programs exist in New England today (see Appendix F), most are designed for and used by professional forest technicians. 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.

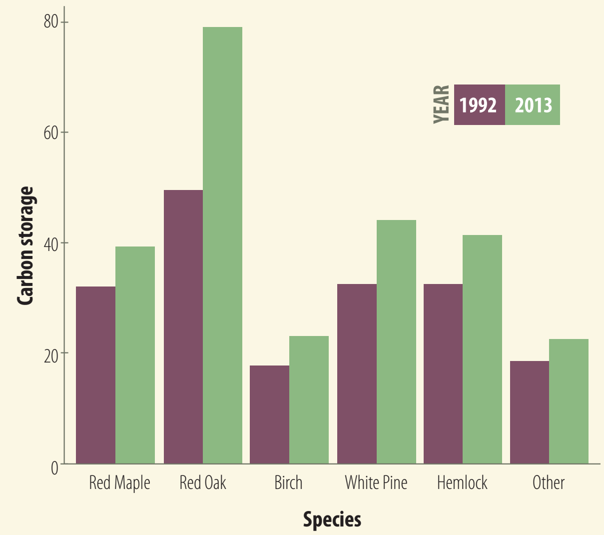


FIGURE 1. Change in carbon storage of tree species between 1992 and 2013 from 60 long-term monitoring plots in Petersham, Massachusetts. Data from the Harvard Forest.

Standing next to a 300-year-old hemlock in a long term forest plot.

HOW DO I BEGIN A LONG-TERM MONITORING STUDY?

Articulating your monitoring objectives is the first step in any monitoring project and 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, is a particular wildflower species declining in your woods? Which tree species are growing well or not so well in your forest? How will a recent ice storm change your forest? Have your invasive plant removal efforts increased the number of native plants? How quickly are your hemlock trees declining from the exotic insect pest hemlock woolly adelgid? Monitoring goals are generally limited only by the characteristics of your property 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.

WHAT ARE THE DIFFERENT TYPES OF MONITORING STUDIES?

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

Basic monitoring involves simply measuring forests over time in one or more locations in your woods. This approach is designed to answer questions about how your forest is changing but not about what is causing that change. Basic monitoring therefore cannot examine the effects of different management actions or disturbances (e.g., logging, blowdowns, or invasive plant removal) on your forest. So basic monitoring would be appropriate for addressing questions about which species are thriving but not about how an ice storm will affect those 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.

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

Comparative or question-driven monitoring attempts to document change and determine the cause of the change. This approach would be appropriate for addressing questions about whether removal of invasives has helped native species and how quickly a species is declining because of an insect pest. Question-driven monitoring involves comparing a disturbed or managed area (e.g., where trees have been cut or invasive plants removed) to a nearby undisturbed or unmanaged (reference) area. 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. Question-driven monitoring can also study the effect of a neighboring disturbance on your forest. For example, you could observe the effect of a forest edge (e.g., a farm field that borders your property) by comparing forest near the edge to an interior reference forest (>100 meters from edge).

HOW DO I MONITOR MY FOREST?

You will use 20 × 20 meter square plots to delineate a subset or sample of the forest. Inside these square plots, you will measure trees and other vegetation. These plots are the standard size for W&W Stewardship Science and 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 need to place your plots in the disturbed or managed area and in a nearby 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 the effects of an ice storm on your forest, and your ice-damaged area is an oak forest on a rocky slope, you should find a similar sloping, rocky, oak forest that remains undamaged in which to place your reference 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 undamaged forest. Such an approach mixes the effect of the disturbance 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, you may need to collaborate with a neighboring property owner, or you may need to abandon this particular monitoring question.

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

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., logged and unlogged × 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., logged and unlogged × 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.

