Inventory & Monitoring Division

National Park Service

Northeast Temperate Network Long-term Forest Monitoring Standard Operating Procedures

2020 revision

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SOP 1 - Preparation and Equipment List

Mid-Atlantic Network/Northeast Temperate Network

Version 2.13

Overview

This SOP delineates preparations for the summer field season and includes a list of necessary field equipment. Preparations should be complete by the start of the summer field season in May or early June.

Staff

This forest monitoring protocol can be staffed by any of several crew configurations, including

a) a forest crew leader plus a crew of two to three crew members, or b) two teams each comprised of a crew leader and one crew member. In addition to the forest crew, a contract botanist (for NETN monitoring) and network staff support will probably be needed as described below.

The forest crew leader(s) should have good northeastern plant identification skills and be knowledgeable about forest sampling methods. If a forest crew leader does not have strong plant identification skills, then contract botanists and/or network staff must be available for each park to identify unknown specimens or to sample the understory vegetation quadrats. The crew should have good northeastern woody plant ID skills. The contract botanist(s) should be well trained in local flora at each park sampled. The protocol also requires some GIS mapping in ArcGIS, and support by network personnel including the data manager.

To secure field personnel, the networks may wish to advertise locally at northeastern universities, as well as nationally on environmental job websites such as the Society for Conservation Biology job board (http://www.conbio.org/jobs) or listserves such as the Ecological Society of America's 13illing listserve (ecolog-l@listserv.umd.edu). Network staff may also find it useful to network with regional environmental professors and professionals to identify skilled seasonal staff.

To ensure travel charge cards and uniforms are issued by the first day of training, it is advisable to start crew members 2 pay periods before the first day of training. Crew members can claim hours spent filling out paperwork, and then be on intermittent status until the first day of training. Background investigations must be cleared before this can happen.

Soon after they are hired, each crew member should receive a welcome packet in the mail to help them prepare for the field season. Welcome packets should contain information about the Inventory and Monitoring program, suggestions on personal gear to bring for the season, directions for ordering uniforms, a schedule for the field season, park specific information, lists of common species in each park, and a NPS passport.

Planning and Coordination

Network personnel or the field crew leader should ensure that each park natural resource manager has a current version of the forest protocol including all SOPs, as well as a current map of sampling locations. A map clearly showing the location of each plot must be provided to each park's cultural resource specialist at least one month prior to any soil sampling, to provide time for determination of the presence of cultural artifacts that might be compromised by soil sampling. Each network's plot marking and tree tagging procedures must be cleared with each park natural resource manager prior to plot establishment at each park, and these procedures may vary by park in response to individual park requirements. Network staff must check with each park to determine whether aluminum or stainless steel tree tags and nails must be used. Aluminum tree tags are used at parks in which trees are or may be cut to ensure human safety during logging. Stainless steel tags are used at parks without logging to avoid adding aluminum to the environment.

Networks should select a soil chemistry laboratory with experience analyzing forest soils, and have a purchase order or other contract in place for analysis of soil samples collected each field season. It may be cost-efficient to join together with other eastern NPS networks to contract a soil chemistry lab to obtain better pricing. Several soil laboratories have sufficient capabilities, including the Analytical Lab at the University of Maine (https://umaine.edu/soiltestinglab, contact Bruce Hoskins, hoskins@maine.edu).

Maps

Prior to each field season, network personnel should prepare both GIS maps and aerial photographs showing sampling locations at each park in the annual panel at scales of 1:24000 or larger. Maps should clearly show location of all plots in relation to topography, roads, trails and park features. Line and point symbols for roads, streams, plots and other features should be clearly visible but not large enough to obscure other features. Scalebars should show miles in addition to kilometers, to aid navigation by car. If possible, smaller locator maps should be included on large scale maps. These maps and aerial photographs should be printed on Rite-in-Rain paper using a color LaserJet printer. Note that inkjet printing does not properly adhere to Rite-in-the-Rain paper. Two full sets (one for each vehicle) of maps for each park should be provided to the forest crew prior to sampling.

The crew should also be supplied with road maps for the region surrounding each park visited.

Coordinates of each plot should be exported, printed, and downloaded directly into the network GPS unit. Trails, park boundaries, and topographic maps should also be loaded on GPS units.

Schedule

The order in which parks are visited during the field season must remain static from year to year in order to reduce the confounding of seasonal with annual variation. In the Northeast Temperate Network (NETN), parks should be sampled from southwest to northeast over the course of the summer in coordination with seasonal progression across the region. This schedule will allow southwestern parks to be sampled when spring ephemerals may still be evident, and allow

northeastern parks to be sampled after shrubs and trees have fully expanded their leaves. For Mid-Atlantic Network (MIDN) parks, sampling should be conducted from northeast to southwest.

Horse-racing season in Saratoga Springs, New York runs from late July to early September, and lodging is difficult and expensive to acquire during this time. Thus Saratoga National Historical Park (SARA) should be sampled prior to late June if possible.

Network staff and the crew leader should carefully consider the crew's capabilities when deciding upon a workday schedule. Flex-time (e.g., four 10-hour days) offers some advantages—but is not appropriate if crew members tire too much to maintain data quality on a long workday. The crew schedule should start as a standard work week (e.g., five 8-hour days, starting at 8:00 or 8:30 am), and only convert to flextime if both the crew leader and supervisor agree that it will work well for that particular crew.

Network personnel and collaborators should hold a mid-season meeting with the crew to discuss the crew's progress and any concerns that have surfaced. This meeting should take place after the first round of QA/QC sampling has occurred.

Logistics

Network personnel or the crew leader should reserve or acquire a field vehicle for transport to and within parks.

Network personnel or the crew leader should contact the natural resource manager at each park represented in the annual panel to schedule a visit and reserve park lodging if available. If no park lodging is available, lodging reservations should be made. Wherever possible, lodging should include access to kitchen facilities and internet. Lodging space should be sufficient to comfortably accommodate all crew members and their gear.

Training

Prior to commencement of each field season, the networks must ensure that all field personnel fully understand administrative responsibilities and field procedures by conducting in-situ training sessions. Training should include PowerPoint presentations that cover the following topics:

- Introductions to NPS, the Inventory and Monitoring Program and the forest monitoring protocol.
- Regulations and procedures related to travel authorizations, credit cards and use of NPS vehicles.
- Guidelines regarding timesheets, credit leave versus comp time and requesting leave.
- Safety and workers compensation
- Examples of how forest data are being used and importance of quality data.
- Introduction to databases and tour of forest database

- Summary of each SOP and unusual situations

Crew preparation should involve careful review and discussion of all protocols, in addition to training sessions led by designated personnel in which training plots are set up and measured. Trainers should start each SOP with a presentation that summarizes procedures and unusual situations before crew members read the SOP. After reading and discussing each SOP, trainers and crew should practice each procedure on test plots in the field.

Training should cover:

- safety hazards such as steep slopes and deer ticks;
- safe field practices to avoid injury such as how to properly pack and wear a field pack and work in areas with poison ivy;
- emergency procedures;
- introduction to network forest and woodland ecosystems;
- review of common northeastern tree and shrub species;
- proper use of all equipment including GPS, field computer, and digital camera;
- proper use of compasses, especially declination settings;
- proper use of clinometer to measure slope as percent and in degrees;
- practice reading sampling maps of plot locations;
- plot layout and installation;
- rules for selecting or rejecting pre-selected plot locations;
- use of laser and sonin rangefinders;
- measurement of horizontal vs. slope distance with measuring tapes and rangefinders;
- estimation of slope distance using slope conversion table;
- determination of physiographic class, stand structure, stand disturbance and crown closure;
- methods for tree tagging;
- accurate measurement of DBH and DRC using a DBH tape, logger’s tape and ruler;
- determination of tree crown class;

- identification of specific tree condition and foliage problems from SOP 8 - Tree Measurements;
- identification of high priority exotic pests and pathogens for the northeastern U.S., such as hemlock woolly adelgid, Asian longhorned beetle, and emerald ash borer;
- snag and CWD decay classes;
- procedures for measuring seedling and shrub height;
- practice estimating percent cover classes;
- visual inspection of forest floor for humus and earthworm casts and burrows;
- procedures for collecting soil samples, using a soil corer and separating by soil horizon;
- procedures for labeling, drying and storing soil samples;
- procedures for labeling unknown plant specimens;
- practice using procedures for careful data collection described in SOP 4 - Data Management & Quality Assurance/Quality Control;
- procedures to minimize plot trampling;
- expectations of crew behavior; and
- proper use and maintenance of park radios.

Training should include both demonstration of all measurements by trainers, and hands-on practice of all measurements by trainees. Training groups should be small to ensure that all trainees have sufficient opportunity to practice measurements thoroughly and question the trainer as needed. Training should thoroughly demonstrate how to enter data into the forest database for each SOP. Training materials should include screen captures of each form in the database.

Training must emphasize the critical importance of careful, accurate and steady data collection to this long-term monitoring program. Trainers must stress the importance of exact adherence to SOP instructions to prevent bias in measurements among years, which will inhibit the networks' ability to detect long-term trends. Trainees should be encouraged to discuss with network supervisors any concerns that arise over field procedures or the datasheet or database recording systems during training or later during the field season—the crew should never deviate from established protocols or alter the datasheet or database without first taking this step.

Training must emphasize the critical importance of careful plot behavior to minimize plot trampling. Packs should be put down and unloaded outside the plot, or placed carefully at the center of the plot where most equipment is first used. Crew should not enter the plot or move within the plot without

an explicit reason to do so. Crew should walk outside the perimeter of the plot whenever possible. Crew should arrange the taking of measurements to minimize walking within the plot. Crew should plan ahead to retrieve all gear needed for a particular set of measurements at once, rather than taking extra trips back and forth across the plot. Extra care must be taken to avoid trampling the regeneration microplot, the herb quads on the inside of each plot corner and mid-point, and any CWD that falls on or near a line transect. Extra care should also be taken in plots with a delicate or moss-covered forest floor.

During training, one crew member should be designated as the field computer lead and another as the GPS lead. The field computer lead should receive extra training in all aspects of the use and care of the field computer and the use of the forest database. Likewise, the GPS lead should receive extra training in the use of the GPS unit, and should carefully study SOP 2 - Using the Global Positioning System (GPS) and the Garmin manual.

Network staff must decide what location provides sufficient logistical support for the initial training session. However, it may be advantageous to begin training at a national historic park to allow familiarization with the larger plots used at National Historical Parks (NHP) and the deciduous forests found within NHP. Marsh-Billings-Rockefeller NHP (MABI) may have sufficient facilities if affordable housing is available. Initial training should include orientation to forest and woodland ecosystems and common shrubs and trees in the area at which training occurs. Supplemental orientation to ecosystems and common shrubs and trees at other parks should occur as the crew traverses the network. At Acadia NP (ACAD), orientation should include a visit to the Wild Gardens of Acadia which showcases plants and ecosystems native to the area.

Training to recognize specific tree health problems noted in SOP 8 - Tree Measurements, and identification of high priority exotic pests and pathogens for the northeast U.S. listed above, should utilize forest pest factsheets available on the web from many sources such as U.S. Forest Service (USFS) and Animal Plant Health Inspection Service (APHIS). Links to useful pest and pathogen fact sheets are listed below. Crew should also carry Early Detection ID cards to help with priority pest identification.

1. USFS Pest Links: http://www.fs.fed.us/ne/morgantown/4557/AFPE/links.html
2. Asian Longhorned Beetle: http://www.na.fs.fed.us/pubs/palerts/alb/alb_pa.pdf
3. Balsam Woolly Adelgid: http://www.na.fs.fed.us/pubs/fidls/bwa.pdf
4. Dogwood Anthracnose: http://www.na.fs.fed.us/spfo/pubs/howtos/ht_dogwd/ht_dog.htm
5. Elongate Hemlock Scale: http://www.na.fs.fed.us/spfo/pubs/pest_al/ehscale/ehscale.htm
6. Emerald Ash Borer: http://www.na.fs.fed.us/spfo/pubs/pest_al/eab/eab.pdf
7. Gypsy Moth: http://www.na.fs.fed.us/spfo/pubs/pest_al/gm/gm.htm
8. Hemlock Woolly Adelgid: http://na.fs.fed.us/spfo/pubs/pest_al/hemlock/hwa_05.pdf

9. Sirex Wood Wasp: http://na.fs.fed.us/spfo/pubs/pest_al/sirex_woodwasp/sirex_woodwasp.pdf
10. Sudden Oak Death: http://www.na.fs.fed.us/spfo/pubs/pest_al/sodeast/sodeast.htm

It may also be useful to organize a day-long forest pest and pathogen workshop during crew training that is led by a regional forest pest expert, such as Wayne Millington (NPS Northeast Region Integrated Pest Management Coordinator, wayne_millington@nps.gov). The workshop should contain both lecture and field identification sections, and cover identification of high priority forest pests and diseases in the eastern US, including emerald ash borer, Asian longhorned beetle, hemlock woolly adelgid and sudden oak death.

Communication and Crew Oversight

It is essential for the crew to keep in regular contact with network program managers and any other supervisors throughout the field season. The crew should carry NETN radios in parks where there is a radio use agreement (currently: ACAD, MABI, Minute Man NHP, Morristown NHP Saint-Gaudens NHS, Saratoga NHP, and Weir Farm NHS). The crew should also carry a cell phone in the field every day in any parks with cell coverage—both for safety and to attempt to call in if any important questions arise. A regular (perhaps twice weekly) telephone call or meeting should be setup between crew leader and supervisors to discuss the week's events while they are still fresh. This regular update should include discussion of any questions or problems encountered with plots, the work, the protocol, logistics, etc. The crew should contact supervisors shortly after arrival at each new location to check in and provide contact information if necessary.

The division of labor among crew leader and crew must allow the crew leader to maintain awareness of crew activity on the plot during the regular course of data collection.

Network program managers and any other supervisors should endeavor to join the crew in the field at least twice during the course of the field season for direct observation of data collection.

Equipment

Equipment and supplies on the equipment list, below, should be obtained. Equipment should be organized and maintained in good working condition. At the end of each season, the crew leader should inventory the condition of all equipment and prepare a list of equipment that needs to be repaired or replaced.

The field computer must be handled carefully and the screen protected from injury at all times. When traveling between plots, the computer should be closed with the screen facing inwards. During hard rain, the field computer should be put away in a waterproof bag and datasheets should be used instead.

General Field Equipment

Park topo maps showing plot locations
Protocols with slope conversion table
Park permits
Park plant species list
Field computer and harness
Datasheets (on Rite-in-the-Rain paper)
Enclosed clipboard
GPS unit with USB cable
Compass (3)
Clinometer
NETN Park Radio (ACAD), cell phone (all but ACAD), Personal Locator Beacon (PLB) and Spot Messenger
Batteries- 9v (4), AA (4), CRV3 (2)
Flagging and survey flags (14)
Sharpened pencils and permanent markers
Daypacks
First aid kit
Insect repellant
Water
Briar-proof chaps and field vests (optional)
Field notes and Early Detection ID cards
Raingear
Lens tissues
10x hand lens (2)
Tree, Shrub and Herb field guides
Arborist throw bag
TruPulse and tripod

Plot Establishment

NETN: 65 cm fiberglass posts (7 per plot)
NETN: 35 cm fiberglass stakes (as needed)
NETN: 45 cm #3 rebar with 90 degree bend (4 per plot); 30 to 45 cm #4 rebar with cap (1 per plot)
MIDN: 45 cm #6 rebar and cap (one per plot); 45 cm #3 rebar with 90 degree bend (7 per plot).
Rubber mallet
Reflective card
Kite string reel

Plot Measurements

Pre-numbered tree tags – aluminum at MABI, MIMA, ROVA, SARA, WEFA and MIDN; stainless steel at ACAD, MORR, SAGA
Digital camera, batteries
Sonin electronic distance measurer
Work belt
DBH tape (2)
PVC pole cut to breast height (1.37 m)
30-cm UV-stabilized nylon cable ties
Compact, waterproof binoculars (8x power)
Sturdy ruler (30 cm)
8-12 cm tree nails: aluminum at MABI, MIMA, ROVA, SARA, WEFA and MIDN; galvanized steel at ACAD, MORR, SAGA
Hammer
Quadrat frame: 1x1 m (0.5x2 m at MIDN)
Clippers
Watch with timer
Sealable plastic bags (both small and large)
Knife or keyhole saw
Soil sampling frame (10x10 cm)
Trowel
Soil corer with extra tip
Cloth to clean corer
Increment borer, and plastic trays

Back in Field Office

Manual of Vascular Plants of Northeastern US and Adjacent Canada (Gleason & Cronquist), and Illustrated Companion (Holmgren)
ACAD: Flora of Maine (Haines and Vining)
Full-size plant press
Acid-free copy paper
Garmin Nuvi GPS Unit (2)
10x dissecting microscope

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.01	June 2006	Geri Tierney and Brian Mitchell	Added Flora of Maine to equipment list. Changed plot markers to fiberglass and included shorter markers for shallow soils.	
2.00	September 2006	Geri Tierney and Brian Mitchell	Added need for crew tree id skills. Added section describing map needs/production. Added section describing schedule. Suggested park order west to east. Added section describing logistics. Expanded list of training needs. Added need for training to id watch list of high priority forest pests/pathogens of northeastern U.S. Included training in use of slope conversion table for plot setup on steep slopes. Included recommendation for special crew member training in field computer and GPS. Emphasized need to minimize trampling. Emphasized need to follow protocols. Added section describing communication and crew oversight. Added suggestions for finding staff. Added caution to protect field computer screen. Added discussion of safety hazards to training. Added need for supplemental orientation to ecosystems and plants as crew travels. Added request for kitchen and internet access for crew lodging. Added note on racing season at SARA. Changed soil lab recommendation. Added need to keep equipment organized and in good working order. Added full-size plant press to gear list. Removed tree calipers from gear list. Added road maps for park regions to gear list. Added Collection of Forest Health Fact Sheets as Appendix E.	

Revision History Log (continued).

Version #	Date	Revised by	Changes	Justification
2.01	December 2006	Brian Mitchell and Geri Tierney	Clarified that optimal crew size is 4-person crew including crew leader. Suggested that regular use of contract botanist in field could reduce need for one crew member. Included suggestion that training could occur in discrete phases. Included recommendation that hands-on training sessions be comprised of a small group. Added soil sampling frame and clippers.	
2.02	April 2007	Kate Miller, Geri Tierney, Brian Mitchell	Clarified use of aluminum tags/nails at ROVA, WEFA, steel at MORR. Added acid-free copy paper to equipment list.	
2.03	November 2007	Geri Tierney, Kate Miller, and Brian Mitchell	Revised staff description to add two team option. Clarified the option for herb quads to be sampled by contract botanists or NETN staff. Added need to discuss in training how the data will be used to assess forest integrity. Added mid-season meeting with NETN and crew. Added more database training Added park radio to equipment list. Added bullet to train crew how to use radios.	
2.04	May 2008	Kate Miller, Jim Comiskey, Brian Mitchell	Minor edits. Removed reference to the GPS real-time correction system. Added MIDN equipment and equipment for new plot establishment method. Removed items no longer needed (plumb bob, one of the 50-m tapes). Revised text to include MIDN methods.	
2.05	December 2008	Kate Miller, Jim Comiskey	Added safe field practices to avoid injury to the list of topics covered during training. Minor editorial changes.	
2.06	April/May 2009	Kate Miller, Sarah Lupis Kozlowski	Minor editorial changes.	
2.07	December 2009	Kate Miller Andrew Vincello	Fixed equipment list format. Added info about forest pest workshop and links to pest ID brochures. Minor editorial changes.	
2.08	October 2010	Kate Miller Jesse Wheeler	Added that starting crews 2 pay periods before training ensure credit cards and uniforms are issued before training. Added importance of sending welcome packet to crew. Added training to include presentations that cover admin, forest database and introduce SOPs Added that GPS units should have topo, trail and boundary maps loaded. Minor editorial changes	
2.09	March 2012	Kate Miller	Added rebar to equipment list in Plot Establishment section.	

Revision History Log (continued).

Version #	Date	Revised by	Changes	Justification
2.10	March 2013	Kate Miller	Revised equipment list to include TruPulse and battery, and removed LAR.	
2.11	December 2015	Kate Miller	Clarified that two full sets of forest plot maps should be provided to the forest crew.	
2.12	February 2019	Kate Miller	Updated UMaine Soil Lab link and e-mail	
2.13	January 2020	Camilla Seirup	Changed SOP number	

SOP 2 - Using the Global Positioning System (GPS)

Mid-Atlantic Network/Northeast Temperate Network

Version 2.02

Overview

This Standard Operating Procedure was adapted from a SOP written by Shenandoah National Park for the Garmin 76CS. It explains the methods that all observers should follow to learn to use Global Positioning System (GPS) with the Garmin GPSMAP 60CSX unit. Forest monitoring crews use GPS to help navigate to and locate pre-existing plots as well as document the location of new plots.

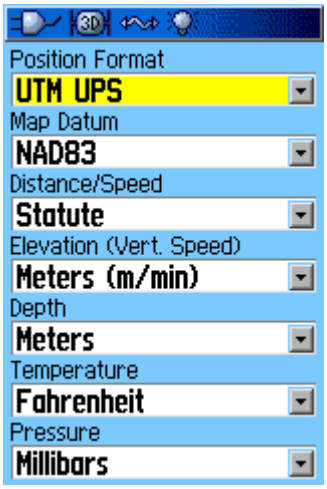
Suggested Reading

Garmin GPSMAP 60CSX Owner's Manual

Setting Up and Using the GPS Unit in the Field

Global positioning system equipment is used in the field to navigate to monitoring sites and locate reference bolts. Detailed steps for setting up and using the GPS unit are presented below.

Setting up the GPS Unit



1. Make sure the GPS is set to UTM NAD83.

    a. Go to the Main Menu by pressing 'Menu' twice.

    b. Toggle to 'Setup' and press 'ENTR'.

    c. Toggle to 'Units' and press 'ENTR'.

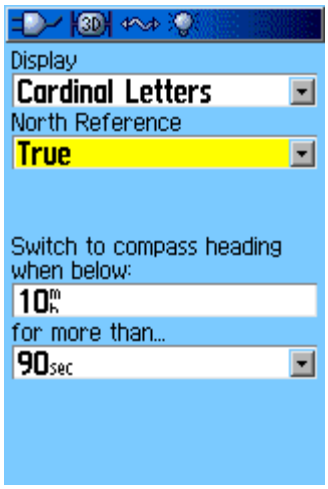
    d. Set the 'Position Format' to '**UTM UPS'** and the 'Map Datum' to '**NAD83'**. To change these, highlight the field press 'ENTR'. Then toggle to the appropriate setting and press 'ENTR' again.

    e. To get back to the Setup menu press 'QUIT'.

2. Make sure the GPS is set to True North.

   a. Toggle to ‘Heading’ on the Setup menu and press ‘ENTR’.

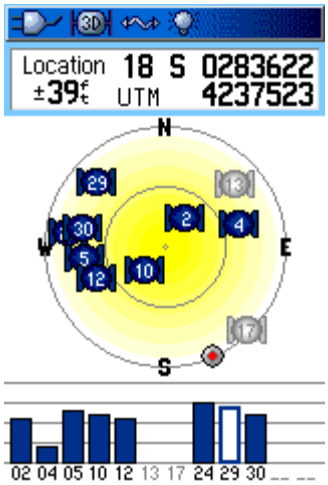
   b. Set the ‘North Reference’ to ‘**True**’.



Note: These settings will be saved on the GPS and should not have to be re-entered each time the unit is turned on.

3. Be sure to carry at least one full replacement of batteries for the GPS receiver.

4. As soon as you turn the unit on, it starts to look for satellites. You can track the status of the satellites by pressing ‘Page’ until you reach the Satellite screen. The GPS is most accurate when it has at least four satellites and a 3D position. The location of satellites in the sky changes from day to day and thus sometimes satellite reception is more difficult to achieve. Openings in the canopy of the forest can increase the strength of satellite signals reaching the GPS unit.



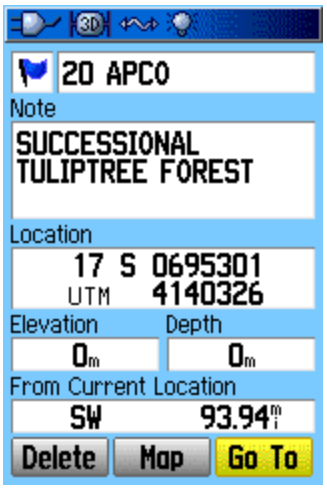
5. The current estimated accuracy of the receiver is also displayed on this page. The accuracy fluctuates as satellite signals are gained and lost. An accuracy of +/– 10 m (30 ft) or better is desirable to precisely document location.

Navigating to a Site

After the receiver is turned on and has adequate reception, press the ‘FIND’ button, highlight ‘Waypoints’ and press ‘ENTR’.

Use the keypad to enter the first number or two and then press ‘QUIT’ to get out of the keypad. Now you can scroll to the appropriate waypoint and press ‘ENTR’.

