2019

Sugar maple regeneration: Citizen Science Training Guide

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Development and production of this guide were supported by the HBR LTER and the Public Engagement with science grants from the National Science Foundation, and USDA NE Climate Hub in partnership with Society for Protection of New Hampshire Forests, Hubbard Brook Research Foundation and Cornell University.

Photos and art by N. Cleavitt unless noted otherwise.

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Project Overview

The Sugar Maple Regeneration Project is a multi-year citizen science research endeavor to establish and monitor between six to eight Forest Society properties for tree health, productivity and regeneration. The project is designed and overseen using methods developed in similar long-term studies at Hubbard Brook Experimental Forest. This project will allow scientists at Hubbard Brook to broaden our understanding of sugar maple regeneration dynamics and any limitations found in other areas of New Hampshire. We hope to expand the project in year 2 to include high school science class partnerships at four sites. The project is a collaborative effort between the Forest Society, Hubbard Brook Research Foundation and Cornell University.

Why are we doing this project?

Sugar maple is an iconic species of the northern hardwood forest. It has notable cultural and economic importance including sugar maple syrup production and high quality lumber. Sugar maple also has a unique ecological role among the “big three” of the northern hardwoods (sugar maple, American beech and yellow birch) and can enrich the soil (Finzi et al. 1998). Sugar maple leaf litter is of particularly high quality and returns many nutrients relatively quickly to the soil. At the ecosystem level, sugar maple plays a unique role in the cycling of nitrogen in the system with much higher nitrate levels than other species (Lovett et al. 2004; Lovett and Mitchell 2004). At the tree level, epiphytes (plants and lichens growing on trees) show preference for the relatively calcium rich bark of maples that is capable of buffering pollution effects on these sensitive species (Cleavitt et al. 2009, 2011). Given the many facets of the unique contributions of sugar maple, the growing number of studies from the northeast documenting regeneration failure is cause for concern and for research into the regeneration ecology of the species.

At Hubbard Brook Experimental Forest (HBEF), we have repeatedly documented sugar maple regeneration failure on our calcium poor soils (Cleavitt et al. 2014, 2018). This failure means that at HBEF, sugar maple will not be an important species in the future forest once mature trees age out and die. The causes of this documented failure of sugar maple seedlings are not entirely understood, but it is likely that there are multiple contributory factors at work.

Acid Rain. There has been a regional reduction of base cations (prevalent soil nutrient ions like calcium (Ca), magnesium (Mg) and potassium (K)) from soil of the Northeast as a consequence of acid rain leaching these nutrients. The acidification of the soil also makes aluminum (Al) (which also has a positive charge) more mobile in the soil. This is troublesome because Al can be toxic to plants and cause severe nutrient imbalance. A calcium addition experiment at the HBEF (calculated to bring the soils back to pre- industrial levels) has shown some promise for maintaining sugar maple in these forests (Juice et al. 2006; Battles et al. 2014); however, strong regeneration by American beech may limit the ability of understory sugar maple to benefit from the treatment (Cleavitt et al. in prep.).

Beech Competition. Beech bark disease is also prevalent in our forest and has both altered the dynamic of sugar maple and beech and greatly lowered the value of beech in managed forests. Beech bark disease is a complex of damage caused firstly by an exotic scale insect and secondly by a native fungus that then enters the beech cambium through cracks in the bark made by the scale insects (see beech id page for more on this topic). A large ecological consequence of beech bark disease has been the production of beech thickets through root sprouting of damaged trees (Giencke et al. 2014). This thick beech understory can suppress sugar maple growth (Hane 2003). Hence, it appears that the trajectory of sugar maple forests with beech bark disease may depend greatly on their soil fertility and feedbacks with sugar maple having greater potential to maintain itself on more fertile soils (Arthur et al. 2017; Lawrence et al. 2018).

Climate Change. Several studies have highlighted the effects of recent climate trends on sugar maple growth (Oswald et al. 2018; Nolet et al. 2018). State Climate Summaries: (https://statesummaries.ncics.org/) give perspective on the specific climate trends each state is experiencing. Sugar maple roots are particularly susceptible to freezing damage, and somewhat ironically, this type of damage is increasing. (Boutin and Roubitaille 1995; Tierney et al. 2001; Cleavitt et al. 2008). Reductions in snow pack, as a result of climate change, increase susceptibility to root damage and therefore cause reductions in tree growth. Overall, this could pose considerable health risks for sugar maple (Reinmann et al. 2018). Understanding the complexity of sugar maple regeneration failure would benefit from study at more sites than HBEF. **That is where the Forest Society properties and you come in!**

The forest reservations of the Forest Society will allow us to study this complex problem of broad ecological and forest management interest at a state level: over a broad latitudinal (climate) gradient and on soils of varying soil fertility. As a citizen scientist, you can help us determine whether sugar maple regeneration failure is occurring at a regional scale, and collect critical information that may help in understanding its cause(s). This Citizen Science project has been rigorously designed so as to provide data leading to a scientific publication on this critical and complex topic.

Project background

This project is designed to complement ongoing plots where we have been studying marked sugar maple seedlings at Hubbard Brook Experimental Forest (HBEF) for 13 years by using the same methods. At HBEF, we have followed several groups of seedlings originating from the same mast seed event (termed a cohort). A mast year has markedly high seed production while the intervening years have negligible to no seed production. Many trees in the northern hardwoods, such as sugar maple and American beech, are mast producing trees.

The most recent mast year was autumn of 2017, and we will be marking the seedlings from this 2018 cohort (year when seedlings emerged and had their first growing season). Within the HBEF, we overlaid our study on a pre-existing network of plots that cover the Hubbard Brook valley (Schwarz et al. 2003; van Doorn et al. 2011) as well as sites where we have long-term collectors for fine litter (i.e., leaves, seeds, fine twigs; Fahey et al. 2005; Cleavitt & Fahey 2017).

Because there are no pre-existing plots on the Forest Society properties, our first step is to establish these plots and gather data for the plots using procedures similar to those used at HBEF. Once established these plots will be re-measured every five years for tagged trees (≥ 10cm in diameter) and understory stems (2-9.9 cm in diameter) and every year for marked sugar maple seedling survival, size and health. Another annual measurement that we hope to install on the plots in 2020 will be fine litter collection baskets. These collectors allow us to both monitor annual primary production, particularly of seeds, and link seed production to future cohorts of seedlings on the plots. In addition, we hope to initiate and maintain high school partnerships with these SPNHF properties to use our project as an educational tool and involve students in at least the autumn litter collections and processing.

Fine litter collector at Hubbard Brook Experimental Forest.

Volunteer commitments

We will be asking that you make a good faith commitment to sticking with the project for three years. **Table 1** provides a detailed summary of the time commitments that we require.

Table 1. Volunteer time commitment over three year project

Year of project	**Year 1**	**Year 2 (established sites)**	**Year 2 (new sites)**	**Year 3**
Time frame				
Early May	1 day training at HBEF	1 day training at HBEF	1.5 day training at HBEF	0.5 day training at HBEF
May	Practice tree ID on your own		Practice tree ID on your own	0.5 day Spring fine litter collections
6 June-2Aug	3-4 days of plot set-up and data collection on site	2-3 days for installing fine litter collectors (6 plots; 3 collectors per plot; 18 per site) 1 day for re-visit and assessment of marked sugar maple seedlings	3-4 days of plot set-up and data collection on site 2-3 days for installing fine litter collectors (6 plots; 3 collectors per plot; 18 per site)	1-2 day for re-visit and assessment of marked sugar maple seedlings, and litter collector repairs, if needed
Early August		0.5 day litter collection	0.5 day litter collection	0.5 day litter collection
Mid-August	1 day wrap-up at SPNHF	1 day wrap-up at SPNHF	1 day wrap-up at SPNHF	
Mid or late August				1 day wrap-up at SPNHF
October		0.5 day litter collection	0.5 day litter collection	0.5 day litter collection
November		2-3 optional sorting sessions (0.5 day each)	2-3 optional sorting sessions (0.5 day each)	Optional leaf processing with classrooms
Time total	**5-6 days**	**5-6 days**	**9-11 days**	**4-6 days**

Ideal Project Timeline (i.e., all funding comes in)

Year 1 – 2019 (participants: SPNHF volunteers, Engaged Cornell undergrads)

Spring Training at HBEF with all volunteers (1 day)

June-mid-Aug Establishment of 12 plots at 4 properties (4 days / site):

1. Complete plot description
2. Tagged trees with data ≥ 10cm diameter
3. Sweep data for trees < 10 ≥ 2 cm in diameter
4. 50 marked seedlings per plot
5. Twelve soil cores – composited in one sample bag per plot.

Mid-late August Wrap up meeting at SPNHF in Concord that includes (1 day):

1. Soil pH measures
2. Wrap-up presentations
3. Formal team-based evaluations
4. Thank yous and plans for next season

Year 2 – 2020 (participants: SPNHF volunteers, Engaged Cornell undergrads)

Spring Refresher and new methods training at HBEF (1 day)

June- Aug Site visits and establishment of fine litter collectors at 6 properties:

1. The 2 new properties will need full plot establishment as in 2019. (4 days / site)
2. Install 3 collectors in 6 plots per site; 18 per site (1-2 days / site)
3. Re-visit and assess all marked sugar maple seedlings for 4 sites (1-2 days)
4. Collect growing season litter in August; bring to wrap-up for sorting (½ day / site)
5. Mid Aug Wrap-up similar to 2019. (1 day)

Late October Collect litter from the collectors and subgroup of volunteers come to HBEF at Pleasant View Lab for sorting sessions; Nat dries and weighs this litter set (½ day collection) (optional 1-2 day sorting)

Year 3 – 2021 (participants: SPNHF volunteers; High school students and teachers, in part)

Spring

1. Training on litter collection and processing at HBEF in early May(1 day) and set dates for litter collections
2. Spring fine litter collections by volunteers and trainers and teacher orientation in field. (1 day per site or two ½ days)

June- Aug Site visits at 6 properties:

1. Volunteers and trainers re-visit and assess all marked sugar maple seedlings for 6 sites (1 day / site)
2. Collect growing season litter in August; bring to wrap-up (½ day / site)
3. Mid Aug Wrap-up similar to 2020, but this time including teachers (1 day).

Late October

1. Collect litter from the collectors coupled with ecology field trip by participating classes to sites hosted by trainers and volunteers.
2. teachers instruct sugar babies curriculum in classrooms

November — Subgroup of volunteers and trainers work with teachers to process litter in the HS class rooms; teach lessons to support data graphing and applicability

Year 4 – 2022 (participants: SPNHF volunteers; High school students and teachers)

In most respects, work will be a repeat of year 3. We could add to project if volunteers and / class rooms are excited about aspects like snow cover and depth, phenology or more properties. Also, we would want to follow any new seedling cohorts as they occur after mast years.

Year 5 – 2023 (participants: SPNHF volunteers; High school students and teachers)

Repeat of year 4. We could add to project if volunteers and / class rooms are excited about aspects like snow cover and depth, phenology or more properties. Also, we would want to follow any new seedling cohorts as they occur after mast years.

Year 6 – 2024 (participants: SPNHF volunteers; High school students and teachers)

This year the large trees and sweep data would be retaken on the four sites established in 2019. All other work remains the same.

Year 7 – 2025 (participants: SPNHF volunteers; High school students and teachers)

This year the large trees and sweep data would be retaken on the two sites established in 2020. All other work remains the same.