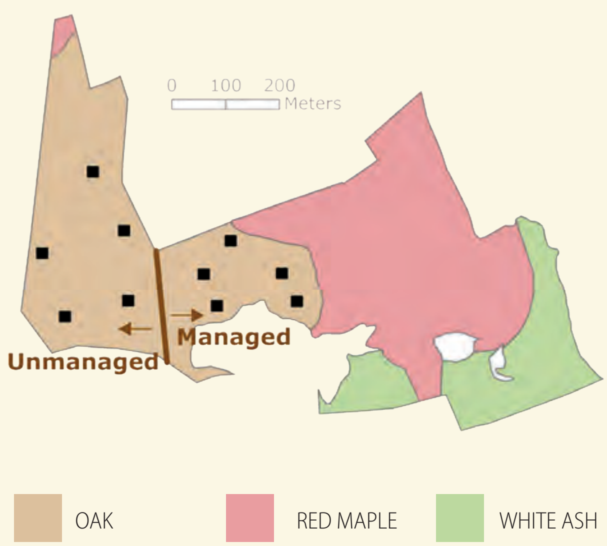


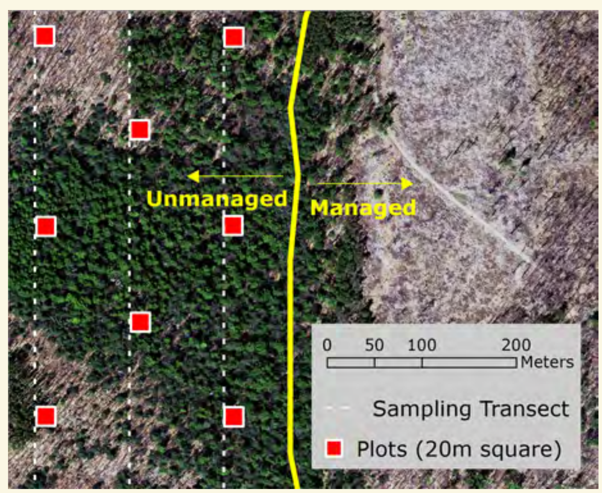
FIGURE 2. Example of plot locations in a comparative monitoring study between managed and unmanaged forest. Note that the plots are positioned in the same forest type in both the managed and unmanaged areas and are at least 50 meters apart within treatment areas and at least 50–100 meters apart between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

HOW FAR APART SHOULD I PLACE MY PLOTS?

We recommend that plots be spaced at least 50 meters apart from plot edge to plot edge, so that data from one plot are not overly influenced by data collected from another plot. Plots between disturbed and undisturbed areas should be separated by at least 50–100 meters to prevent the effects of management or disturbance from influencing the plots in the reference area. Plots should also be positioned at least 50–100 meters from roads and other forest edges (unless, of course, you are studying the effects of forest 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.

HOW FREQUENTLY SHOULD I MONITOR MY PLOTS?

Monitoring intervals will vary depending on the goals of your study and to some extent the type of forest you are monitoring; however, a remeasurement interval of five to 10 years is reasonable. For some projects, you may wish to remeasure the vegetation more frequently. For example, if you are monitoring tree regeneration in a recently logged forest, tremendous changes in the growth of the trees will occur during the first five years. It is important to remember that the longer the duration of the monitoring study, the more valuable it will be for understanding forest trends (see Figure 3).

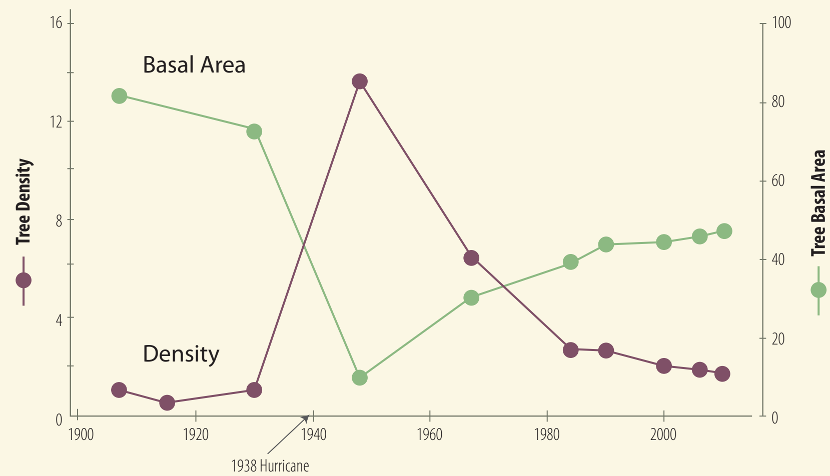


FIGURE 3. Tree density and basal area from long-term monitoring plots in Pisgah Forest, New Hampshire. Note the dramatic shift in density and area after the 1938 hurricane, which knocked down large trees, reducing area and creating space for many new small stems to grow. Data from the Harvard Forest

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 (four to five) 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 either Forestry Suppliers (http://www.forestry-suppliers.com/) or Ben Meadows (http://www.benmeadows.com/).