The waypoint screen will give you detailed information about the waypoint including the Note field and the distance to the point. 'Go To' should already be highlighted so press 'Enter'.



At the top of the Map Page, the distance and bearing to the waypoint will be displayed. The Map Page, Compass Page or Highway Page can be used to navigate to the waypoint. As the distance to the waypoint decreases, the bearing and distance numbers will begin to jump around as the accuracy varies. As the waypoint nears, the use of a hand compass and measurement by pacing will help locate the point.

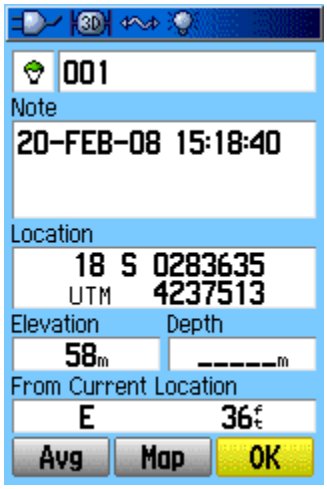
Selecting a Waypoint Symbol

1. Waypoint symbols are a way to group waypoints on your GPS unit. The default symbol for waypoints uploaded to the unit from a computer is the Flag (Blue). The default symbol for waypoints collected in the field is the Parachute Area.

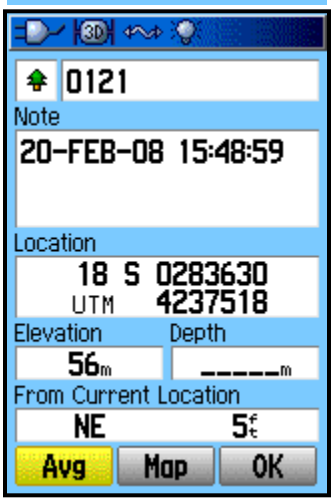
2. It is a good idea to pick a new symbol to distinguish individual and/or groups of waypoints that you collect in the field. This will make it easier to manage, download and delete waypoints on your GPS unit. An example is using a car symbol for a waypoint at the car before you wander into the forest.

Marking a Waypoint

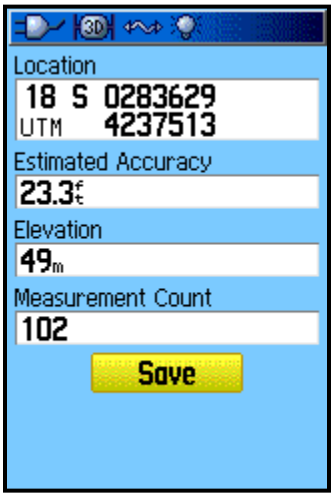
1. Press ‘MARK’ and the Mark Waypoint screen appears.
2. Toggle up to the symbol and press ‘ENTR’ for the Waypoint Symbols screen.
3. Toggle to the symbol you want to use and press ‘ENTR’.
4. The default name of a waypoint is a sequential number starting with ‘001’. To change the default name toggle to the number and press ‘ENTR’.



5. Toggle up and down through the numbers and letters and left and right between characters. Once the last letter or digit has been selected, toggle to ‘OK’ and press ‘ENTR’ to save the name and highlight the whole name field. Reference bolts should have waypoints created based on their six-letter site code plus bolt name (e.g. BASHARASC for the *Ascophyllum* reference bolt at the Bass Harbor Head site).
6. The most accurate way to document a location is to collect a waypoint position that averages at least 100 points. After you have named the waypoint. Toggle to ‘Avg’ at the lower left corner and press ‘ENTR’.

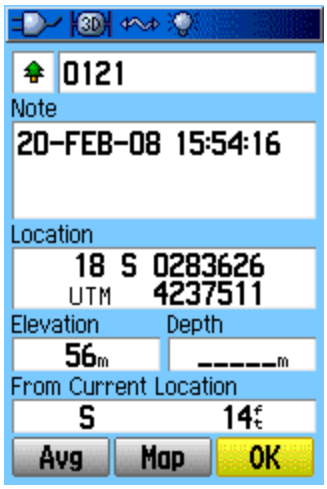


7. The ‘Average Location’ screen appears and measurement counts automatically begin. After the ‘Measurement Count’ reaches 100, highlight ‘Save’ and press ‘ENTR’ to return to the Map Page.



8. You still need to highlight ‘OK’ and press ‘ENTR’ on the map page to save the point.

9. Before leaving the point, make sure that it has been recorded. Press ‘FIND’ and toggle to ‘Waypoints’ and press ‘ENTR’. Does the new waypoint appear on the list?



Navigating

You can navigate using the Map Page, Compass Page or Highway Page. When navigating using the GPS, remember that directional signals you receive from GPS are only valid while you are moving. Unlike a compass, if you stop and turn to face a different direction, the GPS will not reposition until you move again. A compass must be used to determine the correct direction to continue after stopping, and care must be taken to hold the compass sufficiently far from the GPS handheld unit to avoid influencing the compass needle.

Connecting the Garmin 60CSX Unit to a Computer

1. Connect the Garmin 60CSX unit to a computer using a USB cable.

2. Turn the unit on.

3. There are two ways to open DNR Garmin. You should be using version 5.3.2 or higher.

    a. Open DNR Garmin from the Start menu or

    b. Open DNR Garmin from the DNR Garmin toolbar in ArcMap. If the toolbar is not loaded, select View > Toolbars > DNR Garmin Toolbar from the ArcMap menu.

4. Confirm that DNR Garmin recognizes the unit.

    a. If the unit is not recognized, ‘Not Connected’ will appear in the lower left corner (Figure S2.1).

    b. If the unit is recognized, ‘Connected’ will appear in the lower left corner and the GPS unit information should appear on the screen (Figure S2.2).

5. If the unit is not recognized, make sure the Port is set to USB by selecting GPS > Set Port > USB. To refresh the connection, select GPS > Open. Note: this will only work if the GPS is not connected.

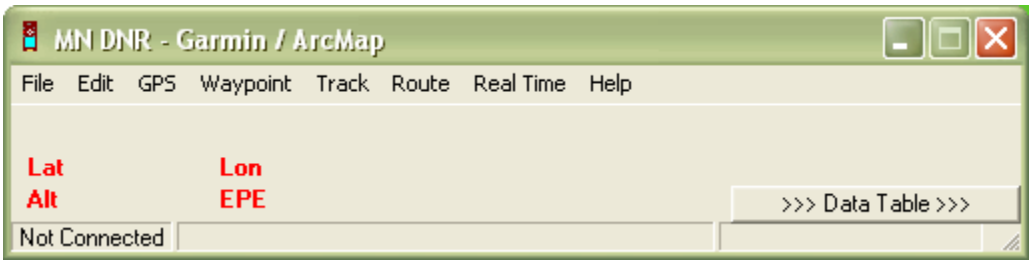


Figure S2.1. MN DNR—Garmin/ArcMap with GPS not connected.

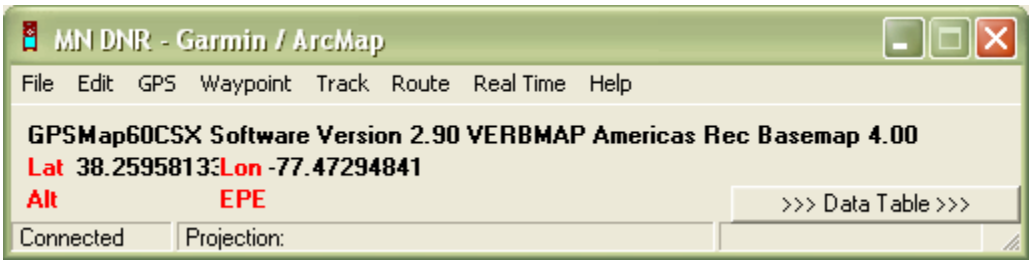


Figure S2.2. MN DNR—Garmin/ArcMap with Garmin unit GPSmap 60CSX connected.

6. Set the default projection to NAD 83, UTM Zone 19N. To open the DNR Garmin Properties window (Figure S2.3); select File > Set Projection. You will need to set the projection three times.

    a. Select ESRI on the Projection tab and select 'NAD_1983_UTM_Zone_19N' from the Datums/Projections drop-down box. You may want to type some of it in to narrow the options.

    b. On the bottom of the same tab, click the 'Load PRJ' button and navigate through 'Projected Coordinate Systems', 'UTM', 'Nad 1983', and then select 'NAD 1983 UTM Zone 19N'.

    c. At the top of the same tab, select ArcMap, click the 'Load PRJ' and navigate to the same projection file as in the last step. Click 'Ok'.

The Projection will now appear at the bottom center of the main MN DNR—Garmin/ArcMap screen (Figure S2.4).

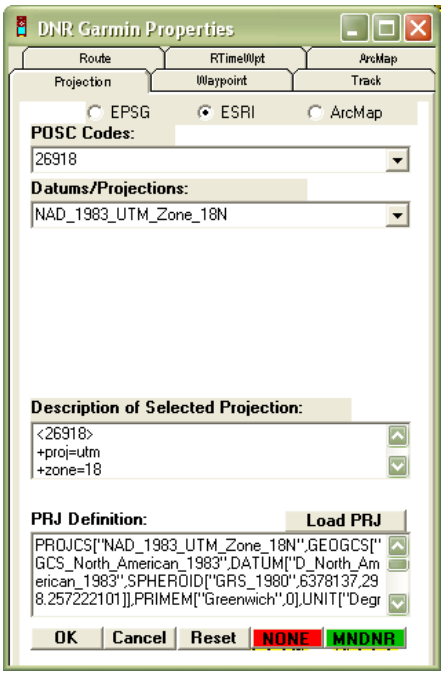


Figure S2.3. DNR Garmin Properties window with projection set to NAD 1983, UTM Zone 18N.

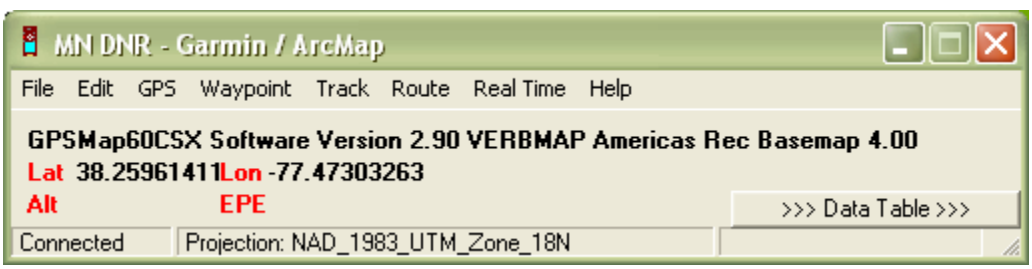


Figure S2.4. MN DNR—Garmin/ArcMap with Garmin unit GPSmap 60CSX connected and projection set to NAD 1983, UTM Zone 18N.

Uploading Waypoints to the Garmin Unit

In order to navigate to existing reference bolts, waypoints with plot Universal Transverse Mercator (UTM) coordinates must be uploaded from a GIS layer to the GPS receiver. The steps for this procedure are as follows:

1. Turn on the computer and open the current ArcGIS map document with the GIS layer loaded. Make sure the GIS layer you want to upload is active. It should be highlighted (Figure S2.5).

2. Connect the GPS unit to the computer using the USB cable and turn the unit on.

3. Open MN DNR Garmin.

4. Select File > Load From > ArcMap > Layer. The Identify Fields dialog box will appear and you will need to select an Ident and Comment field. *Note: If the shapefile already has a comment field, MN DNR Garmin will default to the existing comment field and ignore the*

field selected. You will need to either copy the field you want to use into the existing comment field or delete it.

5. To upload the waypoints to the GPS unit. Select Waypoint > Upload.

6. The GPS will beep when the upload is complete and a small box on the computer screen will read 'Transfer Complete. Waypoints uploaded.' Click OK. Now, you are ready to take the GPS into the field.

7. Note that the default symbol for uploaded waypoints is a blue flag. Press 'FIND' on the Garmin unit and select 'Waypoints' and then press 'ENTR' to see the waypoints that you just uploaded.

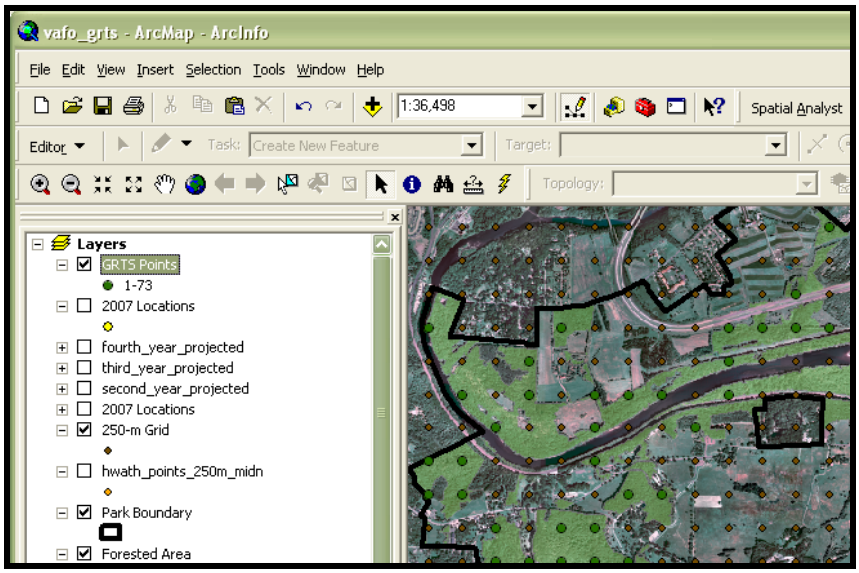


Figure S2.5. ArcMap screenshot, showing that the GRTS Points layer is active in the Table of Contents.

Downloading Waypoints

Waypoints for newly established reference bolts as well as updated waypoints for plots with inaccurate GPS locations need to be downloaded onto the computer upon return to the office from the field.

1. Open the ArcGIS map document with the relevant files.

2. Connect the GPS unit to the computer with a USB cable and turn it on.

3. Open DNR Garmin and verify that the GPS is acknowledged and that the projection is set to NAD 83, UTM Zone 19N. If you need help, see the section above on setting up DNR Garmin.

4. To download waypoints, select Waypoint > Download. The saved waypoints from the GPS will now appear in the table (Figure S2.6).

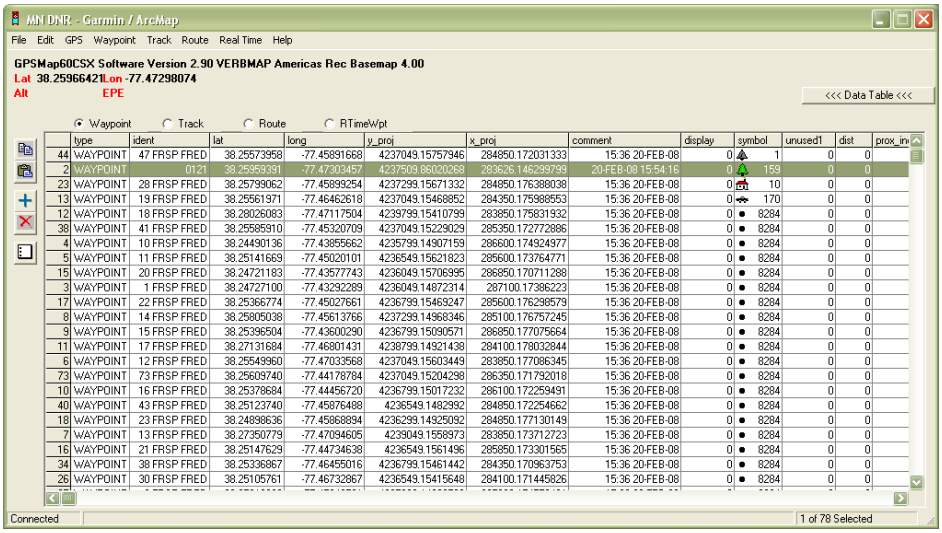


Figure S2.6. Data table in the MN DNR – Garmin/ArcMap application displaying downloaded waypoints.

5. Note that all the waypoints on the GPS are downloaded. You can sort through these by clicking on any of the column headings. For example, click on 'symbol' to sort the waypoints by their symbol.

6. You can either save all the waypoints or select specific waypoints to save. What you choose to do may depend on the project you are working on. If you do not highlight any of the waypoints, they will all be saved. To highlight waypoints, click on the row identifier. In Figure S2.6, clicking on '2' highlighted the row which is Plot 0121.

7. These waypoints need to be saved twice, once as a text file and once as a shapefile.

    a. To <u>save as a text file</u>, select File > Save To > File…

For rocky intertidal plots and reference bolts, the text file should be saved in the '**backup_gps_text_files**' folder. The naming convention should include the date the file was downloaded, the GPS brand and model number, and the type of data following the format "**20080220_Garmin_60CSX_waypoints.txt**".

    b. To <u>save as a shapefile</u>, select File > Save To > ArcMap > Shapefile Layer...

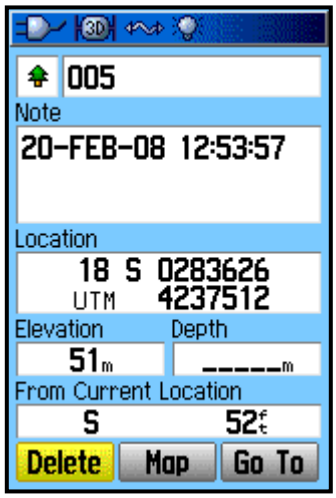
For rocky intertidal plots and reference bolts, the shapefile should be saved in the '**backup_gps_shapefiles**' folder. The naming convention should include the date the file was downloaded, the GPS brand and model number, and the type of data following the format "**20080220_Garmin_60CSX_waypoints.shp**".

8. This file will automatically appear in the Table of Contents of the ArcGIS Map Document that you have open.

9. Close DNR Garmin and verify the contents of the new shapefile in the map document to ensure that your data were properly transferred.

Deleting Waypoints from the GPS Unit

The GPS receiver can hold up to 500 waypoints, but it is advisable to delete the downloaded waypoints from the GPS periodically to keep it from becoming full while in the field. You have three options for deleting waypoints on the GPS receiver.



1. Deleting a single waypoint:

   b. Press ‘Find’ to open the Find screen.

   c. Select ‘Waypoints’ to open the Waypoints screen.

   d. Toggle to highlight the waypoint you would like to delete and Press ‘ENTR’ to open the Waypoint screen.

   e. Toggle to highlight ‘Delete’ in the lower left corner and press ‘ENTR’

   f. When prompted ‘Do you really want to delete waypoint xxx?’ highlight ‘Yes’ and press ‘ENTR’

2. Deleting all waypoints:

   a. Press ‘Find’ to open the Find screen.

   b. Select ‘Waypoints’ to open the Waypoints screen.

   c. Press ‘MENU’ to open the Menu screen.

   d. Highlight ‘Delete’ and press ‘ENTR’

   e. Highlight ‘All Symbols’ and press ‘ENTR’

   f. Confirm that you really want to delete all waypoints and press ‘ENTR’

3. Deleting all waypoints represented by the same symbol
   a. Press ‘Find’ to open the Find screen.
   b. Select ‘Waypoints’ to open the Waypoints screen.
   c. Press ‘MENU’ to open the Menu screen.
   d. Highlight ‘Delete’ and press ‘ENTR’
   e. Highlight the symbol representing the group of waypoints that you want to delete and press ‘ENTR’
   f. Confirm that you really want to delete all the waypoints with the selected symbol by highlighting ‘Yes’ and press ‘ENTR’

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.05	December 2006	Geri Tierney Brian Mitchell	Included advice for navigating with GPS and compass.	
1.06	September 2007	Brian Mitchell	Added section about uploading GPS waypoints from DNRGarmin to the Garmin GPS V.	
2.00	May 2008	Jim Comiskey Kris Callahan Brian Mitchell	Major revisions.	Switch to Garmin 60CSX GPS.
2.01	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.
2.02	January 2020	Camilla Seirup	Changed SOP number	

SOP 3 - Using the LTI TruPulse 360ºR

Mid-Atlantic Network/Northeast Temperate Network

Version 1.01

Overview

This SOP describes proper use of the Laser Technology Inc. (LTI) TruPulse 360ºR (LTI model 0144860).

Suggested Reading

The following manual should be read to ensure proper use of the Hypsometer:

LTI TruPulse 360ºR User Manual First edition, 2011.

The manual is available in PDF format from the Mid-Atlantic Network (MIDN) or Northeast Temperate Network (NETN).

General Use

The TruPulse 360ºR consists of a laser range sensor, an internal compass (horizontal angles), tilt sensor (vertical angles) and digital processor encased in a water resistant housing (Figure S3.1). The TruPulse 360ºR has three buttons ("Fire", up arrow, and down arrow) that access the unit's internal software, which operates the integrated sensors. The device is powered by a single 3 volt Lithium rechargeable battery commonly referred to as CR123A or CR123. The batteries must be recharged every night for the next day's use. Spare batteries should always be available in the field. The Tenergy combo Li-Ion battery charger (TN268) should be used to recharge the batteries (allow at least 4 hours).

A liquid crystal display (LCD) is mounted within the optical system, displaying measurements and units when the operator looks through the adjustable eyepiece. Avoid exposing the eyepiece's internal components to direct sunlight by fastening the cover when not in use.

The TruPulse 360ºR has two lenses at the front of the unit, a transmitting and receiving lens. Do not touch these lenses. Avoid obstructing them while in use. If they need to be cleaned, they should be treated as sensitive optical lenses, using only a soft clean lens tissue to clean it. The measuring point of the TruPulse 360ºR is located at the tripod mount at the center of the unit.

When using a tripod, it must be non-ferrous (non-magnetic) to avoid influencing the angle measurements from the internal compass (Figure S3.2). The tripod should be used to enable accurate distance and angle measurements when positioned over plot center.

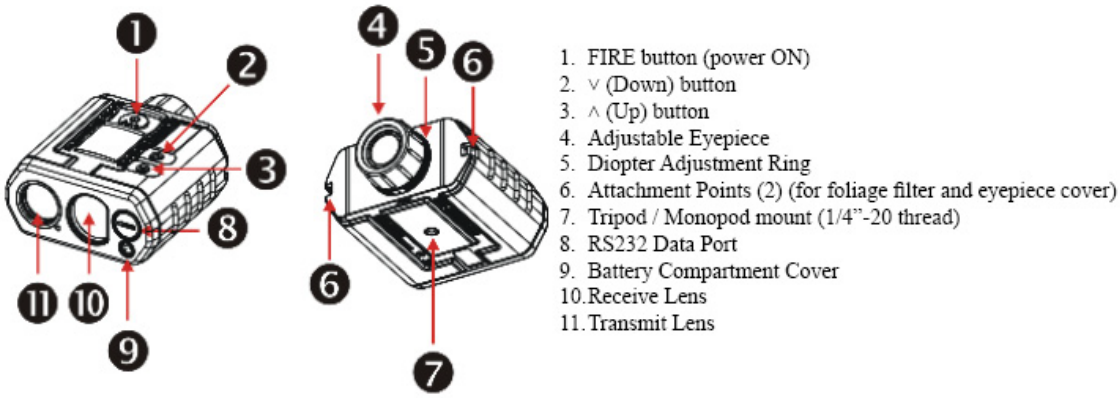


Figure S3.1 TruPulse 360ºR features (© LTI).

Figure S3.2. TruPulse 360ºR setup mounted on an LTI non-ferrous tripod with L-bracket mount and bubble level.

Getting Started

Insert a charged CR123A Lithium-Ion battery, negative end first into the battery compartment at the front of the unit (Figure S3.3). If needed, extend the adjustable eyepiece to fit eyeglasses and block extraneous light by rotating counter-clockwise while pulling up. The diopter adjustment ring at the base of the eyepiece can be used to focus the LCD display relative to the target (Figure S3.4).

With the TruPulse 360ºR in your right hand and looking through the eyepiece, the round “Fire” button will be under your index finger and ∧ and ∨ will be on the top-left of the unit (Figure S3.1). The “Fire” button is used to switch the unit on and to select items on the internal display. The ∧ and ∨ buttons are used to scroll through measurement and setup functions. Simultaneously press-and-hold ∧ and ∨ for 4 seconds to switch the unit off. To conserve power, the unit will shut itself off after 2 minutes of no use. When switching on the TruPulse 360ºR, the display prompts the measurement mode that was last used (Figure S3.5).

Setup

Units of Measure

From the Measurement Mode, press-and-hold ∨ for 4 seconds to access System Setup Mode (“UnitS” will appear). Press “Fire”, then ∨ to scroll through units (Yards, Meters, and Feet), select “Meters” by pressing “Fire” again. You will then be prompted to select angle units (Degrees or Percent). Select “Degrees” by pressing ∨ and “Fire” again.

Figure S3.3. Battery compartment with CR123A inserted.