Project coordination

We will be holding a one-day introduction and volunteer training session at HBEF in spring of 2019. While this training will be helpful as an introduction, each crew of volunteers will work with trainers who have much greater experience with all aspects of the measurements, especially species identification and data quality control. Trainers are associated with specific sites shown in **Table 2**.

In the first year of the project, crews composed of the site trainer and volunteers will visit the sites during the growing season (June – August) to establish 12 plots per site. We will schedule these work days for each site at the spring training day. We will be trying to keep the workdays for each crew within a three-week window in order not to lose efficiency in needing to refresh protocols on each work day. At each site, this work is expected to take about 3-4 full day site visits. We will have another full wrap-up day that will include soil sample processing, data transfer, and project evaluation event in August after field work is completed for all sites.

In the second year of the project, volunteers will re-visit the 12 plots to evaluate the status of marked sugar maple seedlings (live or dead; and leaf area and damage rating for all live individuals) and we will install fine litter collectors on six plots per site, which ideally will be collected three times a year: spring, late summer and the main fall collection. We also intend to add 2-4 more sites chosen for school partnerships in 2020 (see **Ideal Project Timeline**).

Trainers will be responsible for organizing site work days and having all necessary equipment and data sheets to carry out the field work. Trainers are living references on the scientific protocols and species identification outlined in this manual. Their guidance will ensure high data quality and accuracy throughout the project. They will also be able to answer your many questions on the project and forest in general. Once the establishment of plots is completed the trainers may not be accompanying volunteers on all site visits – unless requested in future years. We hope that the investment in training volunteers will lead to volunteer ownership of data collection at their sites for many years.

Table 2. Alignment of trainers with SPNHF properties and contact information

SPNHF site	Trainer	email	Cell phone
Kauffmann	Nat Cleavitt	nlc4@cornell.edu	(603) 960-2519
Monadnock	Sarah Thorne	sthorne@hubbardbrookfoundation.org	(603) 717-5124
Sudrabin	Sarah Thorne		
Yatsevitch	Nat Cleavitt	nlc4@cornell.edu	(603) 960-2519

Dr. Natalie Cleavitt is the Project Leader for the Sugar Maple Regeneration Project. Nat began her work at Hubbard Brook Experimental Forest as a crew member (1993-1996). She earned her PhD from the University of Alberta in 2001, and returned to HBEF in 2002 as a post-doctoral researcher studying the effect of decreased snow pack on sugar maple roots. She is currently the Vegetation Crew coordinator for the site. Nat researches sugar maple regeneration, forest community monitoring and round-leaved orchid demography.

Sarah Thorne has worked many years for SPNHF conserving land and conducting land conservation research. She also taught high school ecology for 14 years and worked at the Hubbard Brook Experimental Forest developing ecology lessons and assisting the field scientists.

Crew safety

For your safety in the woods, it is advisable to bring the following items in a backpack or bag of some sort: map of the research site, compass, cell phone, food/snacks, water, extra clothing (layers, raingear), bug repellent for ticks and flying insects and a basic first aid kit. This work is very unlike a hike on a trail because you are in the same place for large amounts of time and the biting insects will catch up with you. Also, walking off trail or "bushwhacking" requires much attention to where your feet are being placed and whether you are about to get a branch in the face. Note: cell phones may not have reception on the research sites. If possible, try to accomplish fieldwork with at least one other person. In most cases, volunteers will be meeting trainers and/or Cornell students at the site, but if not, you may consider coordinating with another site volunteer. If weather conditions are unfavorable (heavy rain, thunderstorms, etc.) please seek shelter and come back at another time to continue work.

Site descriptions

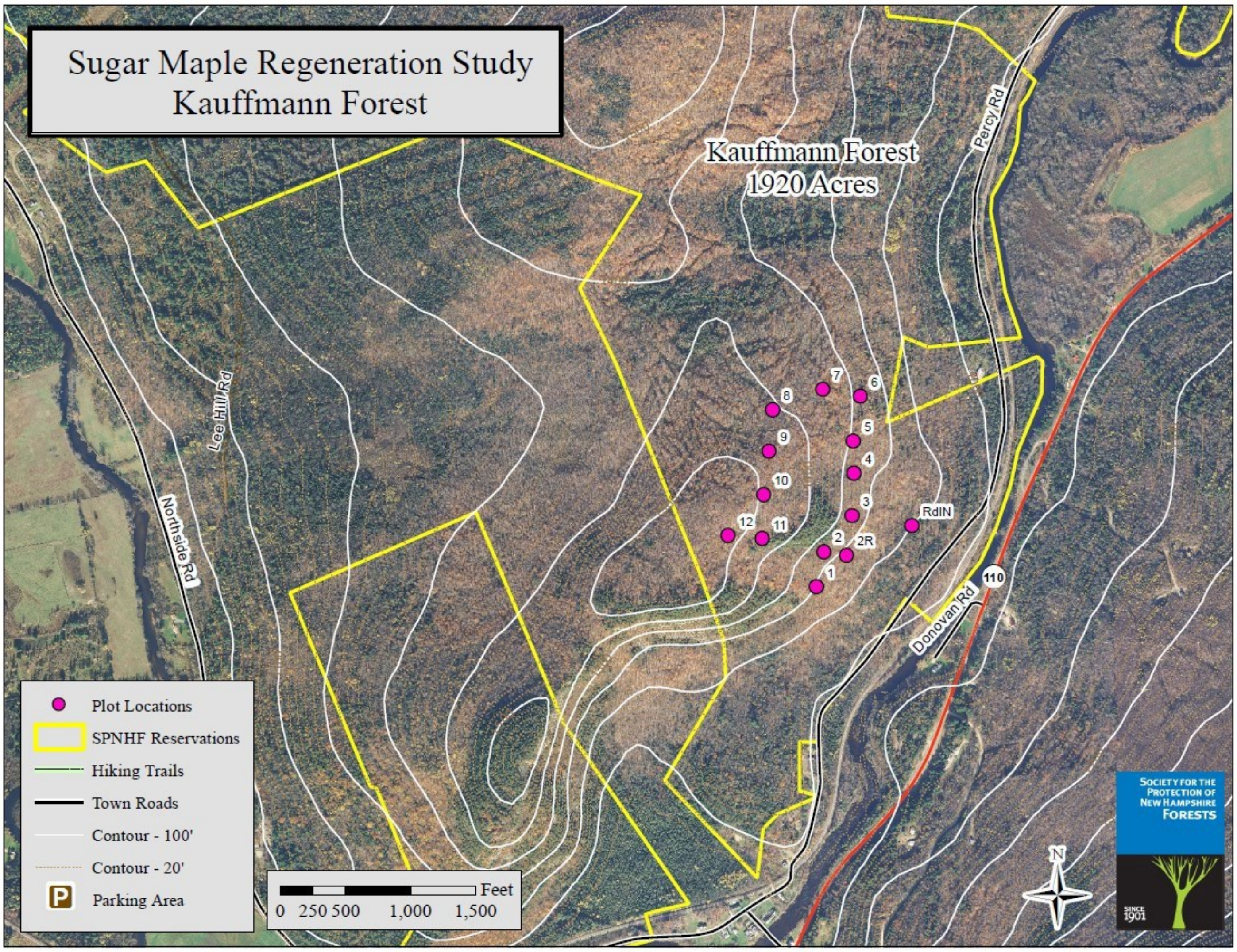
Broader descriptions of the forest reservations included in this study can be found in the comprehensive SPNHF management plans for these properties (these plans are available online in the Sugar Maple Regeneration Study Google Folder). Here we focus only on the portion of the properties where our plots will be located. Plots were established in autumn of 2018. In general, 12 plot locations were determined for each of the four reservations. Plots are spatially-uniform and placed as closely to a 100m grid system as possible with the restriction that the plot had to include three overstory canopy sugar maple trees. This same restriction applied to the plots where we track sugar maple seedlings at HBEF because only overstory trees produce seed, and by extension seedlings. Plots are currently marked at their centers by a labelled orange PVC stake flag (**Fig. 1**).

Figure 1. Plot center marker for Yatsevitch, plot 9. Photo by Sarah Thorne.

All points have been GPS'd and points will be provided at the spring training. GPS locations for parking areas, trail departures (when relevant) and plot locations will also be provided. Carrie Deegan will be providing an overview of how to use a free smartphone navigation app (GaiaGPS) see these points on your mobile device and navigate to them. Volunteers will be expected to bring their own cell phones for navigation and photographs.

Kauffmann Forest, Stark

Our plots are most easily accessed by a left onto Northside Road from Rte 110 through a covered bridge and then soon after a right onto Percy Road. Look for the first parking on the left on Percy Road at the base of an old logging road (GPS points will also be provided). This site has a remarkably diverse tree inventory and some impressive ledges. **Please walk with caution in the boulder areas**. Walk up the old logging road to where it takes a definite right turn. The first six plots run NE to the SE of the rock ledges and then wrap



around the ledges by turning NW and then SW (**Fig. 2**).

Figure 2. Map of Kauffmann Forest showing location of study plots. Parking is at the first pull off heading North on Percy Rd. A larger version of this map is available in the Google Drive folder for the project.

The on plot canopy sugar maples varied in size from 20.9 – 52.1 cm in diameter at breast height (DBH). We recorded the following tree species in the plots in decreasing order of frequency: sugar maple, American beech, red maple, paper birch, white ash, yellow birch and basswood. Dead pin cherry were also noted. White pine, red oak and a butternut tree were also seen while we were walking between plots. Beech tended to dominate in the understory as seen in **Fig. 3**.

Figure 3. Cindy Wood walking through Kaufmann Forest between plots 6 and 7, autumn 2018.

Monadnock: Stand 5, Dublin

These plots are accessed from the Dublin Trail. The Dublin Trailhead is located by taking a left off Rte 101W onto East Lake Road and bearing left onto Old Marlborough Road, then turning left onto Old Troy Road, which is a dirt road. Parking is well marked on the right-hand side. Access the plots by walking up the Dublin Trail for a few minutes. The first plots are located close to the junction of the Dublin trail with a stone wall and old logging road (**Fig. 4**).