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 4.

When you are finished and satisfied that your plot is a 20 × 20 meter square, mark four corners with iron rebar or PVC pipes (at least 30 centimeters long). 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 drawbacks of making them conspicuous to potential vandals. Risk of vandalism will vary tremendously, of course, depending on the location and size of your property.

Top: Using compass for plot layout;
Bottom: Laying out the plot. ›

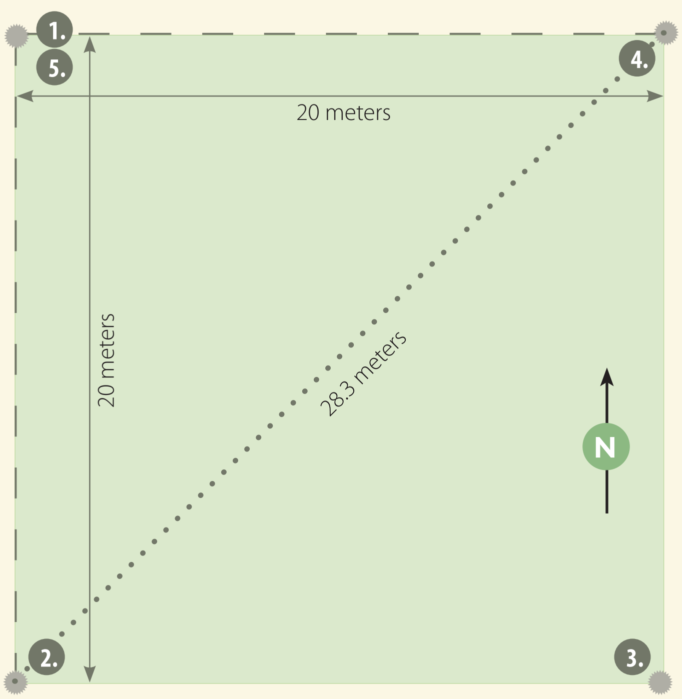


FIGURE 4. Plot layout.

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 39.7 and 40.3 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.

If two people are present, one person can stand at a corner with a compass and guide the other person running out the tape.

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 field data sheet, on page 15). 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 a nonforest 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 and C 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 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.

Decaying American chestnut stump of tree killed by the chestnut blight in the early 20th century.

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 New England Wild Flower Society 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.

Measuring a multi-trunked 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).

WHAT CAN I MEASURE BESIDES TREES?

Depending on your interests, goals, 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.

Measuring percent cover of shrubs and herbaceous plants for monitoring studies concerned with the diversity and abundance of nontree 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 most aggressive invasive plants are shrubs. *Herbaceous plants* include grasses/sedges, ferns, and wildflowers; can be either annual or perennial; and have nonwoody stems. Herbs are the source of much 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.

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.

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)

Monitoring the herbaceous layer.

Red maple seedling.

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 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.

Measuring tree seedlings and saplings for monitoring studies concerned with forest regeneration. 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).

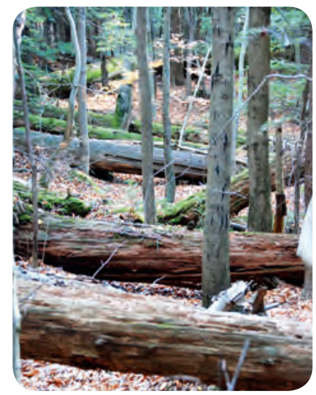
Measuring stumps for monitoring studies that involve timber harvests. Measuring the stumps in your plots will reveal the number, size, and species (if identifiable) of the trees that were logged. Data on stumps will help you interpret vegetation change over time as the forest grows back and will also 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 for an example of a data sheet).

Measuring large downed wood for monitoring studies concerned with the effects of timber harvesting, natural disturbance, or forest age. Large pieces of downed wood on the forest floor (technically known as coarse woody debris) are a good indicator of the intensity of past disturbance to the canopy from a wind or ice storm or other natural disturbance. In some locations where organic decomposition is slow, large accumulations of downed wood are associated with old-growth forests. Downed wood provides important seedbeds for tree seedlings, habitat for small mammals, and long-term storage of nutrients for the soil. It can also protect tree seedlings from browsing mammals.

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).

Measuring tree saplings in a recent timber harvest.



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

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 SUBMIT MY DATA TO W&W STEWARDSHIP SCIENCE?