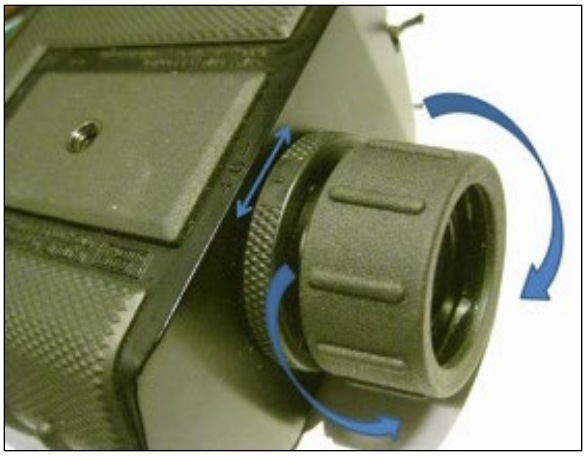


Figure S3.4. Eyepiece adjustment and diopter adjuster ring.

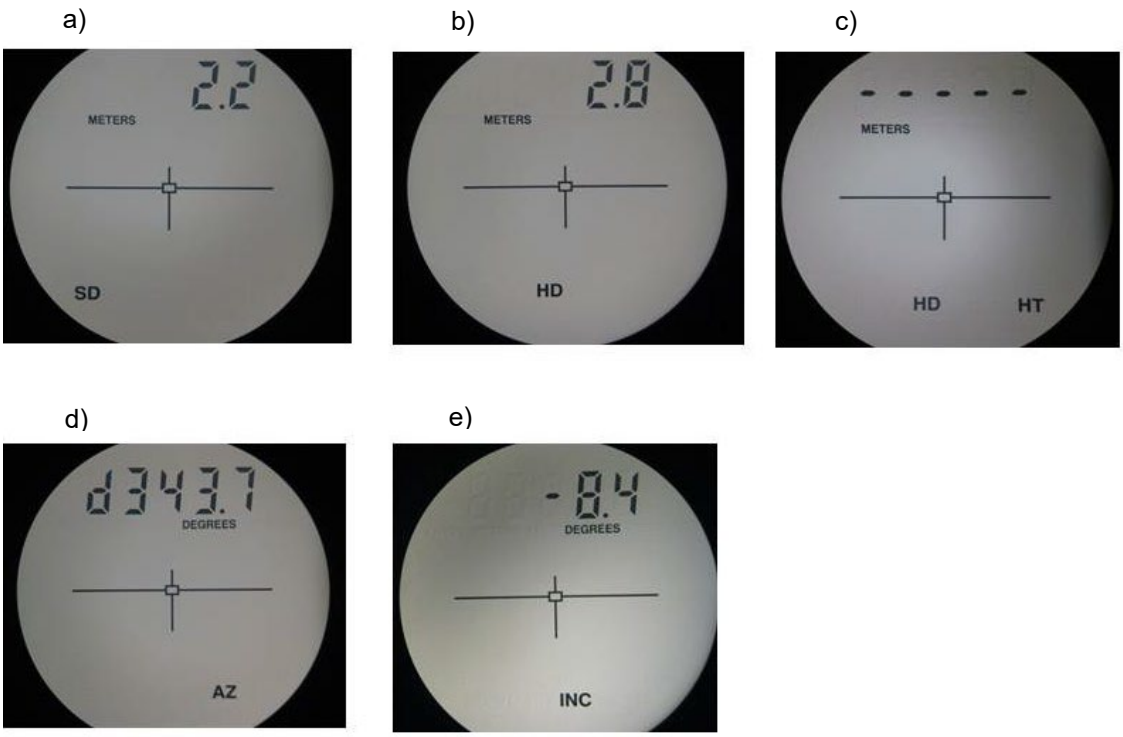


Figure S3.5. Measurement modes used in forest health monitoring; a) SD - slope distance, b) HD – horizontal distance, c) HD (flashing) + HT – tree height routine, d) AZ – horizontal azimuth, e) INC – inclination (slope angle).

Compass Declination

Set the internal compass magnetic declination every time you change Park locations (NETN Park declinations can be found in SOP 6 – Site Selection, Plot Establishment and Remeasurement). From the Measurement Mode, press-and-hold ∨ for four seconds to access System Setup Mode where "UnitS" will appear in the Main Display. Press ∨ to select the "H_Ang" (horizontal angle) option, press "Fire" to bring up "dECLn" (declination) on the Main Display. Select "yes" "dECLn" using ∧ or ∨, then press "Fire" to enter a declination value. The right-most digit will flash, indicating that it can be edited. Press ∧ or ∨ to increase or decrease the flashing number. Press "Fire" to accept the desired value and move the editing to the next digit. After all three digits (##.#) have been entered, the whole value flashes. **IMPORTANT** – The declination value should always be negative for all MIDN and NETN parks (e.g. ACAD is -17.0). Press ∧ or ∨ to toggle the value from positive (East declination) to negative (West declination). Press "Fire" to accept final declination value. **Note:** When in AZ measurement mode, "d" appears as the left-most character in the Main Display as a reminder that a declination value has been entered (Figure S3.5d).

Tilt Sensor

Calibrate the Tilt Sensor any time the battery is changed, the unit is dropped, or the compass calibration is failing repeatedly. Always perform Tilt Sensor calibration on a flat, fairly level surface. Press-and-hold ∨ for four seconds to access System Setup Mode where "UnitS" will appear in the Main Display. Press ∨ to display the "inC" (inclination) option, and then press "Fire". The message "no" "CAL" (no calibrate) will appear in the Main Display. Press ∧ or ∨ to display "YES" "CAL"

(yes calibrate), then press “Fire” to begin tilt calibration routine (Figure S3.6). The Main Display will show “PASS” or “FAiL” when the tilt calibration routine is complete. If the tilt calibration results in a “FAiL” message, repeat the tilt calibration until it passes.

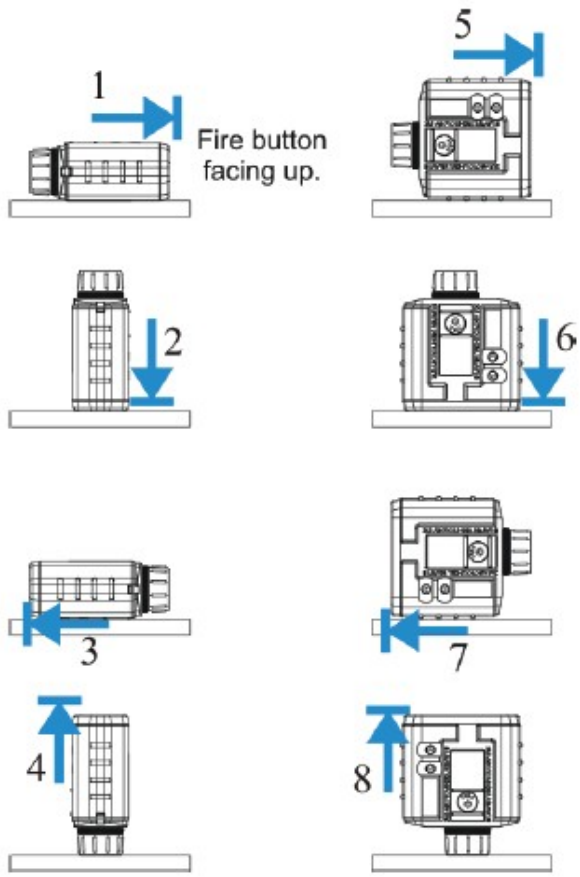


Figure S3.6. Tilt Sensor Calibration Routine, steps 1-8. Press “Fire” button at every step, with 1 second pauses between steps. Hold the TruPulse 360°R on a flat, relatively level surface (+/-15 degrees of level) (© LTI).

Compass Calibration

Calibrate the Horizontal Angle Compass settings every morning before sampling forest plots for the day. This ensures that the azimuths measured will be accurate and relative to true north, no matter the location of the site. From the Measurement Mode, press-and-hold ∨ for 4 seconds to access System Setup Mode where “UnitS” will appear in the Main Display. Press ∨ to select the “H_Ang” (horizontal angle) option, press “Fire” to bring up “dECLn” (declination) on the Main Display. Press ∨ to display the “HACAL” (horizontal angle calibration) option. Press “Fire” to select, then the message “no” “HACAL” will appear on the Main Display. Press ∧ or ∨ to display “YES” “HACAL”, then press “Fire” where “C1_Fd” appears, signifying the start of the compass calibration routine (Figure S3.7). The Main Display will show “PASS” or “FAiL” when the compass calibration routine is complete. If the routine fails, try again, making sure you do the steps slowly and away from magnetic or metal sources (e.g., compass, field computer, and hand lens).

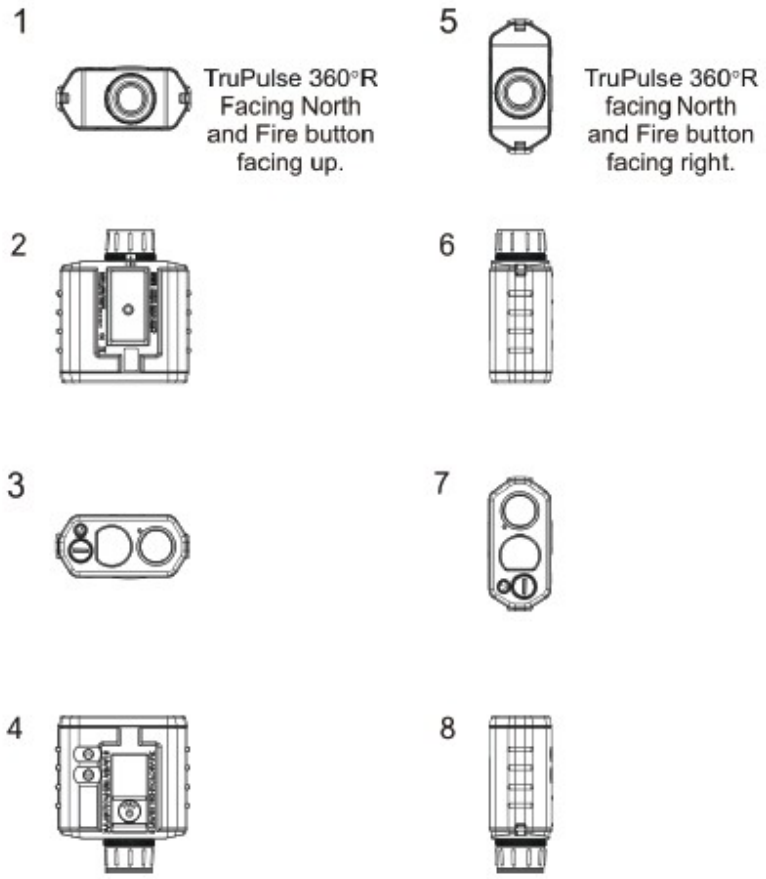


Figure S3.7. Compass Calibration Routine, steps 1-8. Press “Fire” button at every step, with 1 second pauses between steps. Hold the TruPulse 360ºR close to magnetic North (+/- 15 degrees towards North) during the compass calibration routine (© LTI).

Targeting Mode

Select a Targeting Mode theme for your distance measurements. For most applications, where brush and other vegetation may interfere with the distance measure, use the Filter mode with a Foliage filter installed on the receiving lens at the front of the unit. The Filter Targeting Mode will allow for more accurate measurements even when the view is partially obstructed. The most accurate Filter Mode measurements will display distance values with a decimal value included (e.g. 7.3) but when the target is too obstructed, a less accurate, whole digit value will be displayed instead (e.g. 7). Note that the Foliage filter must be installed for the filter mode to read off of a reflective surface.

To change between targeting modes (Standard is the default), press-and-hold ∧ for 4 seconds to bring up System Setup Mode where “Std” (Standard) will appear on the Main Display. Press “Fire” to select for Standard Mode, or press ∧ or ∨ to toggle through other Targeting Modes; Filter (FLt), Farthest (FAr), Closest (CLo) and Continuous (Con), pressing “Fire” to select final choice.

Taking Measurements

For all measurements made from plot center, the TruPulse 360ºR should be mounted on a tripod and leveled using the tripod's built in bubble level. Once mounted and placed over plot center, the unit is ready for use for plot re-establishment and tree mapping. The TruPulse 360ºR can be operated on its own without a tripod, which is useful for measuring stand height.

To take a measurement, align the cross hairs in the scope with the required target and press-and-hold the "Fire" button on the top of the instrument. The measurement will appear at the top of the display area, at which point release the "Fire" button (Figure S3.5). Two of the measurements that are of most interest are the azimuth or horizontal angle (AZ) and the horizontal distance (HD). These measurements are used for establishing the plot as well as for mapping the location of trees within the plot.

Setting Up the Plot

When setting up the plot, the TruPulse 360ºR is rotated and the red "Fire" button pressed until the AZ gives the desired horizontal angle reading (one can hold down the "Fire" button to show instant changes in angle while rotating). For the upper right corner of the plot this angle is 45° greater than the plot orientation (to the nearest 0.5°). **IMPORTANT:** Plots that are not oriented to True North will need to have the angle difference accounted for when re-establishing plot stakes (e.g. a plot oriented upslope at an azimuth of 30º will have its upper right stake at an azimuth of 75º).

Once the angle has been established, a distance measurement is taken. This will require that a second team member holding a reflector move toward or away from the TruPulse 360ºR. The desired horizontal distance (HD) should be measured to the nearest 10 cm. Slope Distance (SD) is only used for CWD transects and establishing microplots in NETN parks.

NOTE: In cases where a tree obstructs the view, the distance measurement (HD) can be taken to either side of the tree and the horizontal angle (HA) registered as that of the obstructing tree.

Mapping Trees

All trees ≥ 10 cm DBH in the plot are mapped. The Horizontal Distance (HD) and Horizontal Angle (HA), to the nearest unit, are recorded. This requires that a measurement be taken with the TruPulse 360ºR to each tree. Care should be taken to aim at the center of the tree trunk when measuring AZ. Accurately measure the HD by positioning the reflector on the side of the tree, ensuring a distance measured to the center of the tree bole.

Stand Height

In each plot, three co-dominant trees and three intermediate trees are chosen and their height is measured with the TruPulse 360ºR. After all plot-level measurements have been taken with the TruPulse 360ºR, move it to a point where you can see the base and the top of the tree, then conduct the automated Height Routine to measure tree heights (Figure S3.8). The 3-Shot Height routine should be used with filter mode and a reflector. Once HT and HD (flashing) are displayed, press "Fire" to start routine. Aim crosshair at a reflector at the tree, press-and-hold "Fire" until a value appears with HD, followed by "Ang_1" at top of display. Aim crosshair to top of tree, press-and-hold "Fire" and when released the display will show a positive angle (INC). The angle value will flash

once, then “Ang_2” appears at the top of the display. Aim crosshair to base of the tree, press-and-hold “Fire” and when released the display will flash a negative (INC) angle, followed by the calculated tree height. **Note:** In order to measure tree heights as accurately as possible, do not select a location downslope or drastically upslope from the tree base. The top and base angles of the tree can be either “Ang_1” or “Ang_2”.

Completing the Survey

When the plot has been delineated and all trees have been mapped, the TruPulse 360ºR can be turned off. Upon completing the work at the plot, the unit should be disassembled from the tripod and each piece of equipment returned to their respective carrying cases. At the end of each day the batteries should be taken out of the TruPulse 360ºR for recharging.

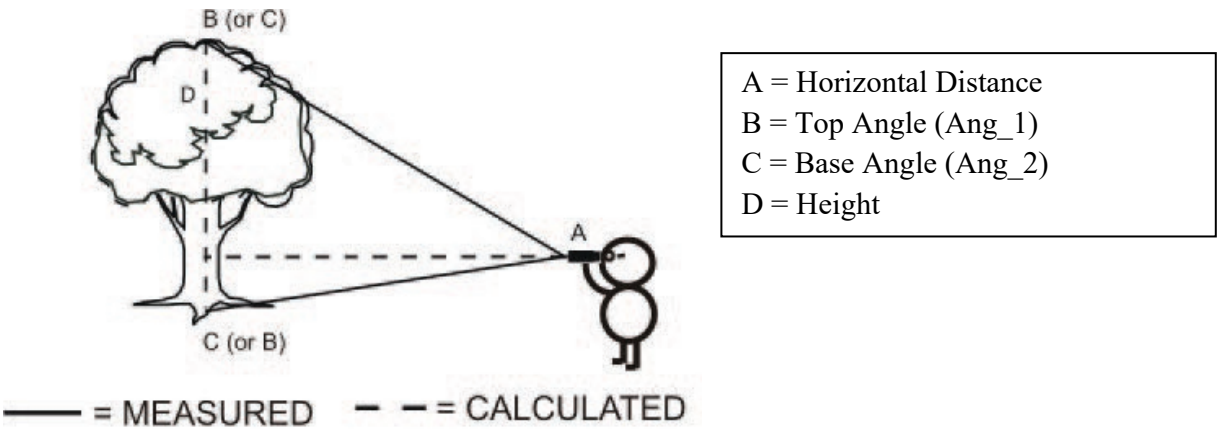


Figure S3.8. Measurements required for the Tree height routine (© LTI).

Troubleshooting

Be aware that when the battery voltage is low there will be a flashing warning “BATT”, and when the power is too low for operation the “BATT” will constantly be displayed. There will not be much operating time left when the battery is low.

The TruPulse 360ºR is protected from dust and rain, but will not withstand submersion. If water leakage is suspected, power unit off, remove the battery and air dry the equipment at room temperature.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.00	December 2013	Jesse Wheeler	Initial protocol	New Equipment to replace Laser Rangefinder
1.01	January 2020	Camilla Seirup	Changed SOP number	

SOP 4 - Data Management & Quality Assurance/Quality Control

Mid-Atlantic Network/Northeast Temperate Network

Version 2.14

Acknowledgements

This SOP benefited greatly from the content and ideas expressed in these documents:

Heartland Network. 2004. Standard operating procedure #11: Data management. *In* Vegetation community monitoring protocol for the Heartland I&M Network and Prairie Cluster Prototype Monitoring Program. Version 1.0. National Park Service, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program, Republic, Missouri.

Thomas, S., and B. Moore. 2007. Standard operating procedure #6: Data management. *In* A protocol for monitoring Allegheny woodrats (*Neotoma magister*) at Mammoth Cave National Park. Version 2.1. National Park Service, Cumberland Piedmont Inventory and Monitoring Network, Mammoth Cave, Kentucky.

Southeast Coast Network. 2008. Quality assurance/quality control & field data collection standards. Version 1.0. National Park Service, Southeast Coast Inventory and Monitoring Network, Atlanta, Georgia.

Overview

Careful, accurate collection of data as directed in these SOPs is critical to the success of Vital Signs monitoring. This SOP describes quality assurance/quality control (QA/QC) procedures for accurate data collection, transcription and stewardship, and assessment of data quality (Appendix S4.A). Networks will use a field computer database or standardized datasheet for data collection, as weather conditions and technology permit.

Field Procedures

Network staff shall use the following procedures to record data in the field:

- To measure distance using a measuring tape, do as follows. When ready, the measurer shall alert the crew member holding the tape origin by calling "mark." The crew member holding the tape origin will then hold the tape securely and directly over the starting location, and reply "mark" to signal readiness. The measurer then pulls the tape taught and reads the measurement.

- To record data, do as follows. The measurer shall clearly call out a data value to be recorded. The recorder shall clearly repeat the value aloud as it is recorded, to ensure the value was

heard and recorded accurately. If the measurer does not hear a response from the recorder, the measurer shall repeat calling out the measurement until a response is obtained.

Field Computer

When weather and technology permit, networks will record data directly into the forest database using a field computer. This will eliminate the time and potential error involved in data transcription from field notes. The database will include clearly designated fields for each measurement to be recorded, including notes, and should have appropriate upper and lower bounds for values. Before concluding data entry on a plot, database users must indicate via their initials that they have checked all of the forms in the database to ensure they are complete and accurate.

The computer database should be backed up daily upon returning from the field, using an external hard disk provided by the network data manager. Furthermore, the database should be uploaded to the network's server periodically during the course of the summer as directed below.

The field computer should not be used in rain more than a light sprinkle—in case of steady rain the computer should be packed away and Rite-in-the-Rain datasheets used as directed below. The database should be designed to match the datasheets as closely as possible, and vice versa.

Datasheets

The crew must always bring datasheets copied onto Rite-in-Rain paper as a backup for data collection in case of rain or computer malfunction. Datasheets will contain as much preprinted project information as possible with designated labels for specific data elements, including general data such as date and collectors' names. Datasheets will clearly identify all required information, using examples where needed to ensure that the proper data are recorded. After paper datasheets have been initialed in the field check box as having been filled out in their entirety, a complete set of working copies will be made (see Data Stewardship section below). Most post-field collection data entry notes and remarks shall be made only on the copies, not to the original datasheets. Post-field collection remarks added to either the original (e.g., unknown species identifications) or copies of the datasheets should be written using a different colored pencil. Using the template at the top of the datasheet, all network staff members (including the crew) who make modifications to the datasheet shall indicate their identity (initials), date of modifications, purpose of their review, and the color used to provide comments or make changes (Figure S4.1).

Data Verification

Data quality and verification involve checking the accuracy of field data at each stage it is transcribed from its original source. To minimize the possibility of carrying entry errors forward into analysis, the data quality and verification process for this protocol involve multiple checks. After computerized data are verified to accurately reflect the original field data (i.e., the entered data match the collected data), the paper forms will be archived and remaining data manipulation shall be done in the database.

Field Data Transcribed Directly to Computer

During the data entry process, the crew member entering the data will verbally double check all field values for accuracy and completeness with the crew member collecting/announcing the data. All discrepancies will be corrected prior to moving to the next data field.

Upon completing data collection at each site, the crew member entering the data will check the entire computer form for completeness. The crew member responsible for completing this field verification should initial each datasheet in the appropriate location.

After completing the last site of the day the number of records present in the digital file shall be compared against the known number of sites for which data were recorded.

Purpose	Color	Date	Initials
Entered to DB	☐		
100% Check	☐		
10% Check	☐		
Validation	☐		
	☐		

Figure S4.1. Verification log found at the top of NETN Forest Health paper datasheets. Log is used to track changes and record the verification and validation status of datasheets for each plot.

Field Data Transcribed to Paper Datasheets

- Datasheets should be protected within an enclosed clipboard.
- All information added to a datasheet must be printed using pencil and clearly legible.
- While manually recording data, the crew member entering the data will verbally double check all field values for accuracy and completeness with the crew member collecting/announcing the data. All discrepancies will be corrected prior to moving to the next data field.
- Information shall never be erased and incorrect or older information shall never be overwritten.
- Revisions shall be accomplished by crossing-out the erroneous data with a single line.
- Upon completing data collection at each site, original datasheets shall be reviewed and checked for legibility and completeness. The crew member responsible for completing this field verification should initial the datasheet in the appropriate location.

Paper Data Transcribed to Computer

During the process of transcribing data from paper datasheets into the database, the crew member will double check all entries and correct discrepancies prior to advancing to the next datasheet.

Following data entry into the computer, a crew member shall review 100% of the records entered to ensure that values present on field forms were accurately and completely transcribed into digital

form. All efforts should be made to prevent the same crew member who originally entered the data from conducting the 100% verification check. Notes or changes made to the datasheets should only be made on the complete set of copies made for this purpose.

Ten percent of records are reviewed a second time by either the data manager or the plant ecologist. All comments and changes should be recorded on the copies of the datasheets. If a significant transcription error (e.g., incorrect values or missing records) is found in one out of 10 datasheets during the 10% review, then the entire data set will be verified again (i.e., repeat the 100% and subsequent 10% checks until the data manager is satisfied with the data quality). In cases where the transcription errors detected follow a pattern (e.g., data entry errors on datasheets with quadrat data that was recorded out of order), then a subset of the datasheets following that pattern will be checked, instead of the entire set of datasheets.

Database Merge Tool

There are several important considerations to ensure the merge tool will merge records between databases correctly:

- The process of merging works best when field backends are merged into a master backend that is stored/managed by the protocol lead or data manager.
- The database backends should only be merged at the end of the week when visits in each backend are complete. For example, if everything except quadrats were sampled on a plot one week, and a contract botanist is scheduled to sample the quadrats the following week, the databases should not be merged. The contract botanist and crew member must also either use the same field computer/database associated with the other data for that visit, or record quadrat data on datasheets.
- One field computer/database is used on a plot, as the merge tool will not recognize two visit records created on the same day and plot, but on different computers, as the same visit.
- QA/QC plots should have a backend that contains the initial visit by the crew that year, to ensure any changed plot-level data are merged correctly.

If these guidelines are not followed, the merge tool may not function properly, and some records may not be incorporated into the merged database.

Schedule of Data Management Duties

A number of data management duties should be performed regularly to ensure that all datasheets, files, and samples are properly accounted for. At the beginning of the field season, each crew member is assigned a specific set of duties to perform over the course of the season, and duties are performed on a daily or weekly basis.