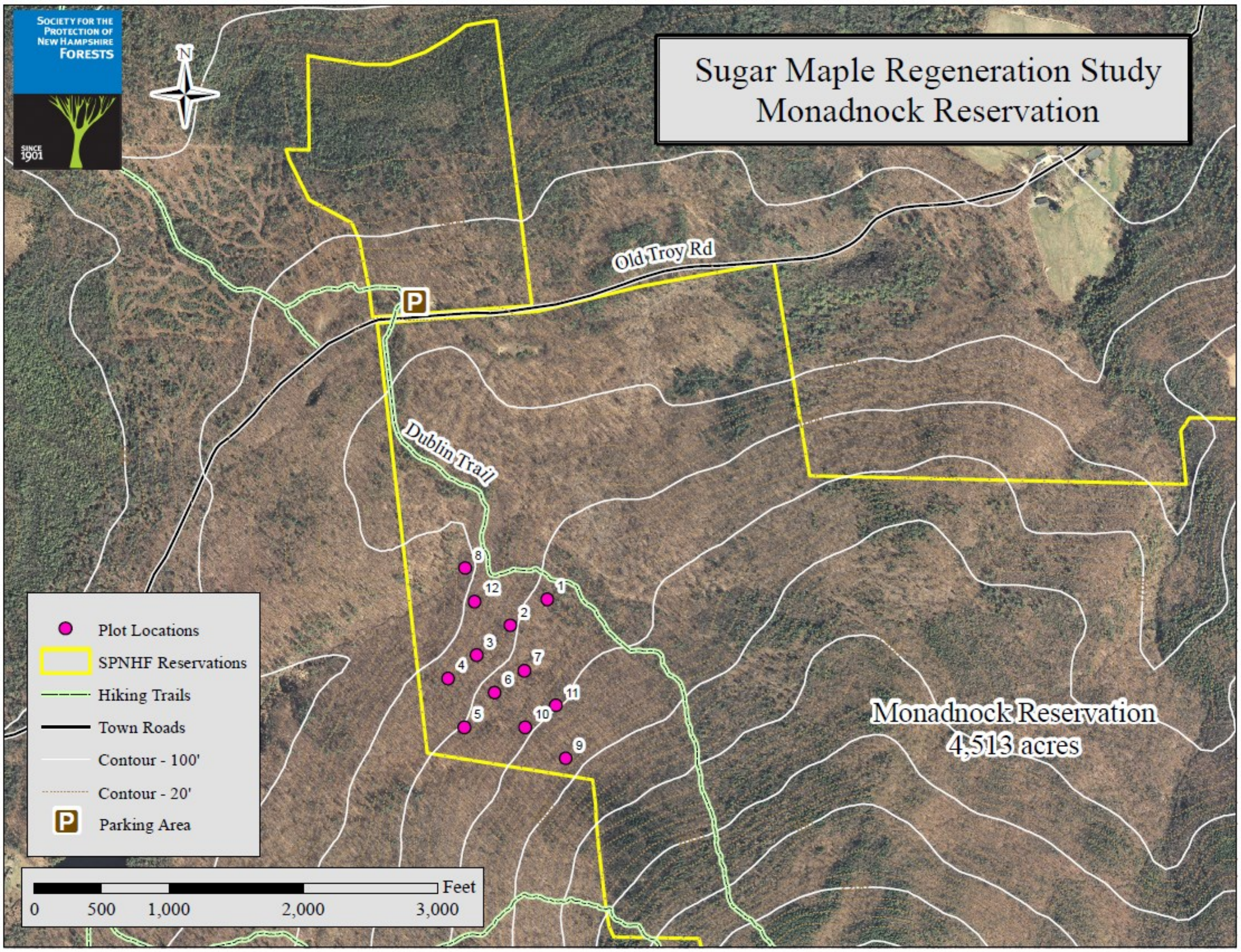


Figure 4. Location of study plots in Stand 5 of the Monadnock Reservation. A larger file size can be accessed in the project Google Drive folder.

Tree composition of the plots in order of decreasing frequency: sugar maple, red maple, white ash, yellow birch, paper birch, American beech, black cherry and red oak. Striped maple and hophornbeam were common understory trees. Buckthorn was noted only in the harvested area around plot 7. Many wolf trees (large, old trees with spreading canopies that likely grew to maturity when the surrounding land was cleared) were noted especially along rock walls and stream drainages (**Fig. 5**). Sugar maple sizes on the plots varied from 23.5 to over 70 cm in DBH.

Figure 5. Taken from the center of Plot 12 in Stand 5 of the Hart and Cooley lots in Monadnock Reservation. Three wolf sugar maples follow the bank of a stream drainage.

Sudrabin Forest, Orange

This site is accessed by walking an unmaintained road, Orange Road from the East (**Fig. 6**). Plots are located on the south side of the road. This site has remarkably uniform forest composition. In order of decreasing frequency in the plots the tree species were: sugar maple, American beech, yellow birch and white ash. Red oak was noted outside the plots on the lower slope of the site. Ice storm damage (presumably 1998 ice storm) was noted on the sugar maple canopies near the ridge top with many now in various states of decline.

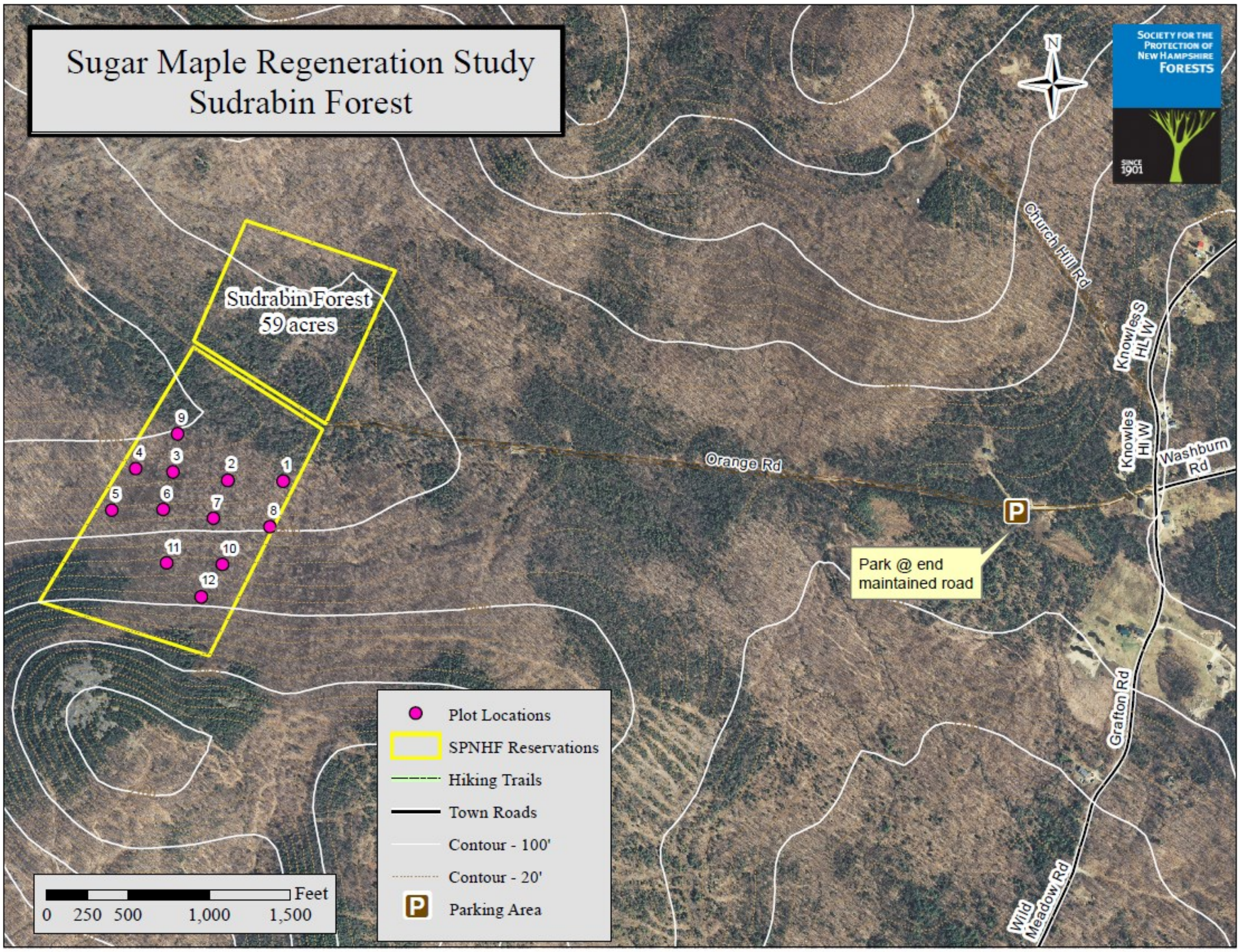


Figure 6. Map of study plots at Sudrabin. Note plot 9 will be relocated in spring 2019 as it was accidentally positioned outside the property boundary.

Near plot 4, pin cherry and an old skid road were evidence of past harvest. Plot 12 was difficult to locate on the uppermost slope where many of the sugar maples were dying. Otherwise, this site has a remarkably uniform species composition and plots were nearly uniform in their placement on the 100m grid (**Fig. 7**). Sugar maple sizes were between 24.5 – 68.3 cm in diameter. A number of bear claw beech were also noted near plots 5 and 6.

Figure 7. Looking down the 100m tape through the remarkably uniform forest of Sudrabin. Photo by Sarah Thorne.

Yatsevitch Forest and EcoReserve, Plainfield

All plots are located in the EcoReserve. Yatsevith Forest is accessed by parking on Pennimen Road near a cow farm (**Fig. 8**). The EcoReserve is a special management area designated by SPNHF in which timber harvesting is typically restricted. In this case, the EcoReserve was designated because the area contains a significant number of uncommon herbaceous plants indicative of rich mesic forest sites.

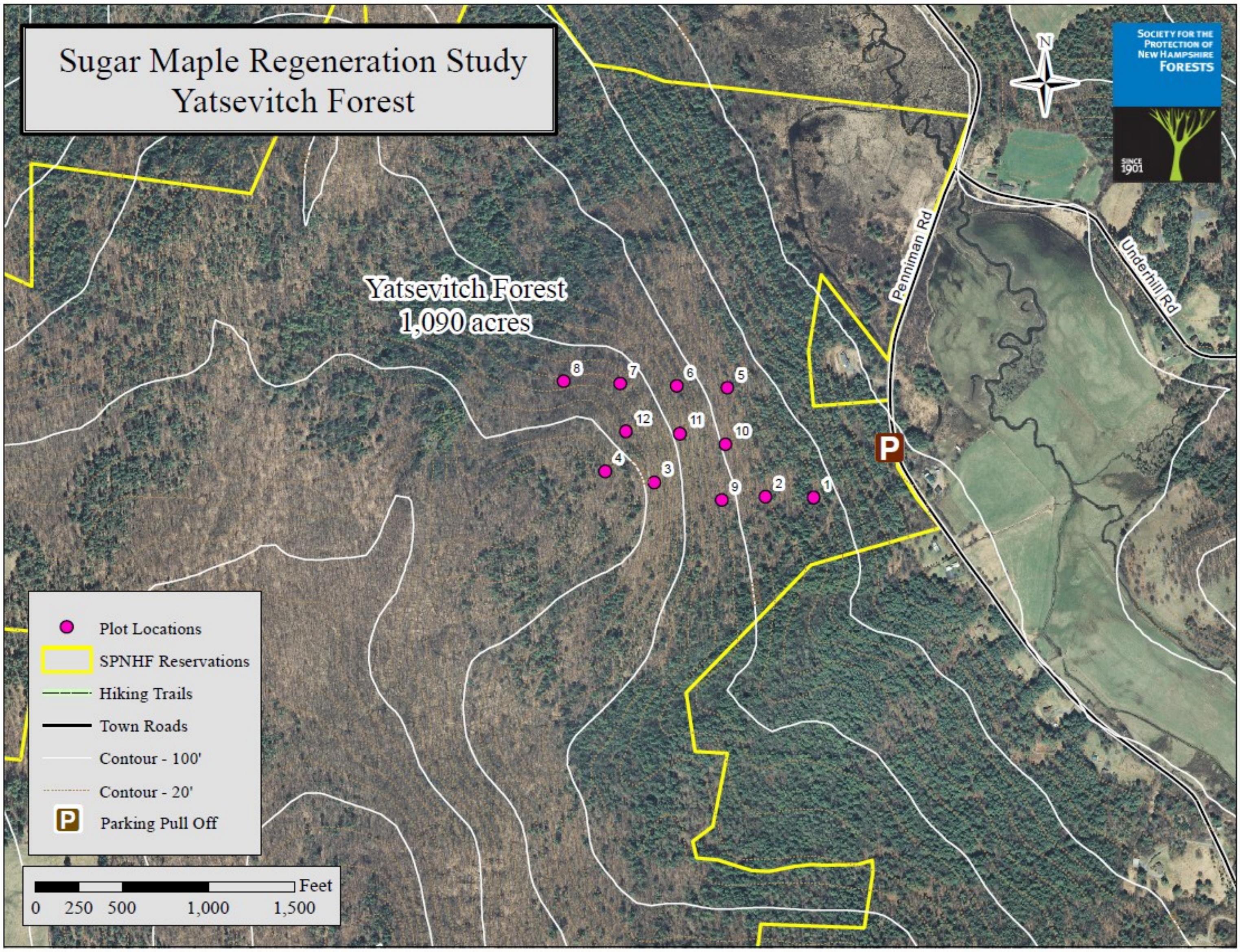


Figure 8. Map of study plots at Yatsevitch Forest. Note that plots 5-8 are still to be positioned in spring 2019.