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.

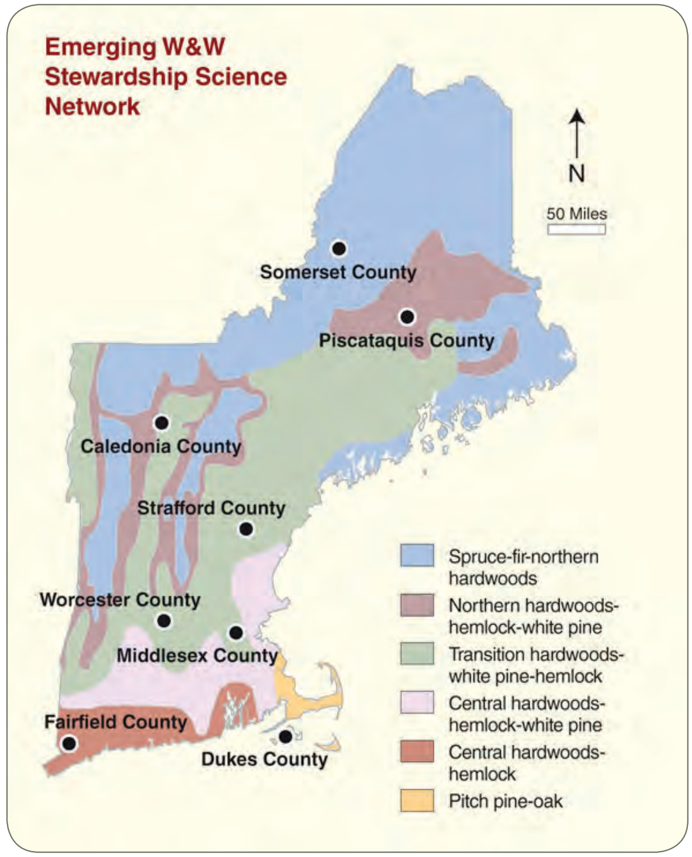
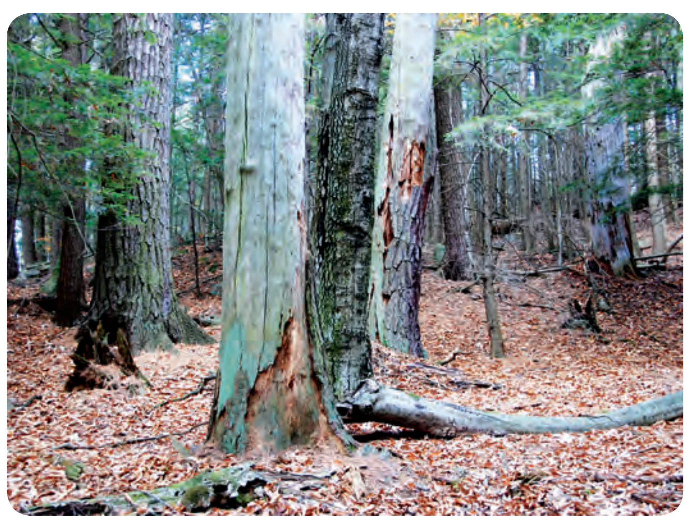


FIGURE 5. Locations of organizations, agencies, and landowners across New England that are part of the emerging Wildlands and Woodlands Stewardship Science network.



Large standing dead trees (snags) in old forest.

WILDLANDS AND WOODLANDS STEWARDSHIP SCIENCE FIELD 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: FIELD DATA SHEET, CONTINUED

WILDLANDS AND WOODLANDS STEWARDSHIP SCIENCE FIELD 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, slight, moderate, steep).

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.