Daily Duties: Backup and Tracking

At the end of every day, one crew member must copy photopoint photos to the designated field computer, and use the rename utility to name the photos correctly. The backend on each Toughbook,

along with the renamed photos should then be backed up onto the provided external drive. The external drive should be stored in a different location than the field computers. The tracking form should also be updated with information on the plots that were sampled that day, including whether the database or datasheets were used on the plot, which Toughbook the plot was sampled on, and the number of soil and unknown samples collected from each plot (Appendix S4.B).

Weekly Duties: Merging the Data

At the end of every week, the forest crew leader will post the latest backends from both field computers on Google Drive. The protocol lead will merge the two field backends into a master backend database. The protocol lead will then check for issues in the plots sampled that week, including running the checker for each plot, and scanning the species recorded in each tab. After the merge is complete and the data are checked, the protocol lead will send the newly merged database to the forest crew leader before the start of the work week. At the beginning of each week, the forest crew leader will then copy the new backend to each field computer and reset the links in the frontend database.

Data Validation

Although data may be correctly transcribed from the original field forms, their values may not always be accurate or logical. For example, some plant species found in southern parks do not occur in northern parks, such as MABI or ACAD. If a southern plant is identified erroneously to be present in a northern park, this would represent a logic error. As often as possible components of the data validation process has been built into the database (e.g., value range restrictions, separate species pick-lists for trees and shrubs, separate favorites species lists for each park, etc.). Although many validation problems can be addressed by a well-designed database, the plant ecologist (NETN) or program manager (MIDN) must also review and validate the data after verification is complete. The plant ecologist and network program manager are the authorities on the methodologies and species involved.

Once the verification process has been completed, statistics should be used to evaluate the data present in the database. The plant ecologist and/or network program manager should generate range and average values to help identify outliers.

Data Stewardship

Good data stewardship practices play a critical role in long term data security and help prevent irretrievable loss of information.

- Sequential copies of the field database should be backed-up to an external hard disk on a daily basis. The computer and the hard disk shall be stored separately. For example, when the computer is being used in the field, the hard disk shall be stored in another location (i.e., a hotel room, or in a vehicle).
- The database should be uploaded by the crew to the NPS ftp site at the end of every sampling week. Network staff should then check the database for errors on a weekly basis during the

first month of sampling, and periodically thereafter to catch and prevent recurring data entry errors. Login information for the NPS ftp site will be provided to the crew during training.

- Datasheets should be photographed or scanned at the end of each field day to preserve a temporary digital record of the datasheet, should the original datasheet get lost. Once data are transferred and certified in the database, the images can be deleted.
- Datasheets should be copied onto acid-free paper within one week of collection, and shall be checked to ensure that all original data are present and legible. Once produced, photocopies of the datasheets should be affixed as coversheets to their corresponding originals and used for all computer data entry and verification procedures. All post-field corrections and remarks should be recorded on the copies. All post-field corrections and remarks should be annotated with the date and initials of the person making the changes.
- Once the computerized data are verified as accurately reflecting the original field data and validation is complete, the paper field forms shall be delivered to the network data manager. The electronic version of the data is used for all subsequent data activities.

Field QA/QC

The networks will resample at least 5% of sampled plots annually to determine reliability of field data collection. Field QA/QC will occur as close as possible to original sample date of the plot to reduce seasonal variability, and will not occur before the plots are sampled by the forest crew. Field staff for remeasurement must not include members of the field crew that originally measured the plot; and unknown plant identification must not be performed by the botanist who undertook this function for the original measurement. In order to control trampling impacts, remeasurement should not occur at plots which are particularly sensitive (e.g., moss dominated ground-layer), and no plot should be measured more than four times in 12 years. The QA/QC team should sample the plot as it was left by the previous crew. Plot markers, the location of tree DBH measurements, and all plot-level data (e.g., tree distance and azimuth, tree species, and plot slopes) should not be changed. If the QA/QC team detects issues with the plot-level data, they should be recorded in the notes, and the protocol lead will review the issues to determine if the original data should be modified.

The field QA/QC team can consist of several combinations of network staff. The QA/QC team must include a botanist capable of identifying all woody and herbaceous plants on the plot, and at least one network staff member who is well versed on the forest protocol. Appropriate QA/QC teams include 1) plant ecologist and/or contract botanist with network program manager, 2) plant ecologist with forest crew leader or member, 3) forest crew leader with contract botanist, and 4) two forest crew members with contract botanist. The QA/QC team must not include anyone who was present at the original sampling event. In the event that the plant ecologist or other network staff were present at the original sampling event (not ideal), a separate contract botanist must identify all species during the QA/QC sampling, and the plant ecologist/ network staff must not participate in any data collection that he/she participated in during the original sampling event.

The QA/QC team must use a database that contains the initial visit from the crew. This will allow for the QA/QC team to view any plot-level data that are changed, such as corrections to plot orientation, tree azimuths, or tree species. If the QA/QC team does not have the initial visit, plot-level records that were changed by the initial visit for that year will have an older time stamp than plot-level records for the QA/QC visit, and the automatic setting on the merge tool will not adopt the correct records.

Importing Soil Data from the Lab into the Database

Once analysis of the soil samples is complete the analytical lab will report the results on a spreadsheet. Data contained in the spreadsheet will need to be imported into the most recent version of the Forest Monitoring Database so that it links up accurately with the plot and visit upon which it was collected. The following are step-by-step instructions on how to prepare, format, and import the spreadsheet into the database.

Preparing the spreadsheet

1. The spreadsheet received from the lab will have the NETN sample number (e.g. 1, 2, 3, etc.) , and a series of data columns: soil PH, % LOI, % TN, % TC, Ca, K, MG, P, Al, Fe, Mn, Na, Zn, acidity, and ECEC.
2. Make a copy of the original spreadsheet from the lab before starting any modifications.
3. Original spreadsheets should use ‘from_lab” in the file name. Modified spreadsheets should use ‘for_DB’ in the file name. Only make changes to the ‘for_DB’ version of the spreadsheet.
4. Final storage of all soil files should be here: Z:\PROJECTS\MONITORING\Forest_Health\5_Data\Data_Files\Soils

Formatting the spreadsheet

1. On the ‘for_DB’ version of the spreadsheet, rename the existing ‘Sample’ column to ‘UMO_Sample”.
2. Insert 8 new columns before the UMO_Sample column: Soil_Data_ID, Unit_Code, Plot_Number, Sampling_Year, QA/QC, Layer, Date_SoilCollected, and Date_Dry, and provide the data corresponding to each sample using the crosswalk datasheet created when the samples were sent to the lab.
    a. ‘Soil_Data_ID’ will remain empty; it will be populated by the database.
    b. ‘QA/QC’ should be “Yes” or “No”, depending on whether the sample was collected during a QC visit.
    c. ‘Layer’ should be the horizon: “O”, “A”, or “10cm”.
    d. ‘Date_SoilCollected’ is the date the sample was collected.

   e. 'Date_Dry' is the date the sample was completely dry.

3. Review the data provided by UMO. Entries of "I.S." refer to samples where there was not enough soil available for the test. Delete "I.S." where it occurs to leave a blank cell.

4. In some cases, data are reported as "< N", where N is a numerical value. These entries are situations where the data are below the reporting limit of the analysis. In these cases, we use the reporting limit as the value for our analyses. We've never had data below the reporting limit for Ca, Mg, or MN. For the other columns (K, P, Al, Fe, Na, Zn, and acidity), do the following:

   a. Insert a new column next to the original column.

   b. Copy the column with data into the blank column.

   c. Rename the original column "X-Reported", where X is the nutrient name (e.g., "K" becomes "K-Reported")

   d. Rename the new column "X-Analysis", where X is the nutrient name (e.g., "K" becomes "K-Analysis")

   e. Highlight the data in the "Reported" column, right-click on the data, and select Format Cells. On the Number tab, choose the Text category and select OK.

   f. Scan the data in the "Analysis" column for "<" symbols, and delete them and the space after them wherever they occur in the column.

5. Save and close the spreadsheet.

Importing data into the database

1. Open the Forest Database (front-end).

2. Make sure the database is linked to the most recent backend (Switchboard → Admin → Link Databases).

3. From the Switchboard/Tools select Append Soil Data.

4. Follow the steps provided in the database tool.

   a. Step 1: Click 'Import' and browse to and select the Excel file with the soil data. NOTE: The workbook may have multiple sheets, but the data to be imported ***must*** be the first sheet. Click 'View' to verify that the import was successful (e.g. all records were imported, all data fields were populated). Soil_Data_ID field should be blank. It will be added in the next step.

   b. Step 2: Click 'Add ID Field' to populate the Soil_Data_ID field with data from the database (based on the unique combination of Unit_Code, Plot_Number, QA/QC, and

Date_SoilCollected). Click ‘View’ to verify that all records now have a Soil_Data_ID value. Take note of/remember the number of records in this file. It will help verify that all are appended in the next step.

c. Step 3: Click ‘Append’ to append the soil data from the temporary file to the tbl_Soil_Data_Lab table. Review the import results using the ‘View’ button. If the file was not formatted properly or there are duplicate records already in the database a error/notification message will appear. The main messages have been defined to help you trouble shoot what went wrong. Click the ‘Troubleshooting Errors’ button at the top of the form to review these. Any changes made to the data itself need to be clearly documented in the table’s ‘Notes’ field.

d. Step 4: Clean up the now redundant temporary file using the ‘Delete Temporary File’ button. Even if the append was aborted during an intermediate step, this button can be used to delete the temporary file.

Appendix S4.A. QA/QC steps quick-reference.

Data Collection	For each measurement, verbally verify its value with crew member before recording it. If raining, record data on paper datasheets to protect the computer.
Data Entry	Never overwrite or erase incorrect information; cross out erroneous data with a single line. After each site, verify with your initials that each form was completed in its entirety. At the end of each day, verify that completed forms exist for each site visited.
Track and Back-up Data	Daily: download and rename photopoint photos. Backup each database and photos onto provided external drives and store in a location separate from the field computer. Daily: update tracking forms for the plots that were sampled that day At the end of every week: post the latest backends of the database using Google Drive. At the end of every week: make a complete set of copies for all paper datasheets.
Merge Databases	Before the start of every week: protocol lead merges the two field backends to a master backend database, checks that week's data for issues and posts the newly merged backend to Google Drive. Before the start of every week: Forest crew leader copies new backend to field computers and links to the new backend in the front end.
Verify Data	A crew member will transcribe all paper records into the computer database. A different crew member will conduct a 100% review of all newly transcribed records. All corrections/remarks should be recorded on copies of the datasheets. Log of all post-field data corrections should be recorded on top of each paper datasheet. Protocol lead will conduct 10% review of all transcribed records. Verification steps will be repeated until Project Lead is satisfied with data quality.
Validate Data	Protocol lead will check data for data logic errors not prevented by database design.
Data Stewardship	After all verification and validation procedures are completed all paper datasheets will be delivered to the Network Data Manager and prepared for archiving. The electronic version of the data is used for all subsequent data activities.

Appendix S4.B. Example tracking form for plots in Weir Farm National Historic Site.

Weir Farm National Historic Site Forest Plot Tracking Form A

	Plot Data				
Plot	**Entry Type & Date** (Pap, DB, Part)	**Partial DB Data** Stand, Trees, ..., CWD	**Location** (TB-Thing #, Vehicle)	**Entered from Pap** Date/Initials/TB #	**Notes**
1					
2					
3					
4					
5					
	Pap=Paper datasheet **DB**= database **Part**=partially on Pap, partially in DB If **Part**, complete next column	Record tabs that were recorded partially on Pap, and partially in the DB	Record Toughbook # or if on paper, the vehicle where data are stored	Record date where data entered from datasheet to database, intials of enterer, and number of TB. Record a checkmark when data are checked.	Record notes such as missing or suspect data

Weir Farm National Historic Site Forest Plot Tracking Form B

	Photopoints			Unknown Plants	
Plot	**Camera**	**Date Downloaded**	**Backup** Date/Lacie #	**# Unknown Samples**	**Location** per sample
1					
2					
3					
4					
5					
	Record camera photos were taken with	Record date photos were downloaded from SD card	Record the date and Lacie drive photos were backed up		Record the vehicle samples are stored in, or Kate, or CB for Contract Botanist

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version	Date	Revised By	Changes	Justification
2.00	September 2006	Geri Tierney Brian Mitchell	Reorganized information Emphasized importance of careful data collection and management, now require only one photocopy of datasheets in addition to original, included note that database and datasheet should match as closely as possible.	
2.01	December 2006	Geri Tierney Brian Mitchell	Removed requirement that Forest database be periodically printed, included requirement that forest database be periodically uploaded to NETN during field season.	
2.02	April 2007	Geri Tierney	Minor editorial changes	
2.03	November 2007	Geri Tierney Kate Miller Brian Mitchell	Clarified requirement that crew should upload database weekly, added that NETN staff check database for errors early in the season, added that field QA/QC should occur as close to the original sample date as possible.	
2.04	December 2007	Geri Tierney Kate Miller Brian Mitchell	Changed Data Verification and Integrity to Data Verification and Quality, removed NPS ftp site user name and password.	
2.5	May 2008	Kate Miller Brian Mitchell Jim Comiskey	Revised to serve as joint MIDN/NETN protocol.	
2.06	November 2008	Adam Kozlowski Kate Miller	Clarified the verification and validation procedures and who has the responsibility to implement them, added that data entry and error checking dates and initials should be written on datasheet, added that any modifications or remarks written on paper datasheets should be written in a different colored pencil, and indicated in the verification log found on the top of each datasheet, added Appendix I to summarize QAQC steps.	
2.07	December 2008	Kate Miller Adam Kozlowski	Clarified that prior to finishing data entry for a plot, the data technician must record their initials to indicate that they checked over each form in the database to ensure complete and accurate data, added an example of a potential logic error in data entry that may not be picked up by validations built into the database, added a transcription error rate at the 10% level that will require another 100% check.	
2.08	April 2008	Kate Miller	Minor editorial changes.	
2.09	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.

Revision History Log (continued)

Version	Date	Revised By	Changes	Justification
2.10	December 2009	Kate Miller Andrew Vincello Brian Mitchell	Minor editorial changes. Clarified appropriate staff combinations for field QA/QC sampling.	
2.11	January 2013	Kate Miller Adam Kozlowski	Clarified roles of QA/QC team and rules on order of sampling. Added procedures for importing soil data from lab into the database.	
2.12	March 2014	Kate Miller	Added information about the merge tool, including considerations for QA/QC. Clarified schedule of data management duties and provided an example of a tracking form.	Revision to match updated procedures.
2.13	December 2015	Kate Miller	Added the responsibility to photograph or scan datasheets at the end of each field day.	
2.14	January 2020	Camilla Seirup	Changed SOP number	

SOP 5 - Site Selection, Plot Establishment and Remeasurement

Mid-Atlantic Network/Northeast Temperate Network

Version 3.11

Overview

This SOP provides instruction for establishing plots, resampling plots and collecting site information. Prior to the field season, plot locations will be selected using GIS and the GRTS sampling algorithm to provide a random, spatially balanced sample. Locations which present a safety hazard or do not fall within forest, woodland or plantation will be discarded. Figure S5.1 is the plot layout for parks in the Northeast Temperate Network (NETN), and Figure S5.2 illustrates Mid-Atlantic Network (MIDN) plot layout.

It is important for NETN and MIDN to ensure that plot marking procedures have been approved by the natural resource manager at each park prior to plot establishment. These procedures may vary by park in response to individual park requirements.

Definitions

Horizontal distance is the straight line distance between two objects. This contrasts with slope distance which is measured parallel to the ground. Slope distance and horizontal distance are equivalent on flat land. On sloped land, the horizontal distance between two objects is less than the slope distance.

True north is the direction of the North Pole relative to your position. This contrasts with magnetic north, which varies across the landscape and over time as the direction towards which your compass needle points when you are in the northern hemisphere. To find true north, use a magnetic declination chart or table to find the correct declination between true north and magnetic north for your position at the time you wish to navigate (such as at http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp). Then, adjust your compass by dialing this declination into the faceplate. All azimuths referred to herein are based on true north. For 2011, use the following degrees west declination for NETN parks: 17 at Acadia NP (ACAD); 15 at Minute Man NHP (MIMA) and Saint-Gaudens NHS (SAGA); 14 at Marsh-Billings-Rockefeller NHP (MABI), and Saratoga NHP (SARA); 13 at Morristown NHP (MORR), Roosevelt-Vanderbilt NHS (ROVA), and Weir Farm NHS (WEFA). For 2009, use the following degrees west declination for the MIDN parks: 13 at Valley Forge NHP (VAFO); 12 at Hopewell Furnace NHS (HOFU); 11 at Eisenhower NHS (EISE), Fredericksburg and Spotsylvania County Battlefields Memorial NMP (FRSP), Gettysburg NMP (GETT) and Richmond NBP (RICH); 10 at Appomattox Court House NHP (APCO) and Petersburg NB (PETE); and 8 at Booker T. Washington NM (BOWA).

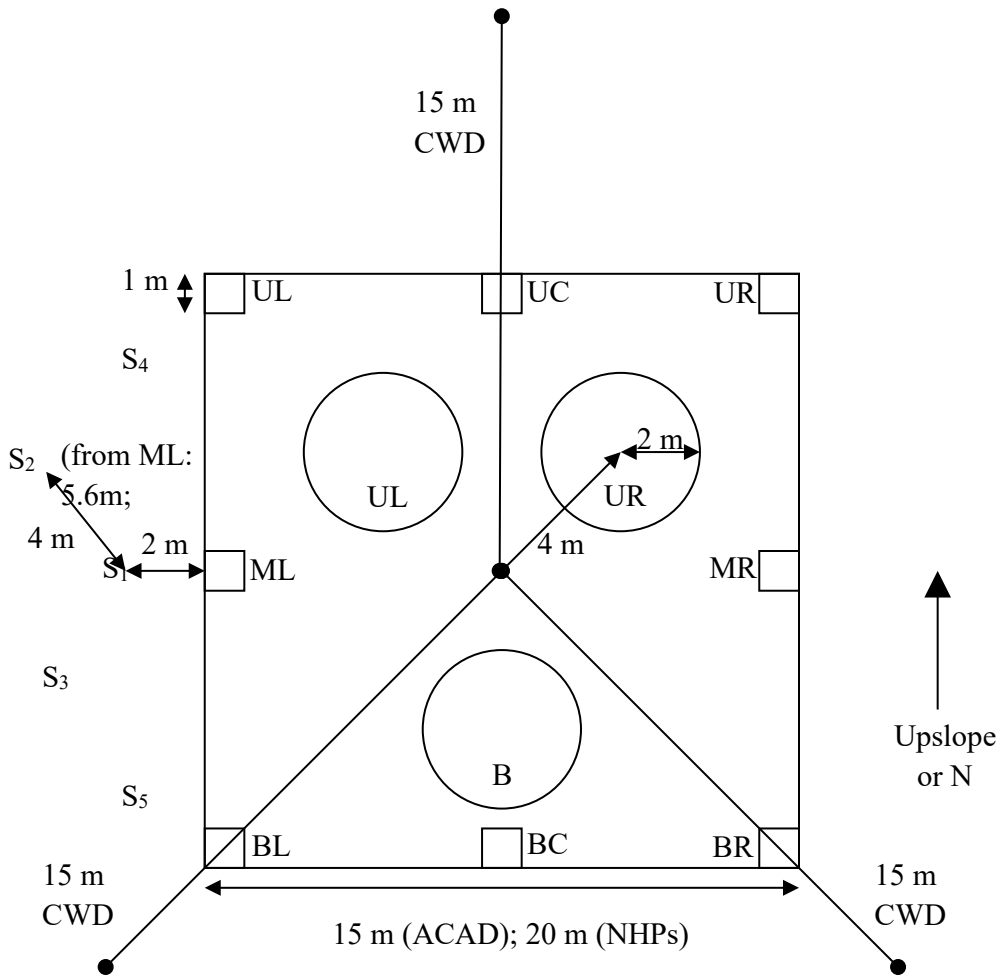


Figure S5.1. NETN plot layout showing square tree plot with three nested 2-m radius regeneration microplots, eight 1-m^2 vegetation quadrats, and three 15-m CWD transects. S_x is location of soil sample.

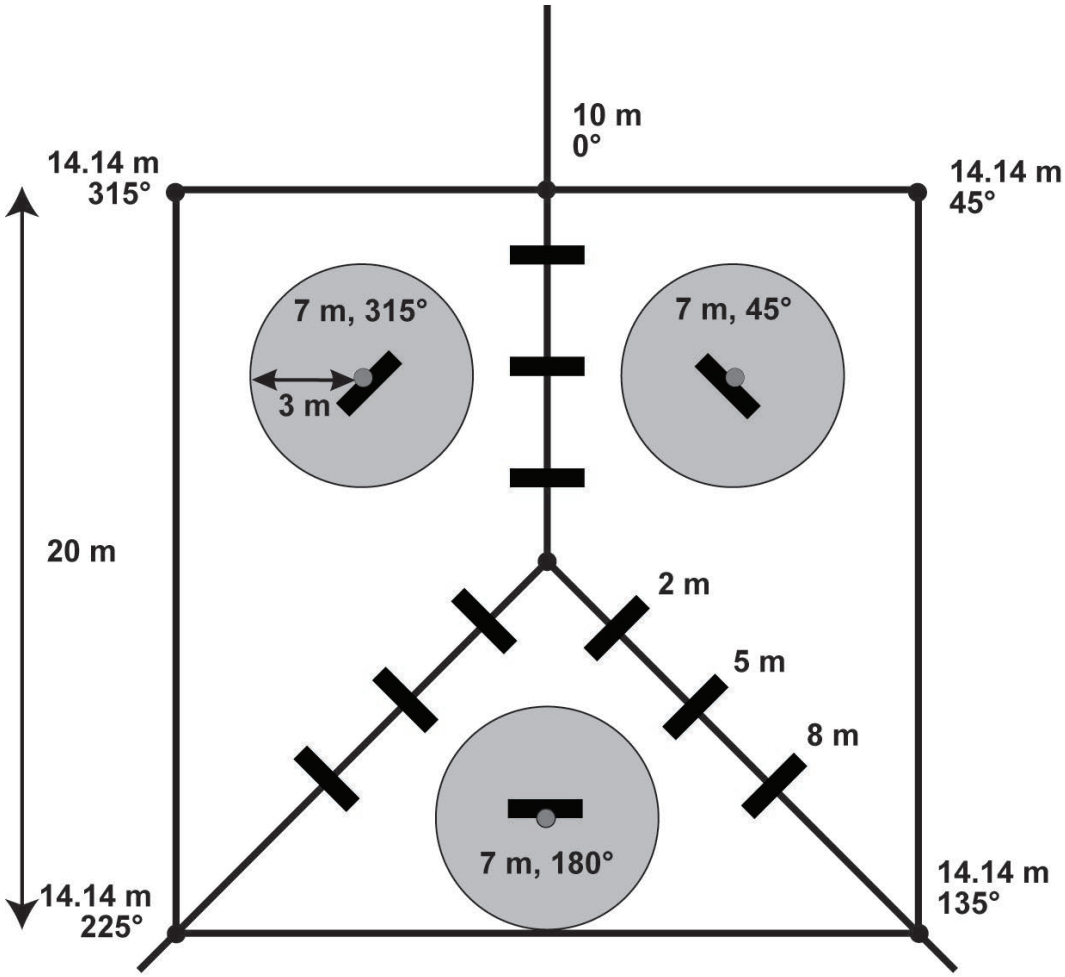


Figure S5.2. The MIDN plot layout showing square tree plot with three nested 3-m radius microplots, 12 one-m^2 vegetation quadrats, and three 15-m coarse woody debris (CWD) transects.

Plot size will be 15 x 15 m square plots at ACAD, and 20 x 20 m square plots at all the national historic sites and parks (NHPs) including all MIDN parks.

Procedure

Plot Establishment

Examine park topographic maps to determine the best route to preselected plot locations. Using GPS and compass, travel to a proposed plot location. The GPS and compass should be held sufficiently far apart to avoid the GPS influencing the compass needle. Do not take safety risks when traveling to plots—if off-trail topography becomes too steep or difficult, find an easier route to the plot location. If a safe route does not exist, discard the location and record the reason for doing so.

As you near the pre-selected location, use the following protocol to locate the plot—do not spend time trying to find the exact pre-selection location. As soon as the GPS indicates you are within 15 m of the pre-selected location, continue exactly 10 steady paces (20 steps) in the direction of the pre-selected location and stop. Do not veer off course to avoid obstacles. This is the location of the center of the plot.