In general the site shows signs of worm presence with very thin litter layer and no organic horizon. Volunteers for this property should read Bohlen et al. (2004) for summary of earthworm effects. Lots of deer scat suggests fairly high deer density (maybe 3-5 times that at HBEF). Site is surrounded by agricultural land. Lots of exotic invasive understory plants were noted in portions of the reserve including black swallowwort, bittersweet and barberry. The fern diversity was notable with large patches of maidenhair spleenwort.

The tree species noted on the plots in order of decreasing frequency were: sugar maple, red maple, white pine, eastern hemlock, bitternut hickory, American beech, paper and yellow birches. This site was the only one currently in the project with several of the plots mono-dominant in sugar maple. Canopy sugar maple size ranged from 26.1 – 101.3 cm in DBH. The remarkably large wolf sugar maple was located at a hill top in plot 12 (**Fig. 9**).

Figure 9. A wolf or pasture sugar maple measuring 101.3 cm in DBH on a hill top in the Yatsevitch EcoRerve. Many animal cavities were present on this venerable tree. Photo by Sarah Thorne.

Establishing a plot

The plot design in this study is based on the valley-wide plot network at HBEF. The plots are 0.05 hectares or 500 m^2 in size measured in a 12.62m radius circular plot. Circular plots have many advantages over square or rectangular plots as everything can be referenced to a single center point. We will be taking plot description data, three sets of vegetation data and soil samples at each of 12 plots per site. The overall plot design is depicted in **Fig. 11a**. NB: *Always take care to avoid stepping on sugar maple seedlings, particularly before they have been marked.*

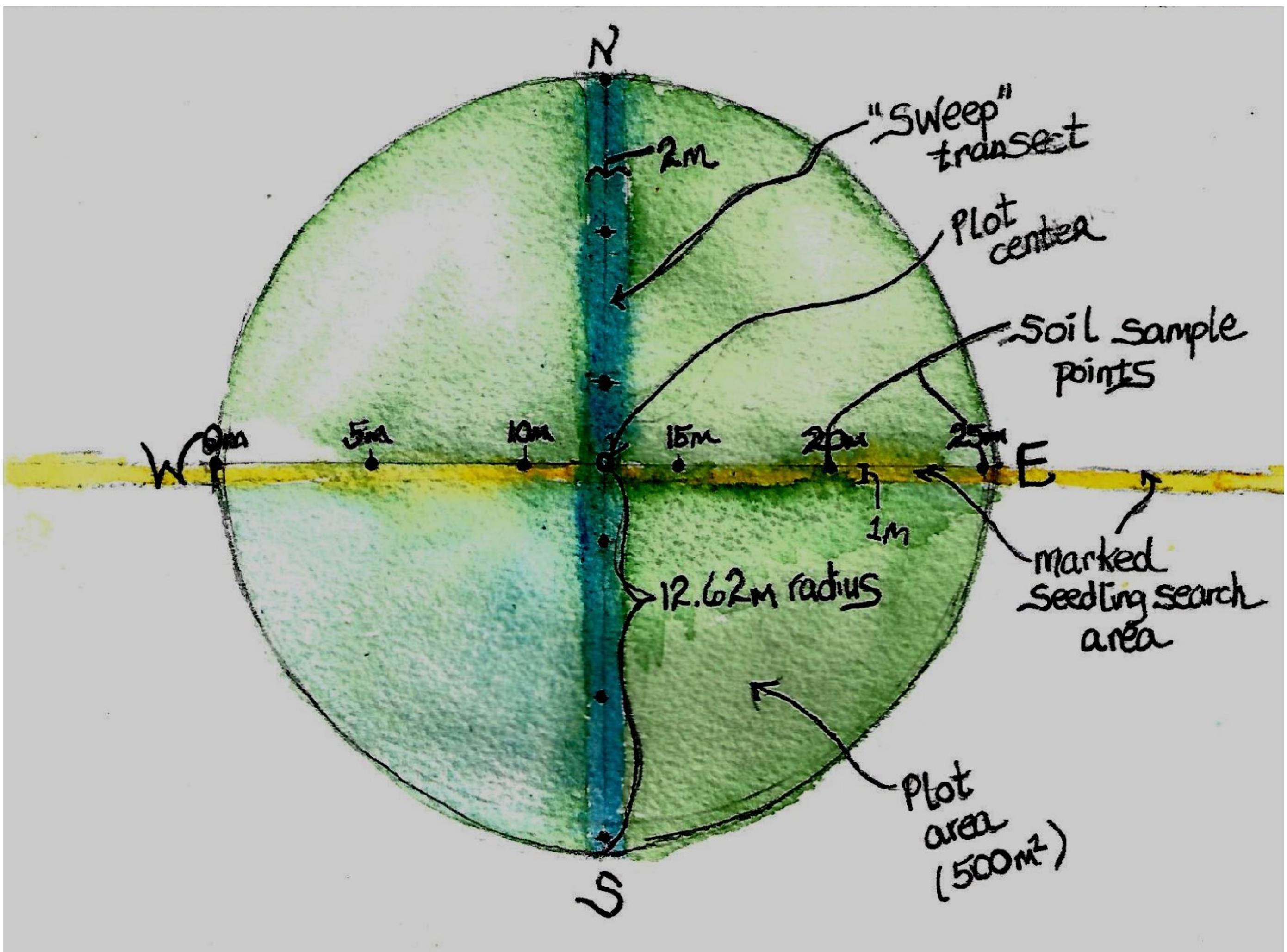


Figure 11a. Plot set up with center point and two perpendicular transects going N-S and W-E. Green is the full plot area. Blue is the two meter belt transect area for stems 2-9.9cm DBH. Yellow shows part of the one meter wide search area for sugar maple seedlings.

Figure 11b. Permanent plot center with numbered tag.

Step 1. (one person) **Plot center**: Locate your plot center using the GPS coordinates. Replace the temporary orange flag with a numbered PVC post as plot center (**Fig. 11b**).

Step 2. (two people) **Plot delineation and slope measurements**. Two thirty meter tapes should be laid to cut the plot into quarter pie pieces along the N-S and E-W diameters. This requires two people working together. One holds the tape at center and the other person runs the tape first until the one person at center has 12.62m and then until the runner reaches 25.24m on the opposite direction (after walking back past center and picking up the tape roll). One of the people needs to be using a compass to orient the line. I prefer to do the compassing as the runner, but others like to have the stationary person direct the runner with the compass. These tapes will remain in place until the plot work is complete.

Slope measurements are taken with a clinometer (see equipment section). We take five slope measures: the four cardinal directions and the slope along the aspect (direction that the slope is facing, taken with a compass). The two people need to stand on flat ground facing each other to determine where the sighter (person with the clinometer) should aim on the stander (person at center). Then take the slope percent (right scale in the clinometer) with one person at center and the other 10m from center along each of the four cardinal directions. This data is recorded on the plot description sheet.

Step 3. (2 people) **Mapping witness trees:** For each plot center, we need to record two close trees that form close to a 90° angle with the center. For each witness tree, we will use the 30 m tape for measuring distance (straightest angle side of tree) and a compass bearing (to the middle center of tree). This method of mapping is termed triangulation (**Fig. 12**). These trees will be the first trees tagged in the plot and must be ≥ 10cm in DBH.

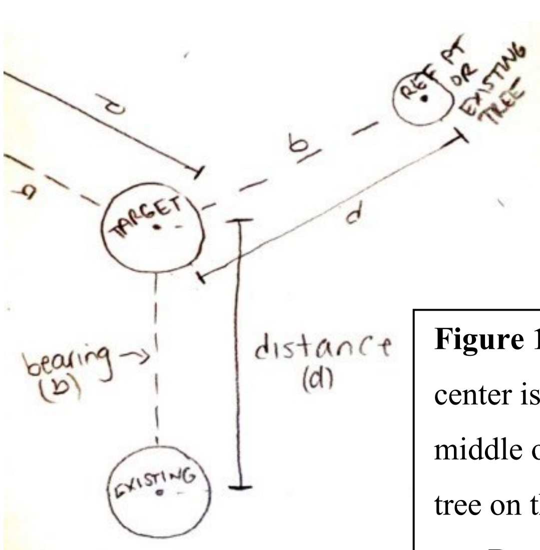


Figure 12. How to map a point with two witness trees. In our case the plot center is the target, note to measure the distance you are positioned at the middle of the side of the tree while for the bearing you are at the center of the tree on the side closest to the target center point. Figure contributed by Natalie van Doorn.

Figure 13. Tagged sugar maple at HBEF showing upward angle of the nail holding a unique number tag on the tree. This unique tag allows us to follow trees and their growth as individuals over time.

Step 4. (1 person) **Tagging the large trees in a circular plot.** All live trees ≥10 cm in diameter at breast height (1.37 m) within 12.62m from the center point will be permanently tagged. Position all tags to face the center post as this greatly helps with center location. Tags should be above where the DBH measure needs to be taken and the aluminum nail should be tilted up about 45° to hold the tag in place (**Fig. 13**). When hammering the nail, you only want to sink it into the cambium (the live cell layer) so that the nail will be pushed out as the tree grows. Usually, two to three hits are sufficient to secure the nail and not sink it in too deeply. Tags should be used in sequence to the extent possible such that having one person tagging on a plot is preferable (however, we encourage rotating jobs between plots). The tagger should be careful to move out from center and back not missing any trees (**Fig. 14**). A tree must be rooted halfway in the plot to be included. Any trees close to the edge need to be checked for distance prior to being tagged.

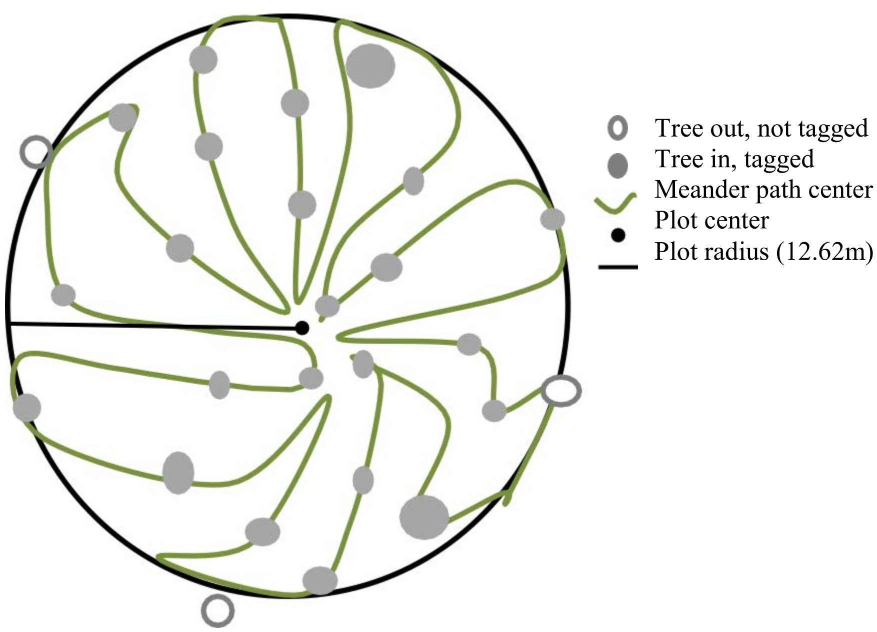


Figure 14. Schematic of meander path for tagging trees and examples of trees that are close to, but not in, the plot area

Step 5 (1-2 people) **Tagged tree protocol and data collection**

Figure 15. Nat taking a DBH measure of a canopy sugar maple. Photo by Sarah Thorne.