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

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

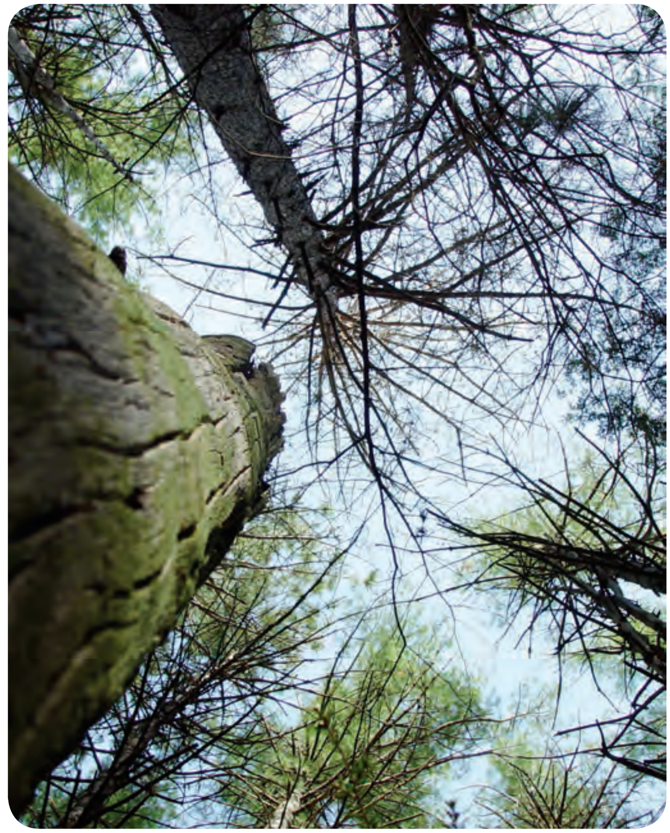
Emerald ash borer – Bright, metallic green beetle (1-1.5 centimeters) and D-shaped boreholes in ash tree are diagnostic. New to region in 2013.

Gypsy 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.

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

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.



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

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), outside the plot less than 10 meters away (O<10), outside the plot 10–50 meters away (O10–50), or outside the plot 50–100 meters away (O50–100). 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)

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)

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

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.

Weather and Other Nonliving 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 may be in your forest.

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 rectangularholes 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.

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

Current and past human activity. Check one or more and designate either I = inside plot; O<10 = outside plot less than 10 meters away; O10–50 = outside plot 10–50 meters away; O50–100 = outside plot 50–100 meters away.

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

Weather and other nonliving natural disturbances. Check one or more and designate either I = inside plot ; O<10 = outside plot less than 10 meters away; O10–50 = outside plot 10–50 meters away.

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

APPENDIX C. OPTIONAL PLOT DESCRIPTION DATA SHEET, CONTINUED

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:

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

SHRUBS AND HERBS Record all species and estimate % cover class in 400 m² 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.

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

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 (if known)	**Length**	**Diameter** 1	**Diameter** 2	**Condition** 1 = Wood hard 2 = Wood soft

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. RESOURCES AND REFERENCES

OTHER FOREST MONITORING PROJECTS IN NEW ENGLAND

Massachusetts Continuous Forest Monitoring Program,
http://www.mass.gov/eea/docs/dcr/stewardship/forestry/monitoring-of-our-forest-resources-with-cfi.pdf

Maine Ecological Reserve Monitoring,
https://www.maine.gov/dacf/parks/publications_maps/docs/Ecological_Reserve_Update_spring2005.pdf

National Park Service Northeast Temperate Network Inventory and Monitoring,
http://science.nature.nps.gov/im/units/netn/

USDA Forest Service Northeastern Forest Inventory and Analysis,
http://www.fs.fed.us/ne/fia/

Vermont Monitoring Cooperative,
http://www.uvm.edu/rsenr/wkeeton/pubpdfs/SleeperetalVMCForestHealthSynthesisReport.pdf

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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, http://highstead.net/ecostudies/Stewardship-Science.shtml
Wildlands and Woodland Project, http://www.wildlandsandwoodlands.org/science-initiatives/stewardship-science

Plant Identification

New England Wild Flower Society, http://gobotany.newenglandwild.org/simple/

Rare Plant Species

New England Plant Conservation Program (NEPCoP) list of plants in need of conservation, http://www.newfs.org/conserve/saving-imperiled-plants/flora-conservanda/

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://www.fs.usda.gov/naspf/sites/default/files/ash_yell.pdf
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
Beech bark disease, https://efotg.sc.egov.usda.gov/references/Public/WV/beech_bark_disease.pdf
Butternut canker, https://www.fs.fed.us/research/invasive-species/plant-pathogens/butternut-canker-disease.php
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
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Hemlock woolly adelgid, https://www.nrs.fs.fed.us/disturbance/invasive_species/hwa/
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, http://www.mass.gov/eea/docs/dcr/stewardship/forestry/health/winter-moth.pdf

Field Equipment Suppliers

Forestry Suppliers, http://www.forestry-suppliers.com/
Ben Meadows, http://www.benmeadows.com/

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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.

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