Upon arrival at this plot location, visually examine the location to ensure it is primarily forested, succeeding to forest, a plantation or a woodland, and that plot center is ≥ 15 m from the park boundary, a road, a carriage road, a perennial stream, a water body, a mowed area, or any obstacle that would interfere with plot establishment. Taking care to examine the plot location will ensure that no part of the plot will fall outside the park boundary, and also that roads, carriage roads and water bodies will not fall within the plot. Abundant poison ivy, dense brambles, and location near or along a hiking trail are not appropriate reasons for excluding a plot. Plots should not be located on top of earthworks in cultural parks if the plot establishment and measurement disturb these cultural resources. In no instance should permanent markers, such as rebar, be installed in an earthwork. To qualify as woodland (ACAD only), the plot must have at least 25% tree canopy cover. Trees need not be 10 cm DBH to qualify as part of the tree canopy—smaller or stunted trees can contribute to this threshold. Early successional areas (NHPs only) that are succeeding to forest due to a change in land management should be measured regardless of canopy cover, as long as tree reproduction is evident or expected at the site. If unsure whether this is so, consult a supervisor. If the site is a forested wetland with standing water covering much or all of the plot, do not discard the site. Where feasible, postpone installation and measurement, and note that the plot should be revisited later in the season when water has receded. If the field schedule doesn't allow for postponing plot measurement, then sample the plot and take extra care not to trample the plot. If the plot does not meet the criteria listed herein, or if the plot presents a safety hazard such as extremely steep slopes (i.e., > 30 degree/ 60% slope) or unstable snags, discard the plot and record the reason in the forest database. Proceed to add the next backup location to the list of plot locations for establishment. Then proceed to the next nearest pre-selected location currently included in the annual sample.

For MIDN parks, plots may be moved if the initial location is not suitable. Temporarily mark the current plot center, and using the compass and rangefinder move 20 m north of the initial plot location and evaluate whether the new location meets the criteria outlined above. If this location is not suitable, return to the initial plot location and repeat the relocation process, this time moving east, then south, and finally west. If after checking each new location in all four cardinal directions it is determined that all points are unsuitable, then the site is discarded and the crew should proceed to the next backup location as outlined above.

If the plot meets all criteria listed above, set the GPS to average readings for a waypoint, and allow it to collect readings at plot center while the plot is being established (see SOP 2 - Using the Global Positioning System (GPS) for more detailed instructions). Install permanent markers as follows to establish the plot. The plot layout is shown above (Figure S5.1 for NETN, Figure S5.2 for MIDN). For NETN, install a #2 rebar stake with pre-marked survey cap at your current position—plot center. In ACAD attach a plastic research tag with the study number (#82) clearly written with permanent marker. For MIDN, a #6 rebar stake with pre-marked survey cap is installed.

If the plot center location is on a rock, an intermittent streambed, or some other obstacle, look for a suitable location to secure the rebar stake within a 1-m radius of the current position. If no suitable location exists within a 1-m radius, expand the search to a 2-m radius. If no suitable location exists within a 2-m radius, return to the original position, and select a witness tree near plot center and record the tree number. Plot tags should be attached to the witness tree using a stainless steel nail at

ACAD, MORR, and SAGA and aluminum nails in MABI, MIMA, ROVA, SARA and WEFA; for MIDN the tag is attached using aluminum nails.

To find the plot corners, determine and record the upslope azimuth from your current position. When determining upslope azimuth, consider the slope at the scale of the plot. If the plot is in a flat location (i.e., ≤3 degrees or 5%), the first marker will be oriented toward true north. Measure the upslope azimuth using the TruPulse) and record this as the orientation of the plot If the plot orientation is not true North, then use the plot map in the database to determine the azimuths of the corners and midpoints for the rest of the plot.

For NETN parks, use the TruPulse to measure ½ the **horizontal distance** of a plot side (7.5 m at ACAD, 10 m at NHPs) along the upslope azimuth (Figure S5.3, step 1). This is the mid-point of the upper plot boundary—insert a fiberglass stake and record the up slope angle (VA). Along the same azimuth, locate the end point of the UC Coarse Woody Debris transect (15 m **slope distance** from plot center), place a survey flag at this point, and measure the slope angle (VA). Rotate the TruPulse in a clockwise direction, taking readings until the compass registers 45° past the plot orientation. Measure a **slope distance** of 4 m to mark the location of the UR microplot (Figure S5.3, step 2). Install a fiberglass stake. Using the same azimuth, measure a **horizontal distance** of 10.61 m (ACAD) or 14.14 m (NHPs) and install a bent rebar stake (Figure S5.3, step 3). Rotate the TruPulse in a clockwise direction, taking readings until the encoder registers 90° past the plot orientation, and measure a distance of 7.5 m (ACAD) or 10 m (NHPs), and install a fiberglass stake. Continue with steps five through 11 to install all corner, midpoint and microplot markers. Mark end points for CWD transects (lines 5 and 8) with survey flags, and record slope angle (VA) for each transect. Also record the down slope angle (VA) in step 7. Distances should be measured to within 10 cm error, and bearings and vertical angles should be sighted to within 1 degree error. Note that plots established prior to 2012 in NETN were marked entirely with fiberglass stakes, and between 2008 and 2010 in MIDN, all but plot center were marked with fiberglass stakes. Starting in 2012 in NETN, plot corners should be marked with #3 rebar that have a 90 degree bend on the top. Plot centers should be marked with #4 rebar with a pre-installed marked survey cap. In MIDN, all plot corners and microplot centers should be marked with #3 rebar that have a 90 degree bend on top.

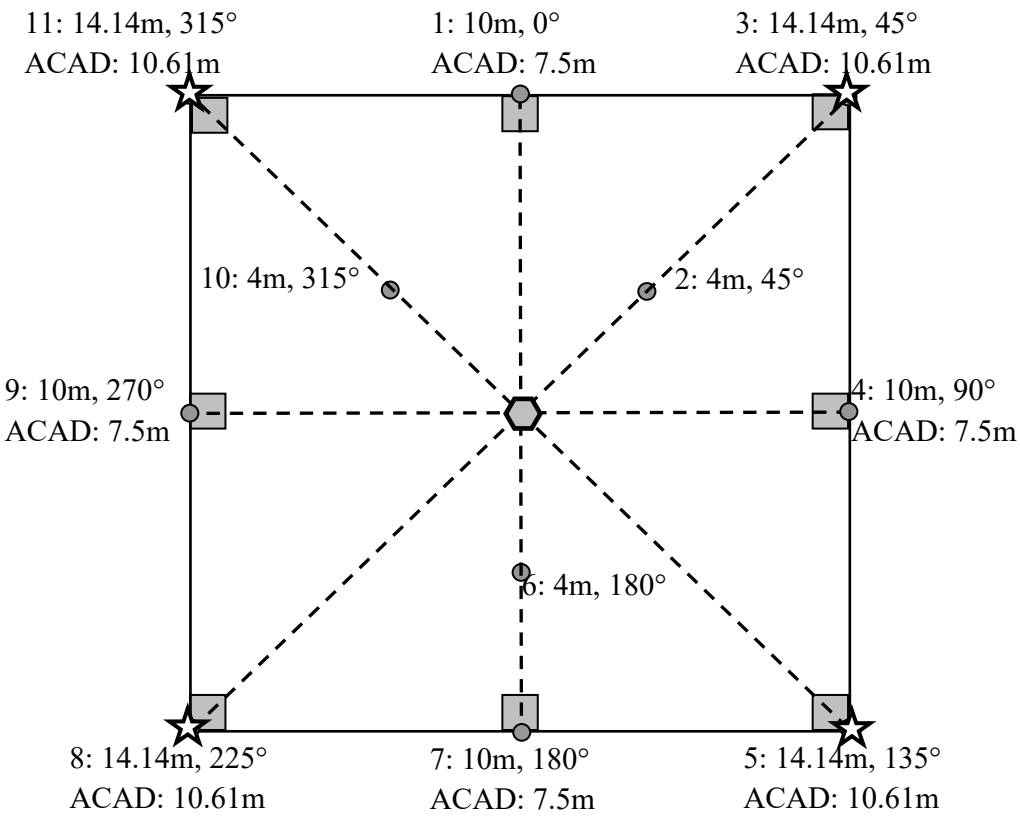


Figure S5.3. Sequential steps in setting up a forest vegetation monitoring plot in NETN parks. Step number is followed by the distance and azimuth for NHPs in NETN. Distances for ACAD are shown on the second line. Distance measurements are in a horizontal plane, except that steps 2, 6, and 10 are 4 meters slope distance. Bent rebar stakes are installed at plot corners (☆). A rebar stake with a pre-marked survey cap is installed as plot center (⬡). Plot midpoints and microplot centers are each marked with a fiberglass stake (●). Azimuths are relative to the orientation of the plot.

For MIDN parks, use the TruPulse to measure ½ the **horizontal distance** of a plot side (10 m at all parks) along the upslope azimuth (Figure S5.4, step 1). This is the mid-point of the upper plot boundary—insert a bent rebar stake and record the upslope angle (VA). Along the same azimuth, locate the end point of the UC Coarse Woody Debris transect (15 m **slope distance** from plot center), place a survey flag at this point, and measure the slope angle (VA). Rotate the TruPulse in a clockwise direction, taking readings until the TruPulse compass registers 45° past the plot orientation. Measure a **horizontal distance** of 7 m to mark the location of the microplot (Figure S5.4, step 2). Install a bent rebar stake. Using the same azimuth, measure a **horizontal distance** of 14.14 m and install a bent rebar stake (Figure S5.4, step 3). Rotate the TruPulse in a clockwise direction, taking readings until the compass registers 135° past the plot orientation and measure a distance of 14.14 m and install a bent rebar stake (Figure S5.4, step 4). Continue with steps 5 through 9 to install all corner and microplot markers. Mark end points for CWD transects (lines 4 and 7) with survey flags, and record slope angle (VA) for each transect. Also record the down slope angle (VA) in step 6. Distances should be measured to within 10 cm error, and bearings should be sighted to within 1 degree error.

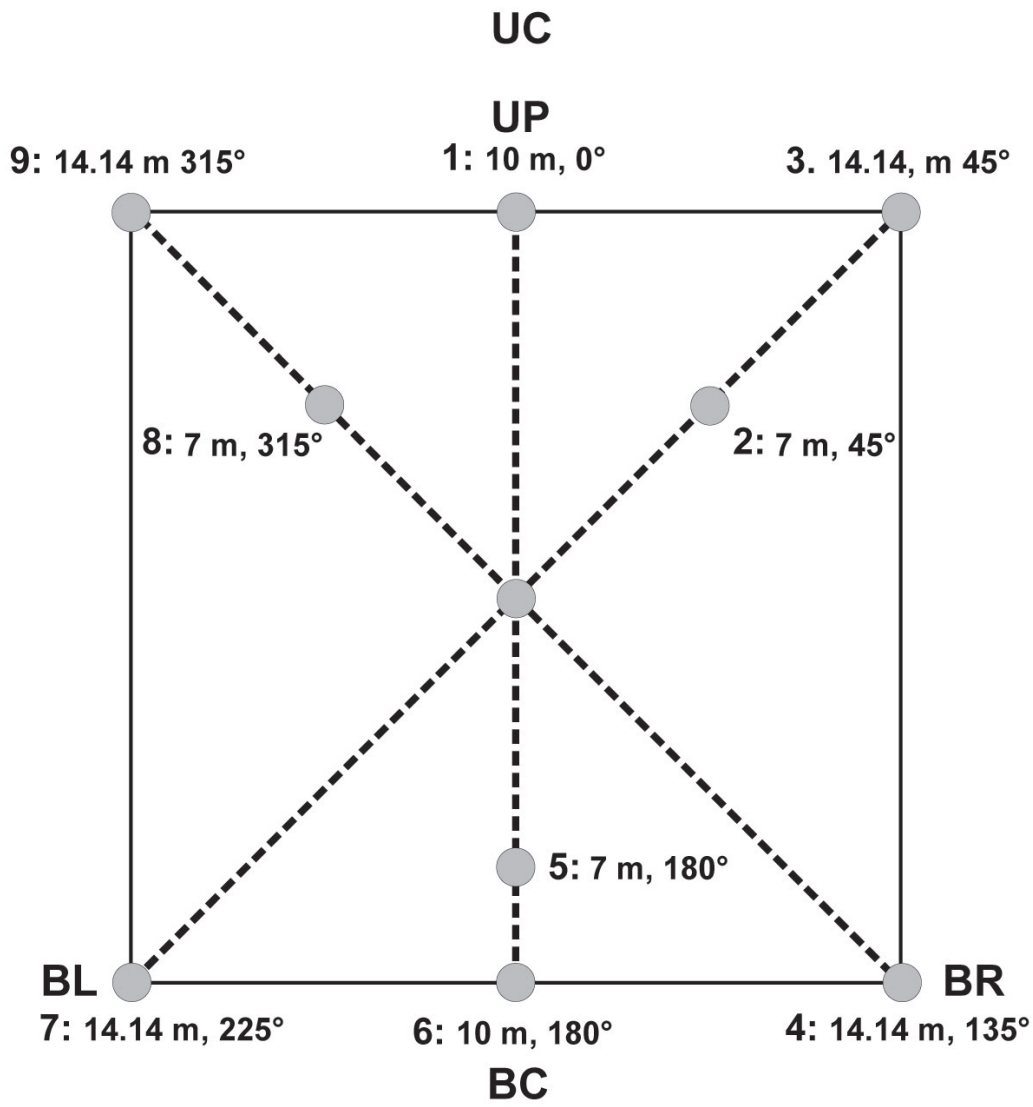


Figure S5.4. Sequential steps in setting up a forest vegetation monitoring plot in MIDN parks. Step number is followed by the distance and azimuth for all parks in MIDN. Distance measurements are in a horizontal plane. Azimuths are relative to the orientation of the plot.

If a TruPulse is not available or not operating correctly, the same steps can be followed using a surveyor's compass or forester's compass (i.e., a compass with a mirror for sighting and an adjustable declination), and a Sonin electronic distance measurer or measuring tape. **When sighting compass bearing, crew members must take care that metal objects such as survey flags do not affect the compass needle.**

Metal survey flags should not be carried by the crew member sighting the compass during plot setup. To **measure horizontal distance**, hold the measuring tape horizontally level rather than parallel to the slope, using a plumb bob if necessary. On slopes, this will result in the upslope tape end held low to the ground while the downslope end is held high. On steep slopes, it will be necessary to measure the horizontal distance in sequential short increments that can be held level.

Install rebar stakes flush to the ground. Install fiberglass stakes half-way into the ground unless the plot is visible from a major trail or visitor location in any park—in this case sink stakes more deeply with only 5 cm extending above ground. Use a mallet to ensure the stake is inserted firmly in the ground. Where soil is shallow to bedrock it may be necessary to use a shorter stake. If shallow soils or exposed bedrock prevent installation of some stakes, note which stakes were omitted, and select a witness tree to aid in relocating the plot corner/midpoint. For each witness tree, record species and DBH along with the bearing and horizontal distance from the tree to the plot corner/midpoint. The crew should temporarily mark stakes with bright-colored survey flags to make them more visible during measurement. It is important that these flags be collected and removed from the site after measurement.

In early successional plots within NHPs stakes will be hard to relocate so **additional plot marking** will be used if permission can be obtained from the natural resource manager at the given park. In this case, use flagging and paint as needed.

Plot Remeasurement

Read the directions and plot notes that were recorded during the original and all subsequent sampling events. Use the notes and field maps to find the safest and most efficient route to the plot.

Once at the plot, use the TruPulse to locate plot corners, midpoints, and microplot centers. In NETN install bent #3 rebar stakes in plot corners, and #4 rebar stake with pre-printed survey cap at plot center. If microplot or midpoint stakes are missing, replace them with fiberglass stakes. In MIDN, install #3 bent rebar stakes at every plot marker location. Use the TruPulse to reestablish any missing stakes, and record this in the notes. If a plot has been vandalized and/or multiple markers have been removed, reestablish the site using the TruPulse. If at all possible, find plot center and set up the plot from that point using the azimuth recorded from the original plot establishment. If plot center cannot be located, use existing plot markers to recreate plot center, and reestablish the plot from this point. If plot center can't be relocated or recreated, reestablish plot center following the same procedures as described in the plot establishment section (i.e., navigate with GPS and walk 10 paces to plot center when within 15m). In this case the plot number must be changed in the database (keep the same GRTS number) to reflect that this is essentially a new plot. Be sure to record thorough notes in all of these situations so future sampling and analyses can account for these issues. If possible, position tree tags and plot markers so they are facing away from a road or opening and are less conspicuous.

Once plots have been established, we will continue to monitor them in most situations, even if they do not meet the original guidelines for plot establishment. There are some rare cases that would lead to a plot being abandoned, based on the plot no longer fitting within the target population for monitoring. Plots will be abandoned if there is a change in park management that has resulted in permanent conversion of forest to open, non-forest habitat (e.g., open field, parking area) within the plot. Note that forestry activities (e.g., harvesting or even clear-cutting at MABI or GETT) are not a permanent conversion, nor is a one-time impingement of mowing into the plot. If a plot has been partially mowed or otherwise affected for two or more sampling events, contact the park resource manager to determine if there has been a permanent change in management for the location. If crew

is unsure of whether a disturbance is significant enough, or if it is permanent, they should contact their supervisor before deciding to abandon a plot.

Note: NETN plots in panel 1 and panel 2 were established manually with measuring tapes and compasses, and are likely to be less accurate (especially on steep slopes) than plots setup with the TruPulse. From 2016 on, only stakes that are off by >1m and/or >4 degrees (based on TruPulse), should be moved to the correct location. Before moving the stake, check notes from the previous survey to see if for some reason the stake was offset. Record stakes that are moved in the notes. Be sure to record all trees that were affected by adjustment of the plot boundary in the notes.

Once data collection is complete and before leaving the plot, the crew must perform several checks between the previous sampling event and the current sampling event. Crew must visually check all plot level data to ensure accuracy, and run the database check on tree, sapling and stand level data. If inconsistencies between the previous sampling event and current event are detected in the check, the crew must verify that the data collected in the current sampling event are correct, and record the inconsistency in the notes. Crew must NOT write over any data collected during previous sampling events.

Data Collection

Park

Record 4-letter park code (ACAD, MABI, MIMA, MORR, ROVA, VAMA, SAGA, SARA, or WEFA).

Plot Number

Record the plot identification number, unique within each park (unique for all MIDN plots).

GRTS Number

Record the GRTS order number.

UTMN

Record the GPS North Universal Transverse Mercator value of the plot center.

UTME

Record the GPS East Universal Transverse Mercator value of the plot center.

Accuracy

Record the positional accuracy of the UTMN and UTME coordinates, as determined by GPS.

Brief Description

Record a brief description of the plot cover and important geographic features. For example, early successional forest with high shrub cover or spruce/fir forest with rocky outcrops.

Slope

Record slope across plot to the nearest degree, using the TruPulse. During plot setup, record upslope in degrees (VA on the TruPulse) during step 1, and downslope in degrees (VA) during step 7 (NETN) or step 6 (MIDN). Observer 1 (with the TruPulse) should take care to sight on Observer 2 (with reflector) at the same height above ground as the TruPulse height.

Orientation

Record the orientation as the upslope (>2.86 degrees, or 5%) azimuth from plot center to UC to the nearest degree. True North will be used when a slope <2.86 degrees is detected.

Aspect

Record aspect in the general area of the plot (approximately 100-m radius) to the nearest 5°. Aspect is determined along the direction of slope for land surfaces with at least 5% (2.86 degrees) slope in a generally uniform direction. If slope is less than 5% (2.86 degrees), record 0 to signify no aspect. Aspect is measured downslope using a compass.

Physiographic Class

Record the physiographic class that best describes the plot area in terms of land form, topographic position and soil, using the codes below. **Xeric codes (11-19)** are for sites that are normally low or deficient in moisture available to support vigorous tree growth. These areas may receive adequate precipitation, but experience a rapid loss of available moisture due to runoff, percolation, evaporation, etc. **Mesic codes (21-29)** are for sites that have moderate but adequate moisture available to support vigorous tree growth except for periods of extended drought. These sites may be subjected to occasional flooding during periods of heavy or extended precipitation. **Hydric codes (31-39)** are for sites that generally have a year-round abundance or over-abundance of moisture. Hydric sites are very wet sites where excess water seriously limits both growth and species occurrence.

11 Dry Tops—Ridge tops with thin rock outcrops and considerable exposure to sun and wind.

12 Dry Slopes—Slopes with thin rock outcrops and considerable exposure to sun and wind. Includes most steep slopes with a southern or western exposure.

19 Other Xeric—All dry physiographic sites not already described

21 Flatwoods—Flat or fairly level sites outside flood plains. Excludes deep sands and wet, swampy sites.

22 Rolling Uplands—Hills and gently rolling, undulating terrain and associated small streams. Excludes deep sands, all hydric sites, and streams with associated flood plains.

23 Moist Slopes and Coves—Moist slopes and coves with relatively deep, fertile soils. Often these sites have a northern or eastern exposure and are partially shielded from wind and sun. Includes moist mountain tops and saddles.

26 Flood plains/Bottomlands—Flood plains and bottomlands along rivers and streams. These sites are normally well drained but are subjected to occasional flooding during periods of heavy or extended precipitation. This category includes associated levees, benches, and terraces, but excludes swamps, sloughs, and bogs with year-round water problems.

29 Other Mesic—All moderately moist physiographic sites not already described.

31 Swamps/Bogs—Low, wet, flat forested areas usually quite extensive that are flooded for long periods of time except during periods of extreme drought.

32 Small Drains—Narrow, stream-like, wet strands of forest land often without a well-defined stream channel. These areas are poorly drained or flooded throughout most of the year and drain the adjacent higher ground.

39 Other hydric—All other hydric physiographic sites.

Directions

Record directions for driving and walking to the plot, including landmarks, distances, and bearings. Include parking recommendations where applicable.

Plot Notes

Record any unusual plot features or problems encountered during plot setup, including the reason for discarding any pre-selected plot locations. Note any problem or irregularities inserting plot markers. Note any features which indicate plot history, including evidence of past agricultural, silvicultural or recreational use regardless of how long ago it may have been.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
2.00	June 2006	Geri Tierney Brian Mitchell	Switched to GRTS sampling. Plot shape changed from circular to square. New plot size at ACAD, and larger at NHP. Changed decision rule for plot inclusion to prevent exclusion of woodlands. Plot layout based on true north, rather than magnetic north. Procedure included for pacing final steps to pre-selected plot location.	
2.01	September 2006	Geri Tierney Brian Mitchell	Clarified upslope determination should be at the scale of the plot. Now marking all edge midpoints with stakes. Included additional marking for early successional stands at NHP. Reinserted plot aspect measurement. Now record evidence of plot history in Plot Notes. Clarified and improved rule specifying minimum distance of plot to obstacle. Taller stakes now used at all corner, midpoint and other locations unless soil is shallow.	

Revision History Log (continued)

Version #	Date	Revised by	Changes	Justification
2.02	December 2006	Geri Tierney Brian Mitchell	Included acceptable error for plot establishment. Added additional guidance for finding plot center if ground is obstructed. Now record GPS accuracy.	
2.03	April 2007	Geri Tierney Kate Miller Brian Mitchell	Minor edit to rule for identifying obstacles within 15 m of proposed plot location. Added two additional regen microplots.	
2.04	November 2007	Geri Tierney Kate Miller Brian Mitchell	Added need to enter rejected plots into database. Changed procedure for locating plot center when stake can't be secured. Crew to attach research plot tags (study #82) in ACAD. Corrected error distance to 1m instead of 0.1 m. Included use of witness tree if fiberglass stake can't be secured at plot corner or midpoint. Added brief description of plot. Replaced Terrain position with Physiographic class.	
3.01	November 2008	Geri Tierney Kate Miller Jim Comiskey Brian Mitchell	Updated declination website. Changed rebar to fiberglass for 7 or 8 plot markers in MIDN plots.	
3.02	December 2008	Geri Tierney Kate Miller Jim Comiskey Brian Mitchell	Added that abundant poison ivy, dense brambles, and location near or along a hiking trail are not appropriate reasons for excluding a plot. Added the process for establishing 2 witness trees in NETN plots. Changed “rangefinder” to LAR. Minor editorial changes.	To aid in future relocation of plot center. To be consistent with Using the Laser Rangefinder SOP terminology.
3.03	April 2009	Kate Miller	Clarified that compasses used for plot establishment must have an adjustable declination and sighting mirror.	
3.04	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.

Revision History Log (continued)

Version #	Date	Revised by	Changes	Justification
3.05	December 2009	Kate Miller Andrew Vincello Brian Mitchell Jim Comiskey	Changed witness trees to only require a check box in trees form Added resampling section Changed SOP to allow plots with temporary standing water to be sampled. Minor editorial changes. Modifications to MIDN plot setup to include slope measurements	
3.06	October 2010	Kate Miller Jesse Wheeler	Clarified that once plots are established, we do not exclude them, unless a portion has been converted to open habitat by park management Changed plot tags to be attached using nails, when a stake at plot center won't work. Changed SOP name to Site Selection, Plot Establishment and Remeasurement Added that if plot center is missing crew should try to recreate plot center from existing plot markers. If this won't work, then crews should reestablish plot using GPS waypoint and 10 paces. Minor editorial changes	
3.07	March 2012	Kate Miller	Revised plot marking directions to use rebar instead of fiberglass stakes.	
3.08	March 2014	Kate Miller	Revised SOP to reflect replacement of LaserAce Rangefinder with TruPulse. Removed need to select and mark two witness trees in NETN plots	Change of equipment. Witness trees not needed when all trees are mapped.
3.09	November 2015	Jesse Wheeler	Revised tolerance level for plot boundary markers to no greater than 1m and or 4 degrees off based on the TruPulse	
3.10	December 2016	Camilla Seirup	Removed mention of witness trees.	
3.11	January 2020	Camilla Seirup	Changed SOP number	

SOP 6 - Photopoint

Mid-Atlantic Network/Northeast Temperate Network

Version 2.07

Overview

This SOP documents the procedure for photographing plots. Photographs will be archived and used as visual reference for change in appearance of plots over time. Photographs should be taken shortly after plot setup in order to visually record the plot before significant field crew impacts occur.