Within the 12.62m-radius plots, all live trees ≥10 cm at breast height (1.37 m) will be permanently tagged and measured for **DBH** (diameter at 1.37m)**, VIGOR** and **SPECIES**. DBH is measured to the nearest 0.1 cm with a special tape (D-tape) that allows us to physically measure the tree's circumference, but read the diameter from the tape (see section on equipment). We use a DBH pole to keep height on the tree consistent and always position the DBH pole on the uphill side of the tree (**Fig. 15**). As you wrap the tape around the tree keep it perpendicular to the tree bole rather than the ground surface.

VIGOR categories (ALL TREES):

1) alive and healthy;

2) alive but obvious signs of damage/decline;

3) alive but dying;

4) standing dead

Species are recorded as a four letter abbreviation (see Tree identification section and field ref sheet).

Strange trees (see **Fig. 16**)**:** clumped, split, or wounded trees follow these rules: If more than one stem originated from the same root system, each stem ≥10-cm is measured separately and given a unique tag. Split trees are counted as two trees if split below breast height, but only as one tree if split above. Trees wounded at breast height are either measured directly above or below the wound, depending on which would give the most representative measure of the tree's volume. Note in the tree notes.

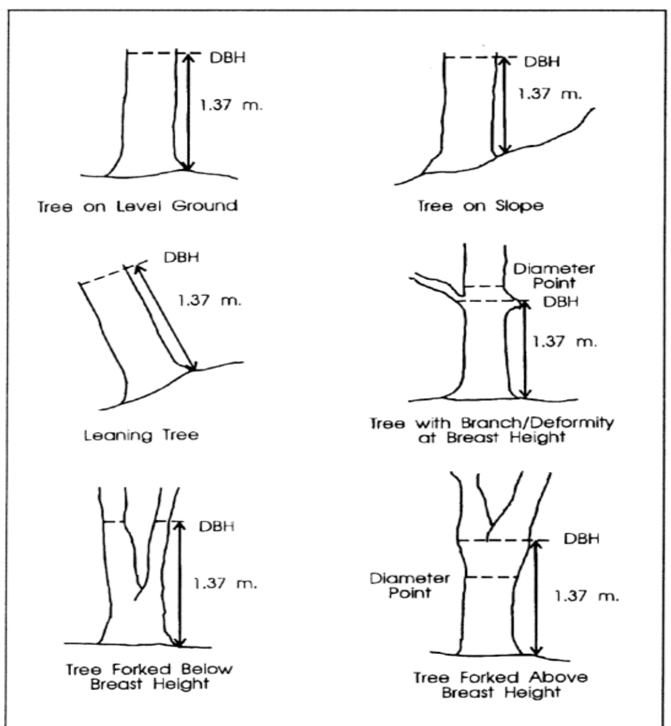


Figure 16. Proper method for measurement of DBH with variations. Note the last four cases should have a note for where DBH was measured (e.g.,"high" "low") and why (e.g., "split tree", "wound at DBH", "branch at DBH").

Data should only be given when all data is known for the tree and then be called out to the recorder in a consistent order found on the data sheet, eg.: “tag#, sugar maple, 42.3,Vigor 1, slight wound, measured high”. I generally keep my DBH tape around the tree until I relay the measurement. Trying to remember the number is a recipe for error and inefficiency to creep in.

Step 6 (1 person) **Recording the data:** The recorder then repeats the data back as it is recorded. This avoids errors from hearing mistakes and allows other to follow along and check the data with the tree. Any uncertainty for tree species id should be checked with a trainer before being given to the recorder. The recorder is responsible for making certain all tree data is complete before moving on to the next tree. Also refer to the section “Recording data in the field” as well as tree abbreviations in the “*Tree Identification Guide*” a separate resource in the Google folder.

NOTE: Steps 4-6 will be completed together by a crew of 3-4 people, while 2 members complete steps 7 and 8.

Step 7 (2 people) **Marked sugar maple seedlings:** The E-W line will serve as the start of the search area for marked sugar maple seedlings. We are aiming to mark 50 seedlings in each plot vicinity, but they may not all be within the plot boundary depending on the density of the seedlings. Sugar maple seedlings from the 2017 mast year (year of notably high seed production) will be in their second season of growth in 2019, and have

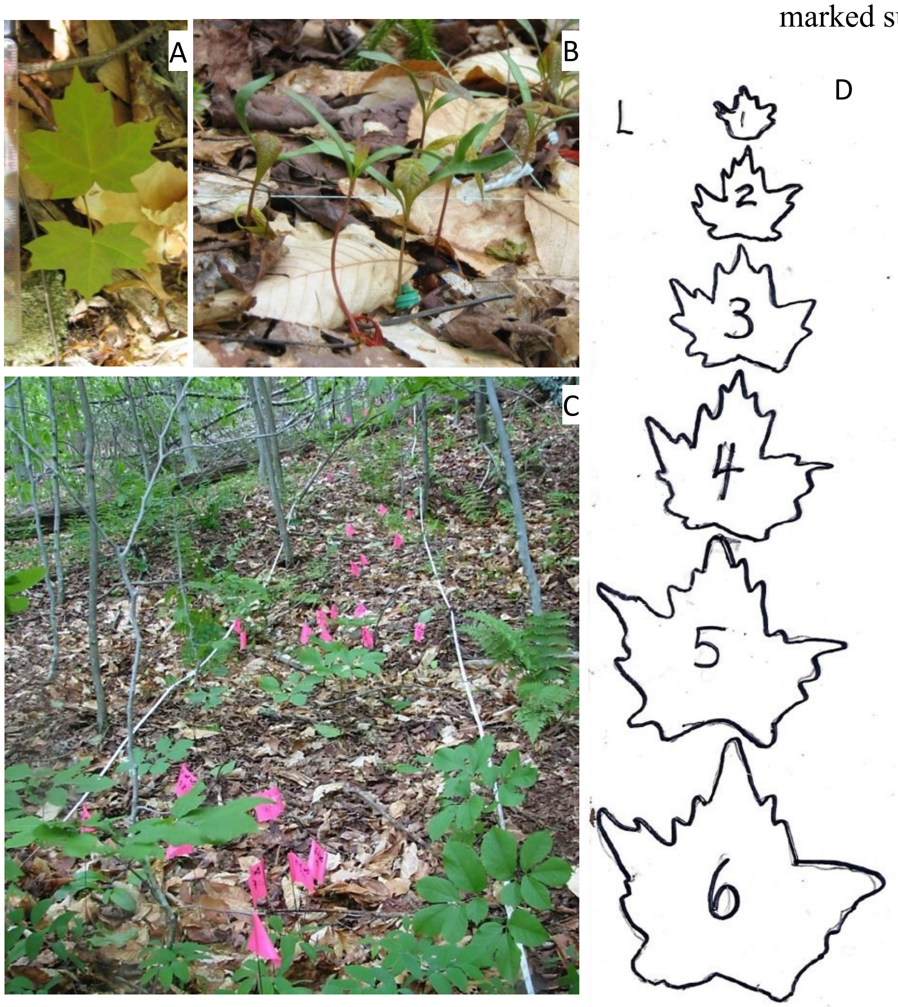


Figure 17. Sugar maple seedling measurement showing: **A.** second year seedling, **B.** first year germinants marked with colored twist ties around the stems, **C.** seedlings marked with uniquely numbered flags within a 1m belt transect, and **D.** a reduced version of the leaf sizer used to evaluate seedling leaf area in the field without touching the plants.

begun to become woody. Many of the seedlings have also already died. We need to mark seedlings in their second year so each seedling must be carefully checked for age (refer to Seedling section under Tree identification) (**Fig. 17A**). We will attempt to find and mark the first 50 seedlings per plot for a total of 600 marked seedlings per site. It is because of their very high mortality that we need to mark so many individuals.

We will mark each seedling in two ways: first with a colored twist tie around the stem (**Fig. 17 B**) and then with a numbered flag (**Fig. 17C**). This double marking is necessary for several reasons: animals will pull out the flags, and seedlings that are close together need to be identified with confidence. Marking the seedlings in a defined area will also help insure relocating them in the future even if flags are tampered with. We will have continuous numbers for each site, so seedling numbers will go from 1-600.

The first 50 seedlings found in a one meter transect centered on the plot area (**Fig. 11a**) will have leaf number and area recorded. A particularly strong predictor of seedling survival at HBEF has been leaf number and size, which represents to the amount of area the seedling has to photosynthesize and make carbon. To make this consistent, we use a "leaf sizer: (**Fig. 17D**). If leaves are larger than 6cm in length (size 6), then measure the leaf length with the centimeter side of the 2m D-tape and record that number as the leaf size. Each leaf is checked for size separately and we record to the nearest half size.

Step 8 (2 people) **Sweeps:** The N-S diameter will serve as the center of a 2m wide belt transect to tally woody stems 2-9.9 cm in diameter (**Fig. 11a**). We call these transects "sweeps". The understory tree composition of each plot is measured by walking the N-S diameter of the plot (25m centered at 12.62m) and tallying all tree saplings, $2 \leq$ DBH <10 cm DBH (diameter at breast height) for 1m on either side of the line. We use a DBH pole with a meter marked on the pole to decide trees that are in the measure area. For all these stems we record **species, DBH** to 0.1cm and **live or dead**.

Understory trees are too small to be tagged, so while they are in some respects easier to identify because you can see all of the characters, their correct identification over time must happen again and again without reference to a tag identifier. For this reason, a trainer should always be present on the sweep data collection. Volunteers are encouraged to try their hand at taking sweep data with a trainer recording for them after they have recorded for a trainer on several plots.

Note: Whichever crew finishes first, will proceed onto Step 9: soil samples.

Step 9 (2-3 people) **Soil samples:** We will collect soil samples per plot at the 5m marks along the N-S and E-W diameters of the plot for six samples per line and 12 per plot (**Fig. 11a**). Start at the “0” mark, then 5m, 10m, etc. We will use 2cm diameter metal push corer and bulk all the samples into the same sample bag labelled with the site, plot #, and date. We will have some data associated with the soil collections, namely the depth of the organic layer and full length of each core. We will teach you how to discern the boundary between organic and mineral soil (**Fig. 18**). For the sample, we take the first 15cm of the mineral soil. The rest of the sample is left in the plot. If the corer will not go in at the 5m mark, keep trying spiraling out from the point until you obtain a core with at least 10cm of mineral soil.

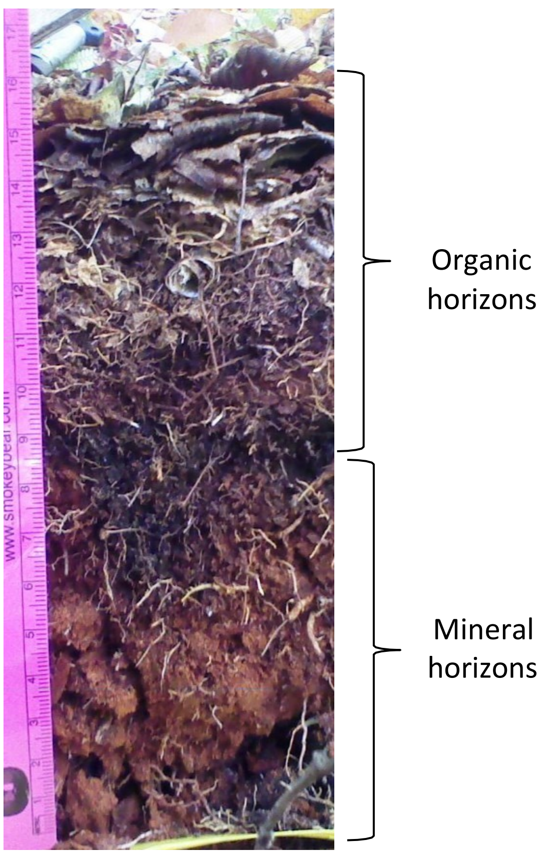


Figure 18. Soil profile from Hubbard Brook showing the distinction between upper organic and lower mineral layers of soil. In spodosols like this one the mineral horizon is often orange.

Step 10. EVERYONE - BEFORE leaving the plot, all data sheets should be checked for completeness and all equipment should be accounted for.

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Field equipment

Measuring tapes

We will use several types of measuring tapes for gathering data (**Fig. 19**). The 30m tapes are used for delineating the N-S and E-W diameters of the plot (**Fig. 19A**). There should be two of these in the crew equipment. We will have two sizes of tapes for measuring tree diameters (D-tapes), 2m and 5m (**Fig. 19B** and **C**). There should be two to three 2m D-tapes per crew and one 5m D-tape, which you will occasionally need for larger trees.

Examine your D-tape and compare the two sides (**Fig. 19D**). The side labelled "DIA. CM TO MM" is the one to use for measuring tree diameter and is simply the cm scale multiplied by pi (3.14). This multiplier allows us to physically measure the circumference while getting a number that corresponds to the tree diameter. Use some caution with the 2m D-tape as it is a metal tape and can both cause finger cuts and corrode easily if it gets wet.

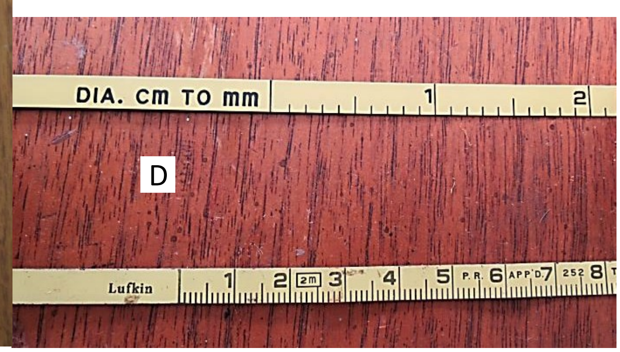

Figure 19. Measuring tapes we will use for gathering plot data: **A.** 30m tape, **B.** 5m diameter tape, **C.** 2m diameter tape, **D.** two sides of the 2m diameter tape.

Tree tagging

The largest challenge with the tree tagging equipment is keeping the tags organized. A carpenter's apron is extremely helpful in this regard. I typically keep a smaller number of tags in order in the tighter center pocket. But however you do it, numbering the trees in sequence and facing center is critical for finding trees again in future re-survey work. We use only aluminum nails and tags as aluminum is soft enough for a chainsaw to cut through without binding and then causing potential damage to the person operating the chainsaw. We also use a fairly light weight hammer because we only need to sink the mails into the tree cambium and lighter hammers cause less fatigue. We do encourage rotating jobs on crew between plots, so that everyone gets experience with all aspects and no one gets fatigued from the same motions plot after plot.

Plot location and description

The plot centers have been marked on a global positioning unit (GPS) and can be relocated using the GPS and a compass (**Fig. 20A** and **B**). The compass will be used not only to find the plot, but also to accurately lay the N-S and E-W diameters of the plot and map the witness trees. The clinometer is used to obtain slope of the plot, which can be important in soil drainage and plot sunlight input (**Fig. 20C**). The compass is used to take the slope aspect, which is the compass bearing of the plot's main slope. We will train you in sighting correctly with a compass and taking slope angle with a clinometer, and also have included an online instruction sheet (see reference section).

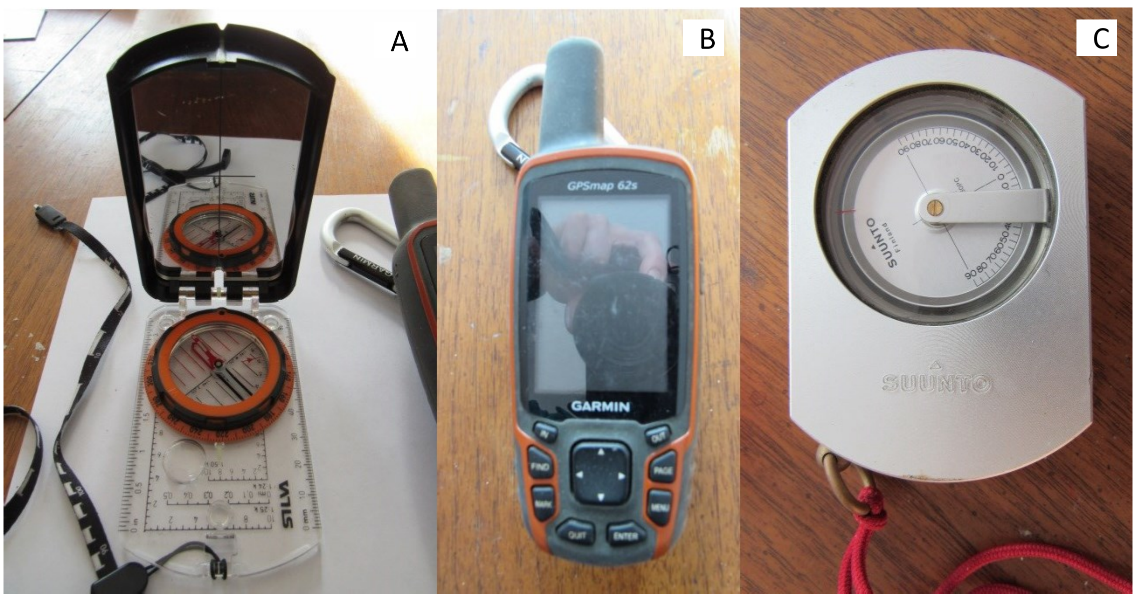

Figure 20. Equipment used in the location and description of the plots: **A.** mirror compass with declination set at about 14°W depending on the site, **B.** Garmin GPS mapping unit and **C.** Suunto manual clinometer.

Our compasses allow the declination to be set such that we are reading true bearings. For both the compass and the clinometer proper positioning is critical to accurate measurements and so we will test everyone to make sure we all get the same readings prior to taking any actual data.

Seedling identification and aging

The term "seedlings" is used variably in the scientific literature and often refers to a size class (say under 1m tall) rather than the origin (from seed) of a stem. In this study, seedlings refer to the cohort of sugar maple seedlings originating after the autumn 2017 mast event. This means the seedlings were germinants (first year germinated from seed and non-woody) in 2018 (**Fig. 21**). In 2019, the surviving seedlings will be starting their second year of growth (**Fig. 21**).

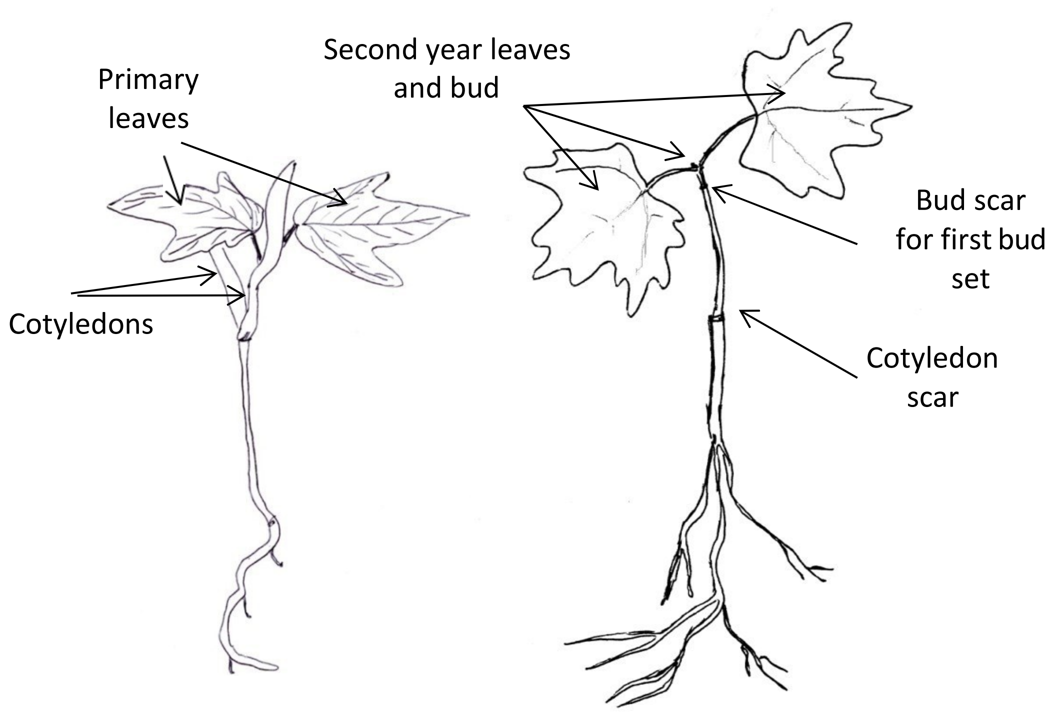

Figure 21. Sugar maple seedlings in their first (left) and second (right) years of growth.

Figure 22. Photos of some common tree seedlings with emphasis on sugar maple seedlings. **A.** a rodent cache of mostly beech and one sugar maple germinants with cotyledons and primary leaves. Note the primary leaves are not yet expanded on beech; **B.** beech (on left) and sugar maple (right) germinants later in the year with fully expanded primary leaves and no cotyledons. **C.** Three year old sugar maple seedling; **D.** Red maple germinants; **E.** Striped maple seedling;

Some important cues to differentiating seedlings are shape and venation of the cotyledons and the primary leaves. Note that sugar maple primary leaves are typically unlobed. This makes them look more like beech germinants, but cotyledon shape (**Fig. 22A**) and the primary leaf venation (**Fig. 22B**) are both very different. Sugar maple seedlings can be reliably aged up to about seven years, if the seedling has not been repeatedly damaged. Try to count the years of growth and stem scars that delimit them on this three year old sugar maple (**Fig. 22C**).

The two other maples often found in the seedling layer are red (**Fig. 22D**) and striped (**Fig. 22E**). Red is much smaller than sugar maple, about one-third the size and the cotyledons are much shorter compared to their width (about 3:1) compared to sugar maple (more like 7-10:1). Striped maple is very serrate and has a much narrower and pointed leaf overall.