Data Collection

Six scenes and the plot tag or marker are photographed at each plot—the first five scenes document the plot overall and the last is a close-up of the microplot in the upper right portion of the plot (UR). The first scene is photographed from plot center, facing the top of the plot and holding the camera vertically (portrait). For the rest of the scenes, hold the camera in a horizontal orientation (landscape). Continue standing at plot center, and rotate clockwise, photographing each of the corners of the plot in turn. The final scene is a close-up of the UR microplot ground cover, taken from a position standing over that microplot. After the scenes are photographed, a final picture is taken of the plot tag or survey marker using the macro (picture of a flower) photo function, clearly showing the plot number.

For every scene, the flag marking the stake of interest should be in the center of view. Photopoints should be taken while the crew members are setting up the plot. If the stake is not visible for the photo, a crew member should stand directly behind the stake with a reflector card or flag over the stake to help orient the photo.

Capture one digital photograph of each scene. Do not zoom-in on the scene. Allow the camera to automatically select the appropriate aperture for the given light conditions. Allow the camera to use flash if necessary for the microplot close-up, but do not use a flash for the overall plot scenes. Photos should be 24-bit color photographs, taken at the highest resolution available on the network camera (at least 1024 x 768 pixels). Photos should be compressed using the high-quality JPEG compression setting on the camera. If photos are accidentally taken in wrong order, are out of focus, taken with the flash on, etc., it is only acceptable to delete the flawed photos and start again if all photopoints from previous plots have already been downloaded and named. Otherwise, take a photo (e.g., photo with lens cap on, blank sheet of paper, back of hand, etc.) that makes it clear the photo sequence will start over after that photo.

In remeasured plots, field crew should examine photographs from previous visits and attempt to recreate the position and angle used.

Note: Only one plot level photo was taken from NETN plots in 2006 and 2007, and it was taken outside of the plot at ML facing plot center. Photopoints for these plots should be relocated using the

procedures described in SOP 7 – Photopoint. The regeneration photopoint location and procedures have not changed.

Camera

Use a designated network digital camera for all pictures. Record the brand and model number of this camera.

Photographer

Record the initials of the photographer.

Weather

Record the presence of sun, clouds, rain or fog.

Data Management

After field work is complete for the day, download the photos to the laptop plot photograph directory. View the photos, and rename the photos using the following format:

Four character park code + 3-digit plot code + Scene (UC, UR, BR, BL, UL, RN = Regeneration, ID = ID photo) + Date (YYYYMMDD), with each element separated by an underscore (_). So the UR photo at MABI plot 15, taken June 18, 2008 would be "MABI_015_UR_20080618.jpg".

Use the Bulk Rename Utility to ensure consistency in file names using the steps below (Figure S6.1). This utility can be downloaded from http://www.bulkrenameutility.co.uk/Main_Intro.php

1. Navigate to the folder containing the files you wish to rename
2. Select the file(s) you wish to rename (SHIFT or CTRL + click to select more than one).
3. Set Filename to 'Remove'.
4. Add the 4 letter park code, underscore separator, and 3 digit plot number code (e.g., ACAD_081)
5. Add an Auto Date
    a. Mode = Suffix
    b. Type = Taken (Original)
    c. Fmt = Custom
    d. Custom = %Y%m%d (Note the capital and lower case letters)
6. Add Numbering
    a. Mode = Insert
    b. Start = 1

   c. Pad = 2
   d. at = 8
   e. Incr. = 1
   f. Sep = _

7. Check that the photo names in the New Name Column are correct
8. Click the ‘Rename’ button
9. Open up Bulk_Rename_Utility_Step_2.bru with the following settings (Figure S6.2)
10. Navigate to the folder containing the files you wish to rename
11. Select the file(s) you wish to rename (SHIFT or CTRL + click to select more than one).
12. Set Filename to ‘Keep’.

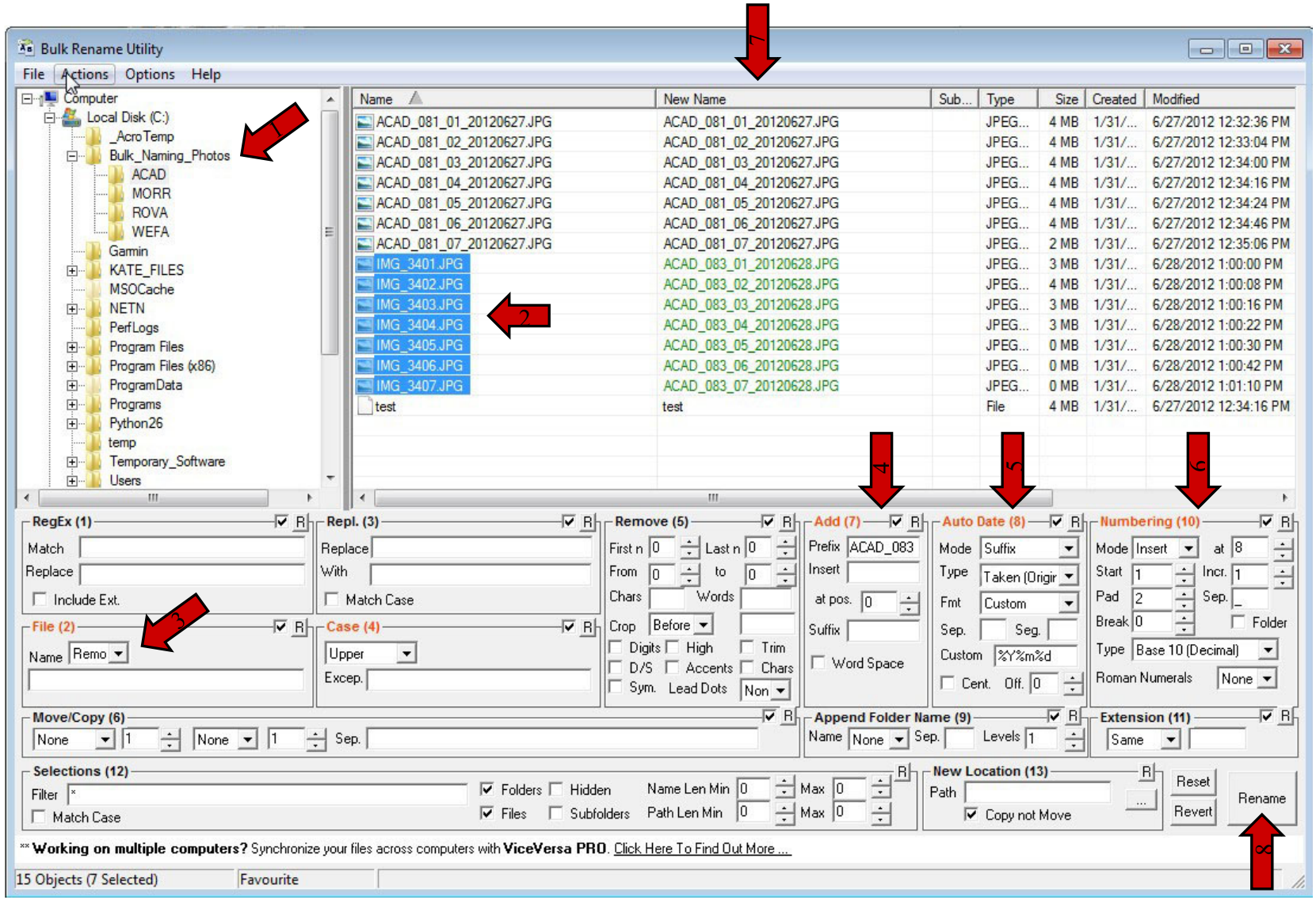


Figure S6.1. Bulk File Rename Utility screen

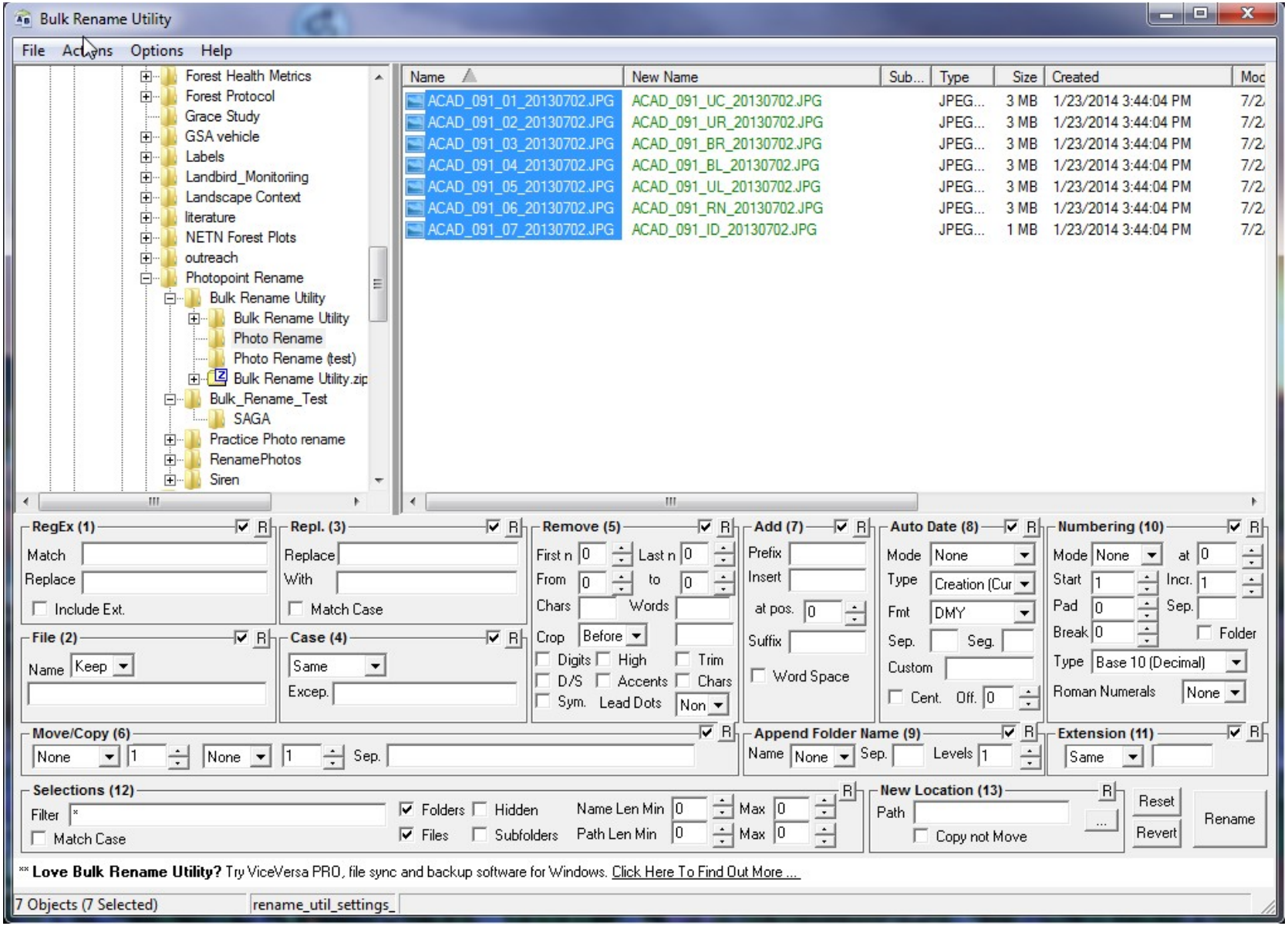


Figure S6.2. Bulk File Rename Utility screen.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.01	June 2006	Geri Tierney and Brian Mitchell	Added instructions not to zoom camera.	
1.02	September 2006	Geri Tierney and Brian Mitchell	Added instructions to use camera date stamp if available.	
1.03	December 2006	Geri Tierney and Brian Mitchell	Plot photograph should be taken from 2 m beyond the plot edge.	
1.04	April 2007	Geri Tierney, Kate Miller, and Brian Mitchell	Specified that the regeneration (regen) photo is taken in the UR regen microplot.	
1.05	November 2007	Geri Tierney, Kate Miller, and Brian Mitchell	Clarified instructions for ID card.	
2.00	May 2008		Changed to MIDN methods to produce joint SOP. No need to record date and time of photograph, since this is recorded elsewhere. Record photographer's initials. Added rain to weather conditions. Added data management section with file naming conventions. No ID card or date/time stamp.	Instead of one overall scene per plot (from left or upper left of the plot), five photos are taken from the plot center.
2.01	November 2008	Geri Tierney, Kate Miller, and Brian Mitchell	Only one photo per scene is taken.	Rather than two.
2.02	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.
2.03	December 2009	Kate Miller Andrew Vincello Jim Comiskey	Removed MIDN's old photopoint file naming Added note about change in NETN photopoint locations for plots sampled in 2006 and 2007.	
2.04	October 2010	Jesse Wheeler	Clarified that macro setting should be used for the plot ID photo.	
2.05	January 2013	Kate Miller	Clarified that photopoints should center the plot stake in the view to maintain consistency. Added instructions for bulk file rename utility.	
2.06	March 2014	Jesse Wheeler	Added Figure S6.2 and steps necessary to add photopoint scene code to file name.	Update procedures.
2.07	January 2020	Camilla Seirup	Changed SOP number	

SOP 7 - Stand and Site Measurements

Mid-Atlantic Network/Northeast Temperate Network

Version 3.14

Overview

This SOP collects stand-level and site measurements. These data will allow proper interpretation of other measures, and will be used to assess stand structure and disturbance. This SOP is designed to be used only during the leaf-on period of the summer months (about June 1 to August 31 for NETN and September 30 for MIDN).

The crew should temporarily enhance plot markers with bright-colored survey flags to make them more visible during measurement. It is important that these flags be collected and removed from the site after measurement.

When canopy closure and cover class are assessed, notice the exact breakpoints (e.g., 25%) are not included in any class. Classes are either above or below each breakpoint. This is not a mistake—it is to encourage the crew not to waste time trying to decide if the correct value is exactly 25%. The most suitable class should be rapidly assessed and recorded.

Data Collection

Stand Structure

Record the basic stand structure in the plot using these codes:

1. Even-aged: A succeeding stand dominated by a single cohort of closely competing trees of relatively uniform size and height with a closed tree canopy (≥ 60% tree canopy cover). Smaller trees are typically stressed or overtopped and have fallen behind their associates. Regeneration and/or tall relics from a previous stand may be present.

2. Multi-aged: A later-successional or mature stand characterized by a distinct canopy with typical regeneration below including trees of may sizes and heights. Canopy trees vary in age and diameter. Typically has a closed tree canopy (≥ 60% tree canopy) but gap dynamics may be evident.

3. Mosaic: Plot contains at least two distinct structural classes each covering at least 25% of the stand.

4. Early-successional: A succeeding stand without a closed tree canopy (< 60% canopy – cover). The stand may be dominated by a mix of trees, saplings, shrubs and herbaceous vegetation.

5. Woodland: A stand with at least 25% but less than 60% canopy tree cover, giving the area an open appearance. Trees are open-grown, or growing in small groups interspersed with shrub or herbaceous cover or bare rock. Do not use this code for early-successional plots

apparently succeeding to forest, or a forested plot that currently has < 60% canopy cover due to gap dynamics. This category only occurs in Acadia NP (ACAD).

Note: In ACAD, plots that could be classified as either woodland or multi-aged (or any other class) should be recorded as woodland. Woodland plots are treated differently in analyses, and it is important that these plots are recorded correctly in the database.

Stunted Woodland

Record 1 if the stand is a stunted woodland (otherwise record 0). A stunted woodland will have a discontinuous canopy of stunted and/or twisted trees generally ≤10 m tall. This habitat will only be found in ACAD.

Crown Closure

Estimate % of plot area covered by live tree crowns directly overhead and record appropriate code. If foliage is not present due to seasonal variation or temporary defoliation, visualize the amount of live crown that would normally be present. Do not visualize foliage that formerly existed on dead branches. Notice that the exact breakpoints (e.g., 25%) are not included in either class. This is not a typo—it is to encourage the crew not to waste time trying to decide if crown closure is exactly 25%. Note the instructions in the overview about breakpoints.

1	< 10%
2	10 to 25%
3	25 to 50%
4	50 to 75%
5	> 75 %

% Vascular Cover by Layer

Estimate the total cover of vascular plant foliage by layer within the plot. A rapid cover estimate is made, ignoring overlap among species. It may help to visualize cover by collapsing each layer into a 2-dimensional space, ignoring normal spaces occurring between leaves. Estimate total cover for each layer: Ground, < 0.5 m above ground; Mid-understory, 0.5-2 m above ground; and High-understory, 2-5 m above ground. Use these canopy cover classes: 0, 1-5, 5-25, 25-50, 50-75, 75-95, 95-100%. Note the instructions in the overview about breakpoints.

% Bryophyte Ground Cover

Estimate the total cover of non-vascular plant foliage within the plot in the ground layer only. A rapid cover estimate is made, ignoring overlap among species. Use these canopy cover classes: 0, 1-5, 5-25, 25-50, 50-75, 75-95, 95-100%.

Deer Browse Index

Visually inspect the plot and record the level of deer impact observed (adapted from Brose et al. 2008). Use the following codes and criteria for all parks except ACAD:

1 Very low impact: No observed browse. Found only inside well maintained, deer-exclosure fences.

2 Low impact: No observed browse. Browse-preferred regeneration (Table S7.1) is abundant and of varying heights. Browse-preferred herbaceous plants (Table S7.2) are present and able to flower and fruit. Stump sprouts are present and have minimal evidence of browse.

3 Moderate impact: Browse evidence is observed but not common. Browse-preferred regeneration is present but with little variability in height. There are no stump sprouts, or stump sprouts are browsed. Nonpreferred browse and browse-resistant plant species (Table S7.3), including beech root suckers, are common and widespread.

4 High impact: Browse evidence is common, or browse-preferred regeneration is rare to absent. Nonpreferred and browse-resilient vegetation is limited in height growth by deer browsing.

5 Very high impact: Browse evidence is omnipresent, or browse-preferred regeneration is absent. The abundance of nonpreferred vegetation is reduced by browsing. Browse-resilient plants show signs of heavy repeated browsing and a browse line is evident.

In ACAD use the following codes and criteria:

1 Very low impact: No observed browse. Found only inside well maintained, deer-exclosure fences.

2 Low impact: No observed browse. If browse-preferred (Table S7.1) regeneration or stump sprouts are present, there is no evidence of browse. In some cases browse preferred regeneration or stump sprouts are not present on a plot in ACAD for reasons other than deer browse. In these situations, crew should record 2 unless there are other signs of deer activity on the plot, including a deer trail, deer scat and/or browse of any plant species on the plot. Be sure to distinguish between hare and deer browse. Hare browse is low to the ground and is a clean, angled cut on the twig (i.e., looks like it was cut by scissors). Deer browse appears more ragged and can occur at varying heights

3 Moderate impact: Browse evidence is observed but not common in browse-preferred regeneration or stump sprouts. Other signs of deer activity are observed on the plot, including a deer trail, deer tracks and/or deer scat.

4 High impact: Browse evidence is common. Nonpreferred and browse-resilient regeneration shows signs of browse and browse preferred species are absent.

5 Very high impact: Browse evidence is omnipresent. Browse-resilient regeneration shows signs of heavy repeated browsing and a browse line is evident.

Table S7.1. Preferred browse regeneration species.

Scientific Name	Common Name
Acer rubrum	red maple
Acer saccharum	sugar maple
Cornus florida	flowering dogwood
Liriodendron tulipifera	tulip poplar
Magnolia acuminata	cucumbertree
Prunus pensylvanica	pin cherry
Sassafras albidum	sassafras
Sorbus americana	mountain ash
Thuja occidentalis	northern white cedar
Tilia americana	basswood
Tsuga canadensis	Eastern hemlock

Table S7.2. Preferred browse herbaceous plant species.

Scientific Name	Common Name
Aralia nudicaulis	wild sarsaparilla
Arisaema triphyllum	Jack in the pulpit
Clintonia borealis	blue bead lily
Eurybia divaricata	white wood aster
Impatiens capensis	jewelweed
Laportea canadensis	Canadian woodnettle
Maianthemum (Smilacina) spp. (racemosum, stellatum)	false Solomon's seal
Medeola virginiana	Indian cucumber
Polygonatum spp. (biflorum, pubescens)	smooth Solomon's seal
Sanguinaria canadensis	bloodroot
Trillium spp. (cernum, erectum, grandiflorum, undulatum)	trillium
Uvularia spp. (grandiflora, perfoliata, sessifolia)	bellwort

Table S7.3. Nonpreferred/browse resilient regeneration and herbaceous plant species.

Species Type	Scientific Name	Common Name
Regeneration	*Abies balsamea*	balsam fir
	Acer pensylvanicum	striped maple
	Fagus grandifolia	American beech
	Pinus resinosa	red pine
	Pinus rigida	pitch pine
	Pinus strobus	white pine
	Pinus sylvestris	Scotch pine
Herbaceous	*Ageratina altissima* var *altissima*	white snakeroot
	Carex spp.	Sedges
	Dennstaedtia punctilobula	hay-scented fern

Species Type	Scientific Name	Common Name
	Juncaceae (includes *Luzula* spp.)	rushes (includes wood rushes)
	Poaceae	grasses
	Podophyllum peltatum	Mayapple
	Polystichum acrostichoides	Christmas fern
	Thelypteris noveboracensis	New York fern

Disturbance Code

Record up to three disturbance codes from most to least important based on visual inspection of the plot. To be recorded, a disturbance must cause "significant threshold" damage equivalent to either 1) 25% of trees in a plot, 2) 50% of an individual tree species' count (but must include at least two trees in or near the plot), or 3) disturbance to at least 25% of the soil surface or understory vegetation. Minor foliage or bole damage to trees on the plot does not qualify as a disturbance. Only record disturbances which appear to have occurred since the previous inventory or within the last four years. If you record an unknown disturbance, attempt to capture a picture illustrating the disturbance.

00 None—no observable disturbance
10 Insect damage
11 insect damage to understory vegetation
12 insect damage to trees, including seedlings and saplings
20 Disease damage
21 disease damage to understory vegetation
22 disease damage to trees, including seedlings and saplings
30 Fire—prescribed or natural
40 Animal damage
41 beaver damage to vegetation
42 porcupine
43 deer/ungulate
44 bear
45 rabbit
46 domestic animal/livestock including grazing
47 flooding caused by beaver
50 Weather damage
51 ice/snow
52 wind including hurricane, tornado
53 flooding caused by weather
54 drought
55 earth movement/avalanches
60 Vegetation—suppression, competition, or vines
70 Unknown/not sure/other. Describe in Notes and take photo.
80 Human-caused damage—other than described in these codes. Describe in Notes.
90 Silvicultural treatment
91 Overstory removal—removal of all or most of the canopy trees

92 Selective cutting—removal of one or more trees from a stand (but see 91)
93 Site preparation—clearing, slash burning, chopping, disking, bedding, or other practice to prepare site for regeneration.
94 Artificial regeneration
95 Other silvicultural treatment—use of fertilizers, herbicides, girdling, pruning, or other activities to improve the commercial value of the stand. Describe in Notes.

Disturbance Threshold
For each disturbance recorded above, record which threshold was triggered: 1) damage to 25% of trees in a plot, 2) damage to 50% of an individual tree species'count, or 3) disturbance to at least 25% of the soil surface or understory vegetation. Note that minor foliage or bole damage to trees on the plot does not qualify as a disturbance.

Disturbance % Class
For each disturbance recorded above, record an approximate disturbance percentage to the nearest 10%. If the recorded disturbance was triggered by threshold 1, record the approximate % of trees in the plot damaged by that disturbance. If triggered by threshold 2, record the approximate % of an individual tree species' count damaged by that disturbance. If triggered by threshold 3, record the % of the soil surface or understory affected by that disturbance.

% Trampled
Record the percentage of the plot showing evidence of trampling by humans, wildlife or livestock. Trampling is assessed relative to the conditions of adjacent undisturbed soil. Include area occupied by established or unofficial trails traversing the plot, and record type of trail in plot notes. Estimate the percentage as: 0, 1-5, 5-25, 25-50, 50-75, 75-95 or 95-100 %. Note the instructions in the overview about breakpoints.