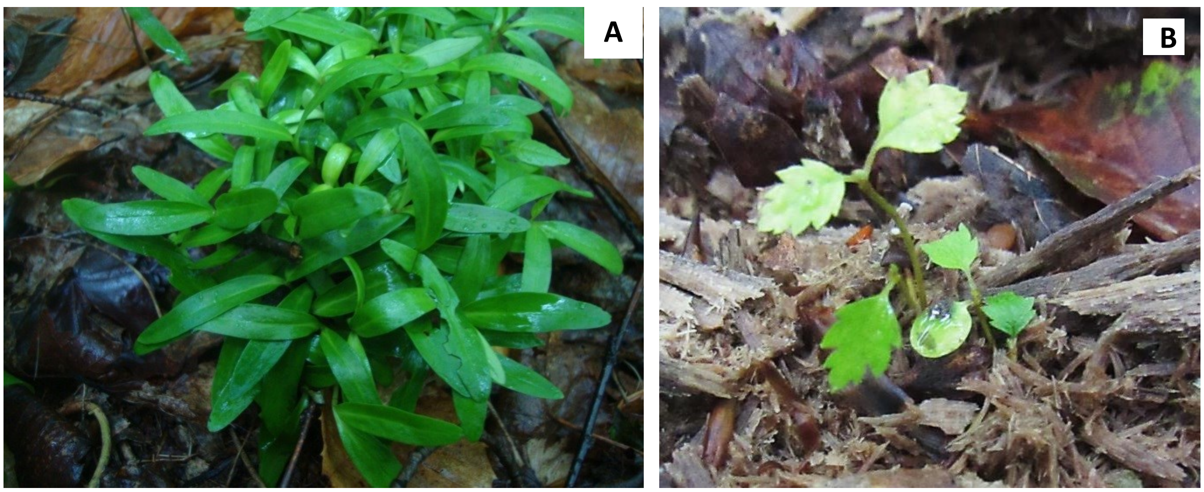

Figure 23. Germinants of A. white ash and B. yellow birch. The white ash seeds have germinated from a rodent cache.

Other common species are white ash and yellow birch (**Fig. 23**). Yellow birch and other birches are near impossible to distinguish and look very similar to raspberry seedlings as well. However, they are about 10 times smaller than sugar maple with round cotyledons. White ash seedlings are very similar to sugar maple in the early season before primary leaves emerge. They can be told apart by the venation of the cotyledons as ash has one central vein and sugar maple has three.

Beech Bark disease (BBD): Overview and Rating

Beech bark disease (BBD) is a disease complex involving a non-native scale insect (**Fig. 24**) and several native fungi, although at HBEF, *Neonectria faginata*, is the only fungus recorded in our surveys. For all beech trees in the plots, including the sweep trees, we record a BBD rating that reflects the severity of the BBD and also the potential impact on our tree diameter measurement. For this reason, the rating is made for bark conditions at breast height.

The scale is fairly broad as this tends to make the ratings more replicable. You should check your understanding of the rating scale on your first few plots for agreement with the trainers and other crew members. This rating should be entered into the notes, or if enough beech are present on site, in the "BBD" column on the data sheets.

BBD rating codes:
0 = no signs of BBD, bark smooth
1 = BBD present, but does not affect DBH measurement; lower bole mostly uncankered
2 = BBD present:1-3 cankers affect DBH measurement
3 = BBD present: 3+ cankers distorts DBH measurement
4 = Cankers have coalesced and trunk is completely disfigured; usually with canopy dieback

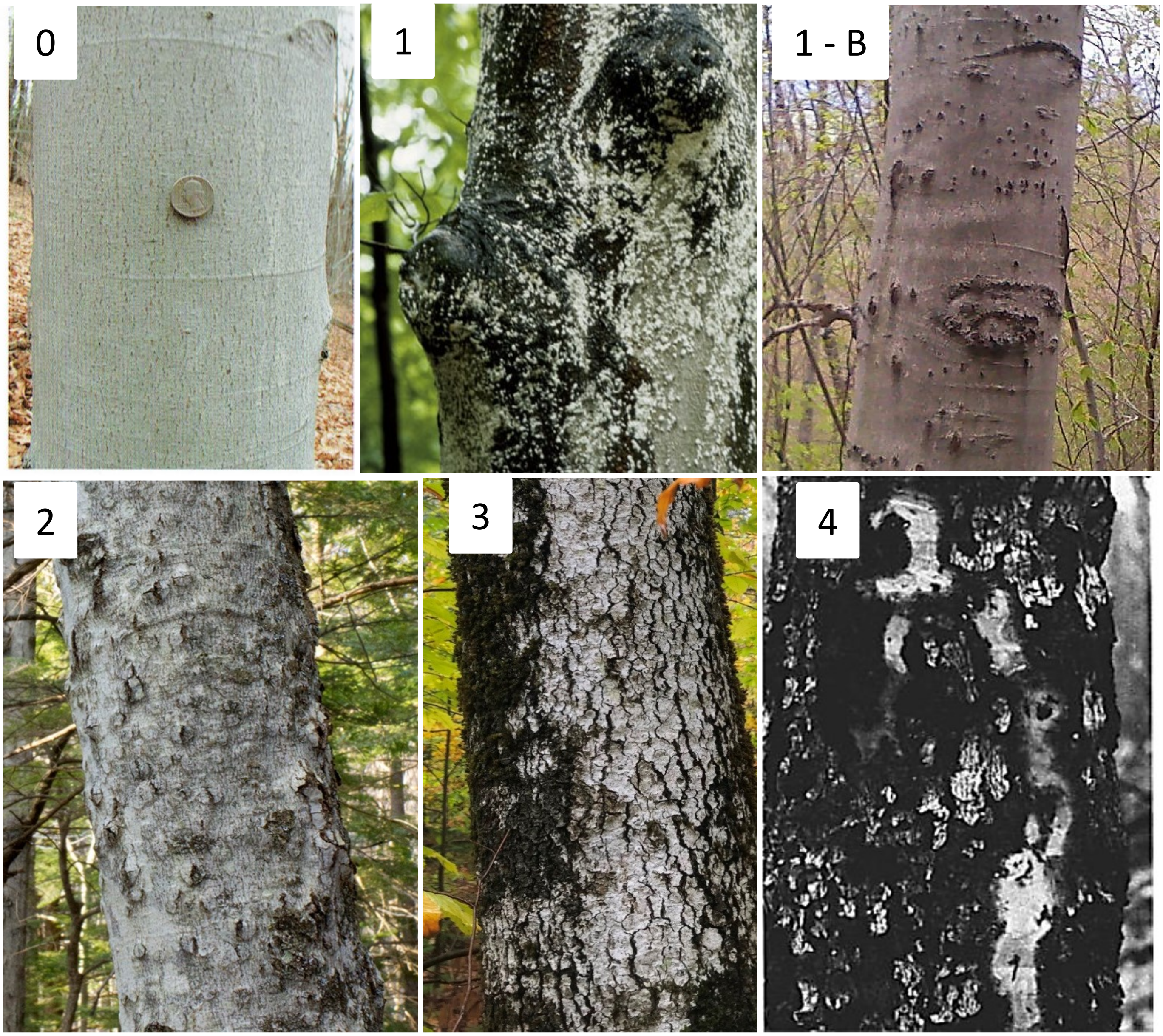

Figure 24. Beech bark disease (BBD) rating codes: 0 = clean beech; 1 = scale or slight cankering not affecting the DBH measure; 1-B = this beech has BBD 1, but also has old bear claw marks; 2 = there are 1-3 cankers that the DBH tape passes over; 3 = there are more than 3 cankers and the trunk has begun to be distorted; 4 – the cankers have coalesced and the trunk outline is distorted and wavy. These photos are from various sources cited in the reference section, except 1-B and 2, which were from Cleavitt and 3 from Forest Society files.

Recording data in the field

There are some important rules for giving data in the field that prevent data errors and insure data quality. First, make certain that the recorder is listening and ready to write. Then say the data loud and clear in a routine order. For instance, tree measurement data goes in the order: “tag number, tree species, vigor status, DBH, any tree notes or notes on measurement”. The recorder then repeats the data back as they are writing it down on the data sheet. This insures that they are writing down what the person measuring actually said, allows other to follow along and check the data with the tree, and know when the recorder is available for more data. The recorder is responsible for making certain all tree data is complete and legible **before** moving on to the next tree.

We will have set data sheets for this project (see Appendix) printed on Rite-in-the-Rain paper. All data should be recorded in pencil and notes squished into the page margin should be avoided. When space limits constrain note taking mark “PTO” for “page turn over” and write the notes, clearly associating them with the line they pertain to, on the back of the sheet.

It is my protocol to check crew sheets for omissions and have the crew return to collect the needed data. However, it saves a lot of time and frustration to make certain the data is complete prior to leaving the plot. Please have the trainer review all data sheets for completeness on the first two plots.

Wrap up meeting

In mid-August, we hope to have all the data collected and a pile of soil samples to process. We will hold a one day wrap-up session where a few important things will happen:

- We will thank you for all your hard work!
- Collect in any stray data sheets
- Take pH measures on our soil samples
- Have a formal team-based inquiry evaluation of your experience
- Make some wrap-up presentations
- Make plans for next season

Thank you for your important contributions to HBEF science and our understanding of sugar maple ecology!

Suggested references

Printed:

Petrides, George A. 1973. *A field guide to trees and shrubs*. Houghton Mifflin Company. Boston, MA.

Wojtech, Michael. 2011. *Bark: a field guide to trees of the northeast*. University Press of New England. Lebanon, NH.

Online resources:

Plant identification:

Our *Tree Identification Guide* posted as a separate resource in the Google folder

Go Botany: New England Wildflower Society: https://gobotany.newenglandwild.org

Northern Forests Atlas: http://northernforestatlas.org/

Equipment use:

Clinometer use for taking slope measurements:

https://openoregon.pressbooks.pub/forestmeasurements/chapter/1-2-field-technique-tips-for-measuring-slope/

Compass use for sighting: "Using a compass to sight a bearing to a distant object".PDF download from MapTools

Compass declination: https://www.ngdc.noaa.gov/geomag/declination.shtml

Hubbard Brook related:

https://hubbardbrook.org/articles/cues-masting-sugar-maple-and-american-beech

https://hubbardbrook.org/articles/watching-forest-sentry-surveys-hubbard-brook

Cited literature

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Appendix A: Tree identification and abbreviations

Identification of tagged trees often relies heavily on bark characteristics because the leaves are high above and often intermingled with those of neighbor trees. Binoculars can sometimes by helpful, if you can reliably follow a branch to the leaves high above. Fortunately, the number of trees that you are likely to encounter on these plots is limited such that we can provide a fairly comprehensive picture guide. This guide includes photographs accompanied by bullet points for distinguishing characters of the tree species. However, note that we focus on bark of larger, older trees. The bark of younger trees can be very different and is generally smoother and less differentiated. For a more comprehensive coverage of this variation we refer you to Wojtech (2011) *Bark: a field guide to trees of the Northeast*.

We also use four letter abbreviations for the tree species that are derived from the Latin binomial (scientific names) by using the first two letters of the genus and species. For example, sugar maple is *Acer saccharum*, which becomes ACSA. It takes a little while to get use to these abbreviations, but they become routine with time and like a secret code to bond gatherers of tree data. A quick reference sheet for these abbreviations is provided at the end of the tree guide.

Perhaps one of the most difficult and critical distinctions is between sugar and red maples. We start the guide with these two species and proceed in alphabetic order by scientific name for the overstory and then for understory trees. Understory trees never contribute to the main mature forest canopy and rarely get larger than 20 cm in diameter.

Trees noted during plot positioning (not complete tree lists for the sites)**:**

Kauffmann: FAGR, ACSA, BEAL, BEPA, TIAM, ACRU, TSCA; PIRU, (JUCI, PIST were off-plot)

Monadnock: ACRU, ACSA, FRAM, BEPA, BEAL; ACPE, PRSE, QURU, OSVI

Sudrabin: BEAL, FRAM, ACSA, FAGR, PRPE, (QURU was off-plot)

Yatsevitch: ACSA, FAGR, OSVI, CACO, PIST, TSCA, ACRU, BEPA

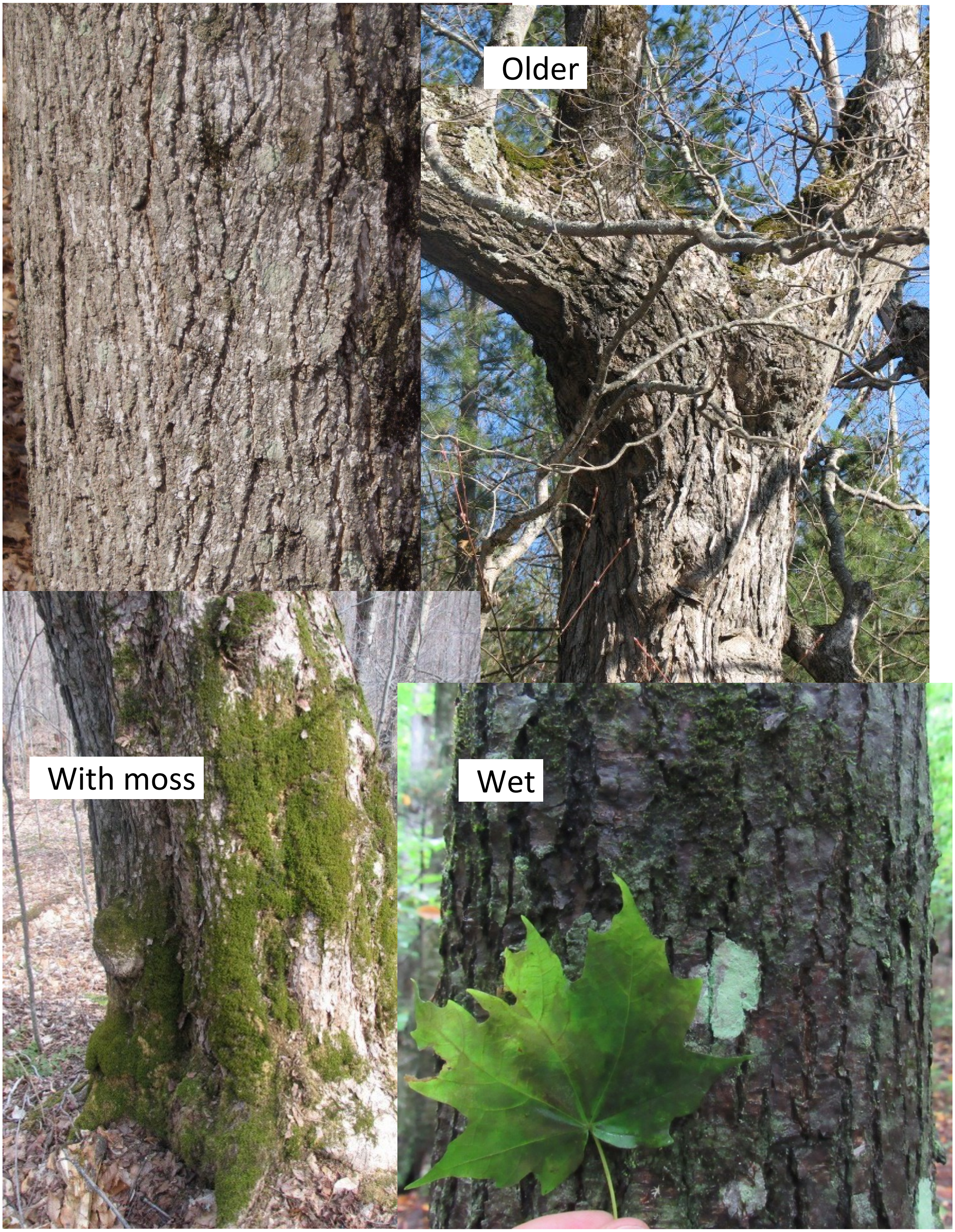
Overstory Trees

Sugar maple leaf and bark.

Sugar maple *Acer saccharum* = **ACSA**

- Broad leaves with three lobes and U-shaped sinuses
- Opposite branching
- Seeds are in fruit (samara): two connected winged fruits
- Bark: gray to brown-gray, cracks deepen with age; corky to touch with fingernail
- Often with abundant moss and lichens

Variations in Sugar maple bark:



Red maple leaves and bark

Red maple *Acer rubrum* = **ACRU**

- 3-lobed serrate (pointed edges) leaves and V-shaped sinuses
- Opposite branching
- Bark: gray to gray brown and peeling in strips with age; much thinner and looser outer bark than sugar maple
- Fungus often forms a “bull’s eye” pattern of cracks in the bark

Variation in Red maple bark with common "bull's eye" pattern from fungus:

Photos by S. Thorne, Forest Society and N. Cleavitt

Balsam fir bark with typical resin blisters and needles showing rounded tips and flatness.

Balsam fir *Abies balsamea* = **ABBA**

- Relatively smooth bark with resin blisters that can pop and make you sticky!
- Flat, friendly needles that are thicker that the other conifers covered here

Yellow birch leaf and bark of younger tree.

Yellow birch *Betula allegheniensis* = **BEAL**

- Broad, oval leaves with a doubly pointed (serrate) edge
- Alternate branching
- Seeds are in winged seeds held in bunches (catkins)
- Bark: golden to yellow-gray with age
- Peeling strips are very thin and often tighly curled
- Long, obvious lenticels (horizontal lines)

Paper birch leaf and bark

Paper birch *Betula papyrifera* = **BEPA**

- Doubly-serrate (big and little points on leaf edge) leaves that are broadly triangular
- Alternate branching
- Bark: white to peach; graying near tree base with age
- Large peels much thicker than the in yellow birch
- NB: Paper birch and gray birch have many hybrids that we will not be able to distinguish

Bitternut hickory bark, buds and leaf with leaflets. Photos from GoBotany website.

Bitternut hickory *Carya cordiformis* = CACO

- Only seen at Yatsevitch Forest
- Compound leaves with 7-9 leafets
- Alternate branching
- Gray bark with flat ridges that look like they are made from clay
- Remarkable pointed, bright yellow, furry buds

American beech with cankers from beech bark disease.

American beech *Fagus grandifolia* = **FAGR**

- Broad, long, oval leaves that are wavy on the edges
- Alternate branching
- Seeds are a nut , 2 per cupule
- Bark: smooth gray even with age EXCEPT for diseased trees with cankers
- See beech bark disease overview and rating in the main training guide

White ash compound leaf and bark

White ash *Fraxinus americana* = **FRAM**

- Compound leaves made up of 5-9 leaflets; usually 7
- Opposite branching
- Bark: Tan to light tan-gray, intersecting ridges make pattern of diamond-shaped furrows
- Bark is very corky and easily penetrated with your fingernails

Butternut leaf with leaflets and young bark. Photo on right from Forest Society.

Butternut *Juglans cinerea* = JUCI

- Only one individual seen off plot at Kauffmann Forest
- Compound leaves with 11-17 leaflets
- Alternate branching
- Bark with light gray ridges and lighter furrows
- Furrows deepen with age / size of tree

Eastern white pine bark and needles with close-up of one group of five needles (fascicle) on the right.

Eastern white pine *Pinus strobus* = **PIST**

- 5 needle pine with long, slender needles
- Bark in purplish plates, lighter color than hemlock

Red spruce bark and sharp-pointed needles

Red spruce *Picea rubens* = **PIRU**

- Pointy needles that develop in groups of tree and so are triangular in cross-section
- Scaly bark, most similar to black cherry but with scales thicker and tighter to the trunk and lacking the horizontal lenticels

Black cherry bark often likened to "burnt potato chips". Photo by S. Thorne.

Black cherry *Prunus serotina* = PRSE

- Scaly bark, burnt chip bark
- Lenticels (horizontal lines) strong
- Leaves linear (see pin cherry leaves)
- Alternate branching
- Underside of leaf with orange fuzz on mid-vein

Red oak leaf and bark. Photo by S. Thorne.

Northern red oak *Quercus rubra* = QURU

- Long ridges of bark often with reddish valleys
- Younger trees have smoother bark
- Alternate branching
- Lobed leaves with pointed lobe tips

American basswood leaf and bark.

American basswood *Tilia americana* = **TIAM**

- Only seen at Kauffmann Forest
- Long ridges and furrows on bark
- Heart-shaped leaves with uneven leaf bases
- Hollow sound when bole is thumped

Eastern hemlock bark and needles above and close-up of top and bottom sides of needles and cone on bottom.

Eastern hemlock *Tsuga canadensis* = **TSCA**

- Shorter (< 2.5 cm long) flat needles growing from each side of the twig
- Two white lines on underside of needles.
- Cones are very small (≤ 1cm) long and hang down on the branch
- Bark: reddish-gray to purplish brown and more deeply furrowed with age

Understory Trees

Striped maple leaf and bark, though tree is wet and harder to see the stripes of green.

Striped maple *Acer pensylvanicum* = **ACPE**

- Large, thin, 3-lobed broad and finely serrate leaves; resembling a duck's foot
- Opposite branching
- Distinctive green or green-gray striped bark; very smooth when young
- Often with wounds from moose rubs
- Understory tree and gap opportunist

Hophornbeam leaf and bark, subcanopy tree. Photo by S. Thorne.

Hophornbeam *Ostrya virginiana* = OSVI

- Understory tree
- Bark in thin, fairly even rectangular strips often curled up at the ends
- Alternate branching
- Oval leaves similar to yellow birch

Pin cherry bark and leaves– photos from the GoBotany website.

Pin cherry *Prunus pensylvanica* = PRPE

- Dark red-brown (younger trees) to gray-brown bark (older trees)
- Alternate branching
- Strong lenticels (the whitish horizontal lines)
- Leaves linear with no orange fuzz on underside of mid-vein

Quick guide for most common tree species

Code	Latin name	Common name	Notes
ACPE	*Acer pensylvanicum*	Striped maple	striped bark, wide leaves, shallow sinuses
ACSA	*A. saccharum*	Sugar maple	smooth gray bark, U-shaped sinuses
ACRU	*A. rubrum*	Red maple	bark like ACSA, leaves V-sinuses, not as serrated as ACSP
BEAL	*Betula alleghaniensis*	Yellow birch	golden bark, thin strips peel, oval leaves
BEPA	*B. papyrifera*	Paper birch	red-brown to pink-white bark, distinct paper piece peels, leaves more serrated than BEAL, triangular not oval
FAGR	*Fagus grandifolia*	American beech	smooth gray bark, leaves long-oval, strong veins, smooth lf edges, **BBD rating** needed
FRAM	*Fraxinus americana*	White ash	bark with some patterning, compound leaves, leaf out late and drop early
OSVI	*Ostrya virginia*	Hophornbeam	bark with thin strips that curl up
PIST	*Pinus strobus*	Eastern white pine	long needled pine with needles in groups of five
PRPE	*Prunus pensylvanica*	Pin cherry	dark red-brown to gray-brown, strong lenticels (horiz lines), leaves linear, no orange fuzz on mid-vein
PRSE	*P. serotina*	Black cherry	scaly bark, lenticels strong, leaves linear, orange fuzz on mid-vein
QURU	*Quercus rubra*	Northern red oak	long ridges of gray bark with reddish furrows; lobed leaves
TSCA	*Tsuga canadensis*	Eastern hemlock	bark brown with ridges (vertical thicker spots) developing, needles flat with white stripes underneath