% Cover Bare Soil
Record the percentage of the plot covered by bare soil as: 0, 1-5, 5-25, 25-50, 50-75, 75-95 or 95-100 %. Include bare soil area beneath water drainage channels. Bare soil is defined as exposed mineral soil with no leaf litter or duff layer (i.e., O horizon) present. Note the instructions in the overview about breakpoints.

% Cover Rock
Record the percentage of the plot covered by exposed bedrock or large rocks (> 10 cm) as: 0, 1-5, 5-25, 25-50, 50-75, 75-95 or 95-100 %. Note the instructions in the overview about breakpoints. Except for crustose lichens that are 2-dimensional, rock does not include lichen cover.

% Surface Water Cover
Estimate the total cover of surface water in the plot (can be temporary or permanent). Use these cover classes: 0, 1-5, 5-25, 25-50, 50-75, 75-95, 95-100%.

Microtopography
Microtopography is small-scale variation in the soil surface caused by tree tip-ups which create a pit and mound undulation. Microtopography is eliminated when a site is plowed, and recovers over time

once an area is reforested. Record presence (1) or absence (0) of pit and mound microtopography on the plot. If pit and mound topography is suggested but not clear, or reduced due to natural features such as exposed bedrock or thin soil, record (9). Only record microtopography as absent (0) when it appears that plowing or other human disturbance has created an unnaturally flat soil surface. Earthworks do not count as microtopography.

Water on Plot

Record the water source having the greatest impact on the plot using codes below. This information will be recorded during the first visit, and verified or updated on subsequent visits. It will be necessary to re-examine the plot for temporary water sources during each visit.

0	None—no water sources on plot
1	Permanent streams or ponds
2	Permanent water in the form of deep swamps, bogs, marshes
3	Ditch/canal—human-made channels such as for irrigation or drainage
4	Temporary streams
5	Flood zones—evidence of flooding when bodies of water exceed their natural banks
6	Vernal pool
7	Other water—specify in Plot Notes

Stand Height

It will not be possible to measure stand height in early successional plots without a distinct canopy—omit this measurement in those plots. Within the plot, select three co-dominant trees and three intermediate trees of typical height and with a canopy visible from the ground. To measure, move to a position as far from the base of the tree as possible along minimal slope while still allowing sufficient view of the tree canopy. In all parks except ACAD, stand height must be measured at least 15m from the tree. In ACAD, stand height must be measured at least 10m from the tree. Do not select a location upslope or downslope from the tree. Determine height to the top of each co-dominant tree using the TruPulse according to SOP 4 - Using the LTI TruPulse 360°R. Sight the base of your chosen tree using the TruPulse, and record the vertical angle (VA) and horizontal distance (HD). Then, sight the top of the tree and record the vertical angle (VA). If a TruPulse is not available, measure HD using a measuring tape or Sonin electronic distance measurer, and the VA with a clinometer. Record which trees were used to measure stand height.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
2.00	June 2006	Geri Tierney Brian Mitchell	Added stunted woodland yes/no. Changed height strata for % cover by layer. Added estimate of disturbance % class. Field assessment of ecosystem removed from protocol. Adjusted terrain position code requirement on minimal slope. Added code for rabbit/hare damage added to disturbance codes. Clarified at least 2 trees must be affected to trigger disturbance threshold 2	
3.00	September 2006	Geri Tierney Brian Mitchell	Added microtop and % cover trampled, bare soil and rock from Forest Floor SOP. Included definition of microtopography. Reinserted instructions for stand height measured by triangulation. Modified stunted woodland ≤10 m tall No longer measure stand height in early successional plots without closed canopy Revised and better defined stand structure codes, dropped Two-storied code. Added temporary flags. Changed rabbit damage code from 48 to 45 to match FIA. Added disturbance code to distinguish clearcut from selective cut	.
3.01	December 2006	Geri Tierney Brian Mitchell	Included clarification regarding breakpoints and cover classes. Included option to use electronic clinometer for stand height as directed by supervisor.	
3.02	April 2007	Geri Tierney Kate Miller Brian Mitchell	Minor editorial changes.	
3.03	August 2007	Geri Tierney Kate Miller Brian Mitchell	Clarified that % cover by layer includes vascular plants only. Added % non-vascular ground cover measure.	
3.04	November 2007	Geri Tierney Kate Miller Brian Mitchell	Added that stunted woodlands will only be found in ACAD. Clarified % Bare Soil measurement to include exposed mineral soil only.	
3.05	April 2008	Geri Tierney Kate Miller Brian Mitchell	Clarified woodland and other definitions in stand structure measure.	

Revision History Log (continued)

Version #	Date	Revised by	Changes	Justification
3.06	May 2008	Geri Tierney Kate Miller Jim Comiskey Brian Mitchell	Incorporated MIDN methods into the SOP (noted duration of summer “leaf-on” in overview). Stand height is now calculated with the LAR.	
3.07	December 2008	Geri Tierney Kate Miller Jim Comiskey Brian Mitchell	Clarified Microtopographyr ratings. Changed % Non-Vascular Cover to % Bryophyte Cover to match the database and datasheet term.	
3.08	April 2009	Kate Miller	Clarified that the Early Successional category in Stand Structure has < 60% canopy cover.	
3.09	May 2009	Kate Miller Sarah Lupis Kozlowski	Changed stand height measurement to measure three trees instead of one. Replaced browseline with deer browse index used by Eastern Rivers and Mountains Network, and added a table of browse preferred and nonpreferred species. Minor editorial changes, formatting.	
3.10	December 2009	Kate Miller Andrew Vincello Brian Mitchell Jim Comiskey	Added % water on plot Revised a deer browse index for ACAD and added MIDN browse species Clarified that minor foliage damage does not qualify as a disturbance. Clarified that earthworks do not count as microtopography	
3.11	October 2010	Kate Miller Jesse Wheeler	Clarified that plots that could either be classed woodland or multi-aged should be recorded as woodland. Changed lowest percent cover class for %cover by strata and substrate from <1 to 0. Clarified that% cover rock doesn’t include lichen cover (except crustose). Added that trees used to measure stand height should be recorded.	
3.12	January 2013	Kate Miller	Added three intermediate trees to the stand height tally.	
3.13	March 2014	Kate Miller	Revised SOP to use TruPulse instead of LAR	Change of equipment.
3.14	January 2020	Camilla Seirup	Changed SOP number	

SOP 7 - Stand and Site Measurements

SOP 8 - Tree Measurements

Mid-Atlantic Network/Northeast Temperate Network

Version 3.19

Overview

This SOP details how to measure species, diameter, and condition of all live and standing dead trees ≥ 10 cm diameter-at-breast-height (DBH) within each forest plot, or alternatively each tree ≥ 10 cm diameter-at-root-crown (DRC) in stunted woodland plots. These data will yield information on tree growth, mortality and condition, and stand structure and composition.

Caution

Dead trees can be a safety hazard. Crews must exercise caution – trees that are deemed unsafe to measure should be estimated but not touched.

The use of any tree tags or nails other than aluminum at parks which undergo silvicultural management or tree cutting will pose a safety hazard to loggers during subsequent tree cutting. **Never use stainless steel tags or nails at Marsh-Billings-Rockefeller NHP (MABI), Minute Man NHP (MIMA), Roosevelt Vanderbilt NHS (ROVA), Saratoga NHP (SARA) or Weir Farm NHS (WEFA)**. Nylon cable ties attached with a single staple are safe to use at all parks.

Definitions

Diameter-at-breast-height (DBH) is measured at 1.37 m above the ground line on the uphill side of the tree.

Diameter-at-root-crown (DRC) is measured at the base of the tree just above the point where the base flares or the ground, whichever is higher.

A stunted woodland will have a discontinuous canopy of stunted and/or twisted trees generally ≤10 m tall.

Live trees are trees with any living parts (leaves, buds, cambium) present at or above DBH, including trees that have been temporarily defoliated.

Dead standing trees are dead trees that lean < 45 degrees from vertical. They need not be self-supported. Once included, dead trees are tracked until they no longer qualify as standing dead.

Recruits are trees that have reached the minimum diameter since the last census.

Standing trees are free standing and less than 30° from vertical.

Leaning trees are trees leaning more than 30° from vertical.

Fallen trees are those with the main stem more than 45° from vertical.

Broken trees are trees whose main stem or branch is broken or missing.

Cut trees occur in instances where previously tallied trees were actively removed from the plot, for example, health cuts in Gettysburg National Military Park, or exotic tree species removal by the exotic plant management teams.

Forks are stems that branch out from the main stem below DBH. In order to qualify as a fork, the stem in question must be at least 1/3 the diameter of the main stem and must branch out from the main stem at an angle of 45 degrees or less. Stems that branch out more than 45 degrees from vertical of the main stem are considered branches and not measured. Forks originate at the point on the bole where the piths intersect. Once a stem is tallied as a fork that originated from a pith intersection between 0.3 m (1 foot) and 1.37m (4.5 feet), do not recognize any additional forks that may occur above that stem.

Procedure

Delineate the plot by placing temporary survey flags at plot corners and mid-points and connecting plot corners with measuring tapes or kite string. **Begin tallying trees from the center-up position and continue clockwise through the plot.**

A tree which occurs on the plot boundary will be included only if the center of the stem base lies directly on or within the boundary. A tree which occurs in a corner of the plot boundary is included if the center of the stem lies directly on or within the boundary. In this situation, the tree notes should estimate percent of stem that is actually in the plot.

As you work through the plot, attach a pre-printed tag consistently to each tallied tree at a location about 10 cm below breast-height (20 cm above in the MIDN parks). When resampling plots that have already been established, crew only needs to tag recruits and trees with missing tags. Tree tags should face plot center if possible, unless the plot is visible from a nearby trail or road. In that case, tags should face away from the trail or road. **Use aluminum tree tags at MABI, MIMA, ROVA, SARA, and WEFA** and stainless steel tree tags at Acadia NP (ACAD), MORR, Saint-Gudens NHS (SAGA), and all Mid-Atlantic Network (MIDN) parks. In Northeast Temperate Network (NETN) parks, tree tags were originally attached using 30-cm UV-stabilized nylon cable ties and a 14 mm staple. Starting in 2010, all tree tags will be attached using nails (**use aluminum tree nails at MABI, MIMA, ROVA, SARA and WEFA** and **galvanized steel tree nails at ACAD, MORR and SAGA**). In MIDN parks, always use aluminum nails.

To attach a tag using a tree nail, insert nail with the nail head slanted slightly downward and leave at least 4 cm of nail protruding to allow the tag to slide down. This will reduce the chance that the tag will be enveloped by the tree as the tree grows. Select a location on the trunk about 10 cm below breast-height and preferably facing plot center. Avoid locations with decay or peeling bark. If there is no good location facing plot center, find a suitable location on another side of the tree—it is more important that the tag be attached securely than facing plot center. Attach the tag to the tree with a single nail making sure that the numbered side of the tag faces out. The nail must reach through the bark to wood to be secured.

Do not tag snags that sway when touched in order to ensure no snags are knocked down. Also do not tag a snag if the tag cannot be securely attached because the wood is too soft and decayed. Note in Tree Notes that the snag was not tagged, and proceed to record data as usual. Be careful to skip the numbered tag corresponding to the un-tagged snag as you proceed through the plot.

Tags should be checked at every remeasurement. Nailed tags which are in danger of being enveloped by bark should be gently released by pulling the nail back, or the nail and tag should be removed and the tag reattached. Cabled tags which are in danger of being enveloped should be removed by cutting the cable, and the tag should be reattached with a nail. If a tree tag has been removed between surveys, reattach a tag using a nail (follow instructions about stainless steel versus aluminum nails).

Keep unused tree tags organized. In NETN parks, hang unused tags at the end of the set. Use a permanent marker to record both the park and plot where each tree tag set has been used on the back of last unused tree tag, so that the set can be easily found for future measurement cycles. Store unused tree tags in a box and clearly label it based on the park and group of plots to which it applies. Crews should carry the corresponding tree tag set with them when resampling the plot. A spare set with all 1-50, 51-75 or pre-stamped, numbered tags should also be carried to replace tags that are missing from trees (i.e., keep 1's, 2's, 3's and so on, stored in bundles for easy replacement). This is not needed in MIDN parks, since consecutive numbers are used throughout the network—tree numbers are unique for the entire network, not just within a park.

Data Collection

Tree Number

Record the tree tag number which uniquely and permanently identifies each tree on the plot.

Distance

Record the horizontal distance from the center of the plot to the center of the side of the tree stem using the TruPulse. The distance is rounded to the nearest tenth of a meter (0.1 m).

Azimuth

Record the azimuth from the center of the plot to the front center of the tree stem using the TruPulse. The azimuth is rounded to the nearest digit.

Species Code

Record species code using the first three letters each of genus and species. If species cannot be determined in the field, bring a twig sample with foliage, buds, cones, or flowers, and/or a photograph to your supervisor for identification. If possible, collect samples outside the plot from similar specimens and make a note to correct the species code later. Record genus or family if known, or use "Unk Con" for unknown conifer, "Unk Har" for unknown hardwood or "Unk" for unknown tree; this is often the case with standing dead trees on newly established plots. Use Ace sac3 for *Acer saccharum* (sugar maple), and Ace sac2 for *Acer saccharinum* (silver maple).

DBH

Measure tree diameter at breast-height (1.37 m) above ground line on uphill side of tree. Do not measure from a pit or atop a mound or emergent rock. Make sure the DBH tape is straight and not

twisted, perpendicular to the bole axis, and not caught on any twigs or irregularities. In stunted woodlands, measure DRC instead (see below). Use a PVC pole cut to 1.37 m to find breast-height. **Round measurement down to the last 0.1 cm.**

In MIDN and NETN parks, all trees are marked at the point of measurement using green spray paint. Ensure that the mark is facing the same direction as the tag, and that it consists of a short thin horizontal line, precisely where the DBH measurement was taken. When encountering **unusual DBH situations** described below, check the box in the database denoting an unusual DBH measurement and describe the location of measurement in Tree Notes, using distances and landmarks found on the tree. During re-measurement, trees with an existing paint mark should be measured at that exact location, even if the location does not follow current procedures for locating DBH.

Irregularities at DBH

On trees with swellings, bumps, depressions, and branches at DBH, measure diameter immediately above or below the irregularity at the place it ceases to affect normal stem form.

Missing Wood or Bark

Do not reconstruct the DBH of a tree that is missing wood or bark. Record diameter of the wood and bark still attached to the tree, and note in Tree Notes.

Curved Bole

Find the point equivalent to breast-height (1.37 m) by measuring along the curvature of the bole on the upper surface (i.e., the short side) of the tree as shown in Figure S8.1.

Leaning Tree

Find the point equivalent to breast-height (1.37 m) by measuring along the underside (i.e., the short side) of the tree; measure diameter perpendicular to the bole as shown in Figure S8.2. Always paint mark DBH on leaning trees.

Live Windthrown Tree

Find the point equivalent to breast-height (1.37 m) by measuring from the top of the root collar along the bole, as shown in Figure S8.3.

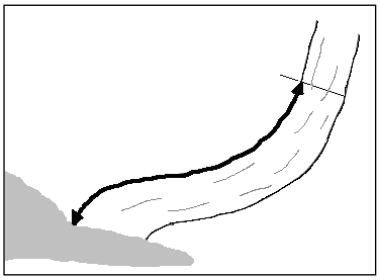


Figure S8.1. Measuring DBH on tree with a curved bole.

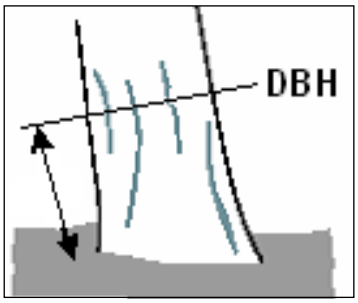


Figure S8.2. Measuring DBH on a leaning tree.

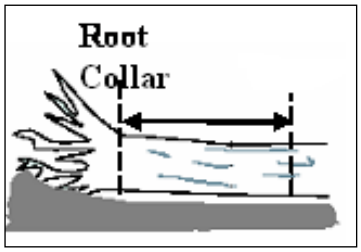


Figure S8.3. Measuring DBH on a live windthrown tree.

Independent Trees That Grow Together

If two or more previously independent stems have grown together at or above the point of DBH, continue to treat them as separate trees. Estimate the diameter of each, and explain the situation in Tree Notes.

Forked Tree

Trees which fork at or above breast-height are tallied and measured as one tree. Diameter should be measured below the point at which forking affects DBH (Figure S8.4A). This point should be marked and recorded in Tree Notes.

In order to qualify as a fork, the stem in question must be at least 1/3 the diameter of the main stem and must branch out from the main stem at an angle of 45 degrees or less. Stems that branch more than 45 degrees from the axis of the main stem are considered branches and not measured. Forks originate at the point on the bole where the piths intersect. Multiple forks can be tallied per tree if the first fork originates below 0.3 m (Figure S8.5A), or if multiple stems originate from roughly the same place on the stem (Figure S8.5B). Once a stem has a tallied fork that originates (based on pith intersection) between 0.3 m and 1.37 m, do not recognize any additional forks that occur above that point (Figure S8.5B).

Trees which fork below breast-height are tallied and measured as multiple trees. The diameter of each fork ≥ 10 cm DBH should be measured at breast-height unless the fork occurs within 0.5 m of breast-height (i.e., above 0.87 m height). In this case, the diameter of each stem ≥ 10 cm at the point of measurement should be measured at a position 0.5 m above the fork (Figure S8.4B). This point should be recorded in Tree Notes, and this tree should be recorded as an unusual DBH. Multiple stems should be recorded in clockwise order, or from front to back when one stem lies directly in front of another. Use the "Fork" field in the database to identify the stems that emerge from a common base. All stems from the same base should be assigned the same letter. For example, if stems four and five are the first forked tree on the plot, enter an "A" in the "Fork" field; stems from the next forked tree would be assigned the letter "B".

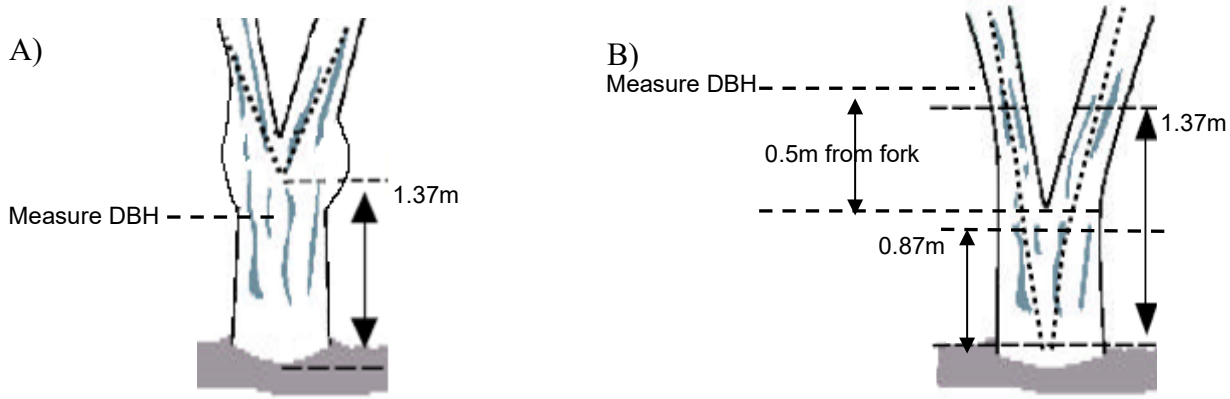


Figure S8.4. Measuring DBH on a tree that A) forks above breast-height, and B) measuring DBH on a tree that forks below breast-height.

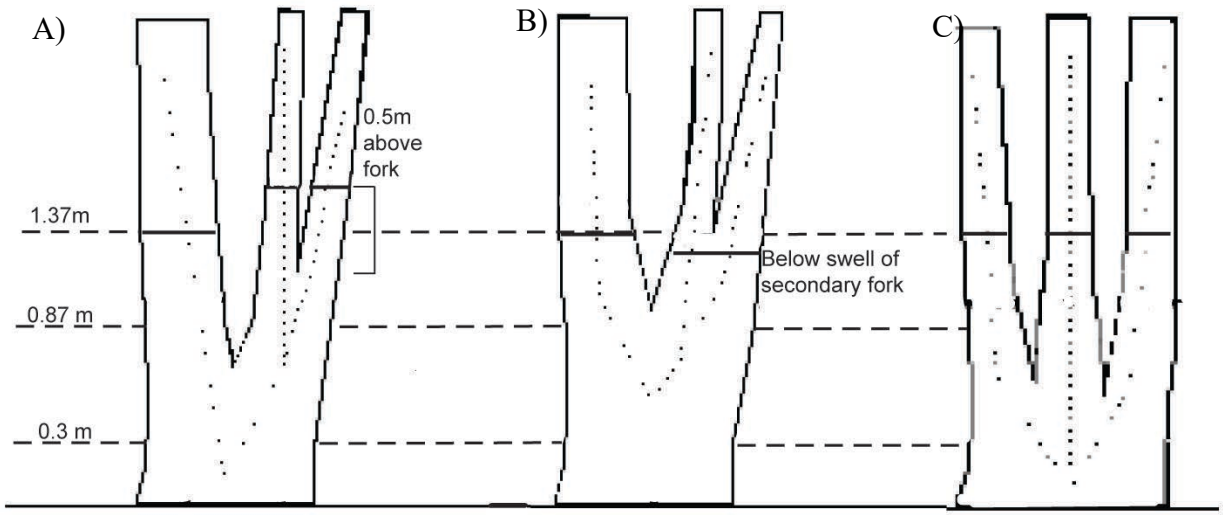


Figure S8.5. Measuring DBH on A) a tree with a fork that originates below 0.3 m, based on the intersection of the pith, and second fork that originates between 0.3 and 1.37m, B) a tree with a fork that originates above 0.3 m, with a secondary fork that isn't tallied and C) a tree with three forks that intersect at roughly the same place on the stem.

DRC

In stunted woodlands (ACAD), measure diameter-at-root-crown (DRC) instead of DBH. Round measurement down to the last 0.1 cm. Wrap diameter tape around base of tree at the ground, as shown in Figure S8.6, or just above the location at which the base flares with root growth as shown in Figure S8.7. Another option for measuring DRC is to use calipers. When using calipers, take 2 measurements that are perpendicular, and average the measurements. Avoid knobs or irregularities in the stem. For trees with bent stems, measure DRC at the lowest suitable location above the bend, taking care to wrap the tape straight across. For clumps of stems sharing a common base above ground, record as a single tree.

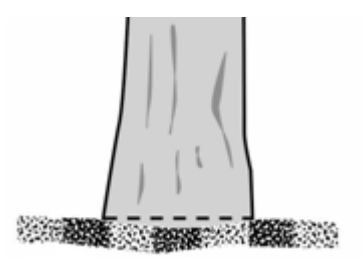


Figure S8.6. For stunted woodlands, measure diameter-at-root-crown, by wrapping the tape around the base of the tree at the ground.

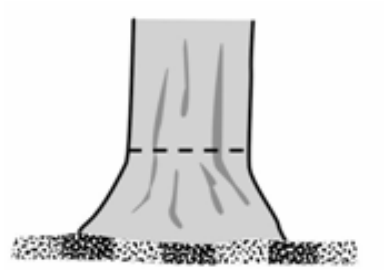


Figure S8.7. Alternative location for measuring diameter-at-root-crown, just above the location at which the base flares with root growth.

Tree Status

Record a status code for each tree to track status over time. Tree status codes are based on two letter codes (Table S8.1). The first letter designates whether the tree is alive (A), dead (D), or is a new recruit (tree that has reached the minimum DBH since previous census) (R). The second letter designates whether the tree is standing (S), leaning (L), broken (B), or fallen (F). For example, "AS" indicates a live standing tree. Not located (NL) is used for trees that were not found in a subsequent census, dead cut (DC) for trees that were cut and removed from plot, missed alive (AM) and missed dead (DM) are used where trees are > 12cm DBH indicating that they were missed during the previous census. NL should be used infrequently and only when no explanation can be found for why the tree was not found. If the missing tree is likely to be DF, record it as DF. Excluded trees are previously tallied trees that have been removed from the sample. The excluded shrank status (XS) is for live trees that shrank below 10 cm DBH. If a dead tree shrinks below 10 cm DBH, record it as DF even if it is still standing. This indicates that the individual no longer meets the requirements for a tree as defined in this protocol and will not be measured in the future. The XP status is for a tree that is excluded because it is outside of the plot. The XO status is for a tree that is excluded for a reason other than XS and XP. In the rare occasion that a tree status is recorded as "XO", crews must explain in the tree notes why the tree was excluded from the sample. When encountering a previously labeled XP tree that appears to be in the plot, continue to exclude the tree. Likewise, a tallied tree from a previous visit should continue to be measured, even if the tree appears to be outside of the plot. A tree that has been assigned an excluded status of XP or XO in the current visit will be updated by the plant ecologist so that all previous records of that tree are the same excluded status. Trees that were assigned a status of NL in the previous visit, but are likely to be DF, should be labeled DF. Trees that were assigned a status of NL in the previous visit, and that are unlikely to be DF, should be assigned XO or XP (if determined to be outside of the plot) on the second visit and the crew should leave explanatory notes. The plant ecologist will review the data and change the previous visit's NL status to XO, DF, or XP.

Table S8.1. Tree status codes.

	Alive	**Dead**	**Recruit**
Standing	AS	DS	RS
Leaning	AL	DL	RL
Fallen	AF	DF	RF
Broken	AB	DB	RB
Cut	-	DC	-
Missed	AM	DM	
Not located	NL	NL	-
Excluded-Shrank	XS	-	-
Excluded-Not in Plot	XP	XP	
Excluded-Other	XO	XO	

Crown Class

Assign code describing tree crown position in canopy relative to immediate neighbors (Figure S8.8).

1 Open-grown—Crown has received full sunlight from above and all sides through much of its life, particularly during early development, as seen by well-developed lower branches. Lower branches may currently be devoid of leaves.
2 Dominant—Crown extends above canopy. Taller than the average tree in stand and has well-developed crown.
3 Co-dominant—Crown is at the general level of the canopy. Typically, co-dominant trees have medium-sized crowns and are crowded on the sides; in dense stands, co-dominant trees have small crowns.
4 Intermediate—Tree is shorter than co-dominant trees but with a crown that extends into the general canopy. Tree has small crown and is very crowded from the sides.
5 Sub-canopy—Crown is entirely below the general level of the canopy.
6 Gap-exploiter—Tree is of intermediate or sub-canopy height, but is exploiting a gap within otherwise closed canopy forest and receives direct light from above.

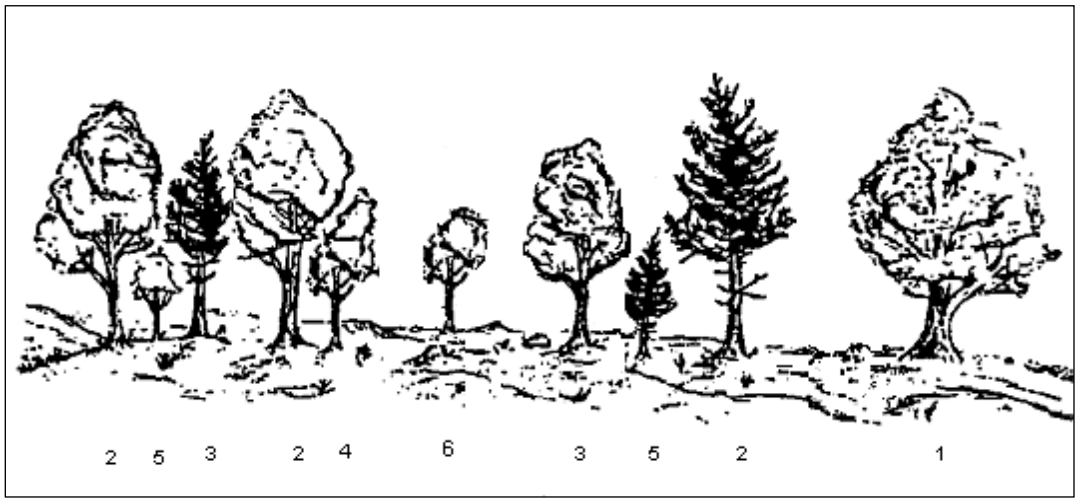


Figure S8.8. Illustration of crown classes in a forest canopy.

Tree Condition

Record the presence of any of the following: Advanced decay (AD including fungal infection), Asian longhorned beetle (ALB), balsam woolly adelgid (BWA; not found in MIDN), beech bark disease (BBD; record degree of severity using codes below), burl/gall (G), butternut canker (BC), dogwood anthracnose (DOG), emerald ash borer (EAB), epicormic branching (EB), gypsy moth (GM), hemlock woolly adelgid (HWA; record degree of severity using codes below), elongate hemlock scale (EHS), insect damage (ID; record in notes if insect is known), large dead branches (DBT; in canopy, including broken or dead top), open wounds (CW; includes cankers), sirex wood wasp (SW), spruce budworm (SB), sudden oak death (SOD), vines in crown (VIN; record species), vines on bole (VOB; record species), other damage (OTH; describe in notes), small cavity (CAVS), large cavity (CAVL), red pine scale (RPS). If none of these conditions exist, record “healthy” (H).

Additional notes on vines in crown (VIN) and vines on bole (VOB): VIN is recorded if a vine is present in a tree's crown. VOB is recorded if a vine is present on a tree's bole at or higher than 1.37 m (DBH), but does not reach the canopy, as defined for foliage conditions.Each vine species growing on a tree should only be counted once, and be assigned the highest category. That is, if there are grape (*Vitis* spp.) vines growing on the bole and in the crown of a tree, record only VIN (vine in crown) and *Vitis* for the species. If more than one species of vine is present in a tree, record the highest condition for each species of vine. For instance, if the tree in the previous example also had Virginia creeper (*Parthenocissus quinquefolia*) growing up the bole, but not reaching the canopy, the following tree conditions would be recorded: VIN – *Vitis* spp.; VOB – *Parthenocissus quinquefolia*.

Note that small and large cavities are the only conditions recorded for both live and dead trees. To qualify as a cavity the walls of the opening must be approximately cylindrical shaped and penetrate the inner bole of the tree. The cavity does not have to penetrate the heartwood, but it must appear at least as deep as the opening is wide. Foraging excavations by woodpeckers do not qualify as cavities. Small cavities are 3 to 5 cm diameter, and large cavities are over 5 cm diameter.

Record BBD severity for all American beech (*Fagus grandifolia*) trees using the following scale:

1—No sign of BBD
2—Scale insect present, some cracks in bark, 75% canopy remains
3—Heavily cracked bark, Nectria cankers present, some limb loss, 25-75% canopy remains
4—Severe bark cracking, large girdling cankers present, < 25% canopy remains. For trees that have grown in post invasion, tree crown is stunted and not reaching into the canopy

Record HWA/EHS severity for all eastern hemlock (*Tsuga canadensis*) using the following scale:

1—No sign of HWA or EHS
2—HWA and/or EHS scale insect present. Foliage appears healthy (< 10% of foliage appears to be effected).
3—HWA and/or EHS scale insect present and 10-25% of needles have chlorosis and/or necrosis
4—Severe impact. Greater than 25% of total foliage has needle loss on fine twigs, chlorosis and/or necrosis.

Foliage Condition

Visually assess **canopy** foliage and record up to three problems as chlorosis (C), necrosis (N), holes (H), small leaves (S), wilting (W), leaf loss (L), or other (O—describe in Tree Notes). Chlorosis is yellowing of leaves associated with loss of chlorophyll. Foliage necrosis is dead leaves or dead patches on leaves. Only record leaf loss (L) for needle loss if fine twigs in the canopy are affected—disregard lower branches and large dead branches. If no foliage conditions are observed, select none (NO).

Foliage Percentage

Estimate the total percentage of leaves affected by foliage conditions and the percentage of leaves affected by each foliage condition using the following classes: 1-10, 10-50, 50-90, 90-100%. Estimate using the number of leaves affected. For example, if approximately 20% of leaves are affected but only a small amount of surface area of each leaf is affected, choose class 2 (10 – 20%) for foliage percentage. Notice the exact breakpoints (e.g., 10%) are not included in any class. Classes are either above or below each breakpoint. This is not a mistake—it is to encourage the crew not to waste time trying to decide if the correct value is exactly 10%. The most suitable class should be rapidly assessed and recorded.

Percentage of Leaf Area

For the chlorosis (C), necrosis (N), and holes (H), estimate the percent of the leaf area that is affected by each specific foliage condition. For example, if approximately 20% of leaves are affected, but only about 5% of the area of each of these leaves are affected, then choose class 1 (1 – 10%) for percentage of leave area.

Decay Class

For each standing dead tree, record code indicating the tree's stage of decay (Table S8.2). Note that snags in decay class V are rarely, if ever, encountered.

Tree Notes

Record any unusual tree features or notes required above, including location of diameter measurement if not measured at breast-height.

Table S8.2. Decay class definitions for standing dead trees.

Class	Bark	Branches and Twigs	Wood Condition
I	Firmly attached	Branches retain many small twigs	Sound wood covered by intact bark
II	If present, decayed, faded, and not firmly attached	Branches and small twigs may be present	Hard wood—impenetrable with fingernail or pen point, may be case hardened with powder wood beneath.
III	Generally absent, except in *Betula* and *Prunus*	Branch stubs present but no twigs	Soft wood—will spring back if compressed and can be penetrated with fingernail or pen point.
IV	Generally absent	Some branch stubs may remain but no twigs	Spongy wood -responds to finger pressure and may exude moisture—and powder wood—flows through fingers like coarse sawdust.
V	Absent	No branch stubs or twigs	Powder wood

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
2.00	June 2006	Geri Tierney Brian Mitchell	Added tree tagging procedure using cable ties. Adjusted foliage condition classes to be similar to SHEN. Added alternative root-crown-diameter measurement in stunted woodlands. Added balsam woolly adelgid to tree condition measurement. Changed decay classes—now adapted from Pyle and Brown (1998) for eastern trees. Added caution not to tag snags which sway when touched.	
3.00	September 2006	Geri Tierney Brian Mitchell	Added status code for fallen dead tree. Emphasized need to mark trees and record note for trees with special DBH situations Clarified DRC measurement and provided 2 figures. Included tree health codes, and record absence of problem as NONE Added BBD disease scale. Clarified DBH measurement must not occur from atop a mound or down in a pit. Labeled figures and removed English units. Renamed ‘overtopped’ canopy class to be ‘sub-canopy’. Changed "overtopped" crown class to "sub-canopy.” Modified “advanced decay” to substantial decay” under tree condition Changed names of lower quarters (L) to bottom (B) to avoid confusion with left (L).	
3.01	December 2006	Geri Tierney Brian Mitchell	Included instruction that tree tags face plot center unless plot is visible from road or trail.	3.01
3.02	April 2007	Geri Tierney Kate Miller Brian Mitchell	Added crown classification for short tree in gap. Added other canker/gall (CG) to TREE CONDITION. Clarified use of aluminum tags/nails at ROVA, WEFA, steel at MORR. Clarified snag decay classes. Included text to ensure good DBH measurement.	3.02

Revision History Log (continued)

3.03	November 2007	Kate Miller Geri Tierney Brian Mitchell	Clarified boundary tree inclusion rules. Revised directions for recording unusual DBH measurements. Clarified open grown and Gap-exploiter crown classes. Refined tree condition categories. Added definitions of chlorosis and necrosis to foliage condition. Clarified foliage percentage estimation.	
3.04	December 2007	Brian Mitchell Kate Miller Geri Tierney	Added figures S8.4 and S8.5 to illustrate location of DBH on forked trees.	
3.05	May 2008	Kate Miller Jim Comiskey Brian Mitchell Geri Tierney	Incorporate MIDN methods into SOP.	
3.06	December 2008	Kate Miller Jim Comiskey Brian Mitchell Geri Tierney	Clarified that standing dead trees should not be tagged if the tag cannot be secured due to soft, decayed wood. Changed crown condition to only consider relative height in canopy, and not light availability. Added figure and table captions. Added illustration of a gap exploiter to Figure S8.8.	
3.07	April 2009	Kate Miller	Minor editorial changes based on external review.	
3.08	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.
3.09	December 2009	Kate Miller Brian Mitchell Jim Comiskey	Clarified when a tree is considered in a plot Added that species of vines in canopy be recorded for NETN too. NETN adopted MIDN's tree status codes and tree mapping procedures. Added a index for HWA/EHS severity.	
3.10	October 2010	Kate Miller Jesse Wheeler	Changed all tree tags to be attached using a nail instead of cable tie. Added that tree tags that have been removed between surveys should be reattached with a nail. Added that trees >40cm DBH should get paint marked at DBH Added that all leaning trees should have a paint mark at DBH Added that once a tree has a paint mark for DBH, that location should never be moved. Added option to use calipers for DRC. Added that all DRC measurements should be paint marked. Added Dogwood anthracnose to priority pest list. Clarified that trees that shrink below 10cm (e.g., snags) should be given the EX status with "shrank" in notes.	
3.11	April 2011	Kate Miller Jesse Wheeler	Corrected the definition of fallen as greater than 45° from vertical.	

Revision History Log (continued)

3.12	March 2012	Kate Miller	Added small and large cavities to tree condition	Park (MABI) request
3.13	January 2013	Kate Miller	Added new fork tally rules to be consistent with FIA procedures.	
3.14	March 2014	Jesse Wheeler	Revised what the crew needs for replacement tree tags in NETN plots. Replace references to LAR with TruPulse.	Updated procedure. Change in equipment.
3.15	December 2014	Kate Miller	Added XS and XP tree status codes, and replaced EX with XO to ensure that common reasons for tree exclusions are documented consistently.	
3.16	November 2015	Jesse Wheeler	Added that Foliage Condition would also include % of foliage area affected in addition to % of leaves. Revised language for unusual DBH situations. Clarified that trees near plot boundary should continue to have the same status as they did last visit, as long as the tree is still measureable.	Foliage area assessment informs us on annual tree health Plot boundaries should no longer be adjusted.
3.17	December 2016	Camilla Seirup	Clarified that the XS tree status code is only for live trees.	
3.18	February 2019	Camilla Seirup Kate Miller	Added RPS and VOB tree conditions and clarified not located and excluded tree status codes	
3.19	January 2020	Camilla Seirup	Changed SOP number	

SOP 9 - Microplot

Mid-Atlantic Network/Northeast Temperate Network

Version 3.12

Overview

This SOP quantifies live saplings, established seedlings, and shrubs by species on three 2-m radius circular microplots for Northeast Temperate Network (NETN) parks. Seedlings are also quantified by size class. These data yield information on advance regeneration, future cover, and the effects of deer browsing. For Mid-Atlantic Network (MIDN), three 3-m radius circular plots are used to quantify live saplings and shrubs by species; seedlings are quantified in the quadrats.

Definitions

Saplings are defined as juvenile trees with diameter-at-breast-height (DBH) at least 1 cm but less than 10 cm in forest plots, or diameter-at-root-crown (DRC) at least 1 cm but less than 10 cm in stunted woodland plots (Acadia NP).

Established seedlings are defined as live juvenile trees that are at least 15 cm tall with at least two true leaves and no cotyledons present, and are smaller than saplings (i.e., less than 1 cm DBH). Any juvenile tree ≥ 15 cm tall but less than 1 cm diameter at breast height (1.37 m tall) is considered a seedling.

Shrubs are woody, sub-canopy species (includes vine species). To qualify for counting in this protocol, shrubs must be at least 30 cm tall. When determining shrub height, do not measure along the stem; instead determine the highest point the shrub reaches in its natural position. Do not straighten or otherwise manipulate the individual. Vines are only measured up to 2 m tall. All shrubs are measured by % cover.

Horizontal distance is the straight line distance between two objects. This contrasts with slope distance which is measured parallel to the ground. Slope distance and horizontal distance are equivalent on flat land. On sloped land, the horizontal distance between two objects is less than the slope distance.

Height of seedlings or shrubs is defined as the distance from the root crown to the top of the terminal bud, or to the top of the tallest fork. Do not include leaves or needles in this measurement. To measure height, gently align seedling or shrub along a ruler. Realign the ruler along any curves present to account for additional height masked by a curved stem.

Data Collection

The microplot centers are marked by stakes located 4 m slope distance (NETN) and 7 m horizontal distance (MIDN) from the full plot center, in the direction of the upper plot corners and the lower boundary midpoint. The microplots are circular plots of 2-m radius horizontal distance (3-m radius

for MIDN). To identify saplings, established seedlings or shrubs within the microplot, one crew member holds a tape at the microplot center, while a second crew member stretches the tape a horizontal distance of 2 m toward plot center (3 m for MIDN). The second crew member then slowly circles clockwise at this fixed distance from microplot center. In NETN parks, both crew members examine the ground for all saplings, established seedlings and shrubs that fall within the 2-m radius; in MIDN parks, the crew members measure all saplings and some shrubs within the 3-m radius. In MIDN parks, all saplings and shrubs that are measured are marked and tagged.

Microplot Code

Specify in which microplot each sapling, seedling and shrub measurement has been observed as UR (upper right), UL (upper left) or BC (bottom center).

Unknown Species Code

If an unknown species occurs throughout the plot, and it is easily distinguishable from other species, record every occurrence of that species as “Unk type 1” in the database and on the sample bag. If there are multiple commonly occurring and distinguishable unknown species, use consecutive numbers for each separate species. Otherwise, record "Unk type" and a consecutive number for each specimen on the sample bag and in the database. Type refers to hardwood, conifer, shrub, etc. Do not carry over unknown names and numbers to other forest plots. Store unknown specimens with different numbers (denoting different species) in separate bags.

Sapling Species Code

Record species code using the first three letters each of the genus and species. If species cannot be determined in the field, bring a twig sample or photograph to your supervisor for identification. If possible, collect samples outside the entire tree plot from similar specimens and make a note to correct the species code later. Record genus or family if known, or use “Unk Con” for unknown conifer and “Unk Har” for unknown hardwood.

Sapling Diameter

Measure DBH at 1.37 m above ground line on the uphill side of each sapling. Round the measurement down to the last 0.1 cm. See instructions for measuring DBH in unusual situations in SOP 9 - Tree Measurements. In stunted woodlands (Acadia NP), measure sapling diameter as diameter-root-collar (DRC) rather than DBH. See instructions for DRC in SOP 9 - Tree Measurements. All saplings > 4 cm and < 10 cm in diameter are measured using a DBH tape, and in MIDN these saplings are tagged with a nail. All saplings with a diameter < 4 cm are measured using calipers, and in MIDN parks these saplings are tagged with a cable tie, thus minimizing injury to smaller individuals when using nails. If the shape of a sapling that is < 4 cm DBH is not round, take the average of the largest and smallest caliper measurement, and round down. In addition, the cable ties also serve to indicate that the measurement was taken with calipers. Saplings are not tagged in NETN parks, but they should be paint-marked at DBH.

Saplings that fork from a tree must originate below DBH, be at least 1/3 the diameter of the tree, and be less than 45 degrees from the main stem of the tree to be tallied as a sapling. Forks originate at the point on the bole where the piths intersect. Multiple forks can be tallied per sapling if the first fork originates below 0.3 m, or if multiple stems originate from roughly the same place on the stem. Once

a stem has a tallied fork that originates (based on pith intersection) between 0.3 m and 1.37 m, do not recognize any additional forks that occur above that stem (See SOP 8 – Tree Measurements).

In NETN plots with a dense sapling component, only the first 10 saplings of a species encountered per microplot should be measured for DBH. The remaining saplings in the microplot should be tallied by species, and paint-marked at DBH to indicate which saplings were included in the count for that microplot.

Sapling Status

For MIDN only, record a status code for each sapling to track status over time. Sapling status codes are the same as those used for SOP 9 – Tree Measurements, with the exception that alive missed (AM) saplings are > 2 cm DBH. Not located (NL) should be used very infrequently with saplings, and only when there is no explanation for why a sapling could not be found. Saplings that die and fall over between cycles may decompose quickly and are difficult to locate and identify. In order to accurately track sapling mortality and recruitment, it is important that these stems are recorded as dead fallen (DF), not NL. Therefore field crews should assume that a sapling is DF if they are unable to locate it and only record NL if there is reasonable suspicion of unusual events. As with trees, the excluded shrunk (XS) status should only be used for live saplings; dead saplings that shrink below 1 cm DBH should be given a DF status.

Sapling Notes

Record any unusual sapling features, including if sapling is sprouting from a stump.

Seedling Count

NOTE: seedling count for MIDN parks is conducted in the quadrats instead of the microplots (SOP 13 – Quadrat Measurements).

Within each microplot (quadrat for MIDN parks), record the number of live, established tree seedlings by species within each height class: 5-15 cm (VAFO only), 15-30 cm, 30-100 cm, 1-1.5 m, > 1.5 m. Do not recount saplings. Count up to five individuals per species and height class (in MIDN all tree seedlings are counted; see SOP 12 – Quadrat Measurements for more details). Estimate the total count by five if there are more than five individuals of any species in any class.

Multiple “suckers” that originate from a common base are considered one seedling. Do not count stump sprouts from a live tree; however do count stump sprouts from a dead bole, counting all sprouts from a common base as one seedling. Do not count “layers”—undetached branches partially or completely covered by soil, usually at the base.

Seedling Species Code

Record species code using the first three letters each of the genus and species. If species cannot be determined in the field, record genus or family if known, or use “Unk Con” for unknown conifer and “Unk Har” for unknown hardwood. Bring a sample collected from outside the microplot or photograph to your supervisor for identification. If possible, collect samples from outside the entire tree plot from similar specimens and make a note to correct the species code later.

Shrub Species Code

For each shrub species encountered on the microplot, record species code using the first three letters each of the genus and species. If species cannot be determined in the field, tally the shrub and bring a twig sample or photograph to your supervisor for identification. If possible, collect samples outside the entire tree plot from similar specimens and make a note to correct the species code later. Record genus or family if known, or use "Unk" for unknown shrub.

Shrub % Cover

Estimate % shrub cover by species using the following classes: 0, < 1, 1-5, 5-10, 10-25, 25-50, 50-75, 75-95, 95-100% (Table S9.1). Notice the exact breakpoints (e.g., 25%) are not included in any class. Classes are either above or below each breakpoint. This is not a mistake—it is to encourage the crew not to waste time trying to decide if the correct value is exactly 25%. The most suitable class should be rapidly assessed and recorded. Shrubs must be ≥ 30 cm length to be included in the cover estimate. Only estimate cover of vines up to 2m in height.

Special case - Tree-sized Shrubs

Occasionally, certain species of shrub can grow to be tree-sized as defined by this protocol. In the MIDN and NETN, this list includes *Alnus serrulata*, *Morella cerifera*, *Ligustrum* spp. and *Rhamnus cathartica*. These species are all assessed as shrubs in both NETN and MIDN for all growth stages except for when they become tree size (i.e., ≥ 10 cm DBH). Individuals ≥ 10 cm DBH should be tagged and measured as trees. All other non-tree sized individuals of these species should be assessed as shrubs and given a % cover estimate. Do not tally these species as a seedling or measure DBH as a sapling if < 10 cm.

Table S9.1. Area in square meters for each microplot cover class breakpoint.

	NETN	MIDN
< 1%	present	present
1%	0.126 (~35 x 35 cm)	0.283 (~50 x 50 cm)
5%	0.628 (~80 x 80 cm)	1.414 (~1.2 x 1.2 m)
10%	1.257 (~1.1 x 1.1 m)	2.827 (~1.7 x 1.7 m)
25%	3.142 (~1.8 x 1.8 m)	7.069 (~2.7 x 2.7 m)
50%	6.283 (~2.5 x 2.5 m)	14.137 (~3.8 x 3.8 m)
75%	9.425 (~3.1 x 3.1 m)	21.206 (~4.6 x 4.6)
100%	12.566	28.274

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.01	September 2006	Geri Tierney Brian Mitchell	Included alternative measure of shrub cover in early successional stands. Included description of microplot procedure. Clarified established seedling definition. Clarified instruction to estimate seedlings and shrubs counts by multiples of 5.	
1.02	December 2006	Geri Tierney Brian Mitchell	Clarified that the radius of the regeneration plot must be measured as horizontal distance. Included clarification regarding breakpoints and cover classes. Improved criteria for using shrub cover measurement rather than shrub count.	
2.00	April 2007	Geri Tierney Brian Mitchell	Minor editorial changes. Added 2 additional regen microplots.	
2.01	November 2007	Geri Tierney Kate Miller	Minor editorial changes.	
3.00	May 2008	Brian Mitchell Jim Comiskey Kate Miller	Incorporated MIDN methods.	
3.01	November 2008	Kate Miller Jim Comiskey Brian Mitchell	Adjusted saplings section to only require first 10 saplings per microplot to require a DBH measurement.	
3.02	December 2008	Kate Miller Jim Comiskey	Changed SOP title from Regeneration to Microplot Added rule that calipers will not be used to measure DBH of saplings > 4 cm and < 10 cm.	More accurately reflects NETN and MIDN protocols.
3.03	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.
3.04	December 2009	Kate Miller Andrew Vincello Jim Comiskey Brian Mitchell	Changed shrub tally to shrub percent cover Clarified that vines are considered shrubs Clarified how to document unknown species Added the 5-15 cm seedling class for VAFO	
3.05	October 2010	Kate Miller Jesse Wheeler Jim Comiskey	Clarified that vine cover is estimated up to 2m MIDN has stopped measuring DRC of shrubs. All shrubs that previously had a DRC measurement are now included in cover estimates only.	

Revision History Log (continued)

Version #	Date	Revised by	Changes	Justification
3.06	January 2013	Kate Miller Jesse Wheeler	Clarified that small saplings that aren't round should be measured as the average of the largest and smallest caliper measurement. Added new fork tally rules to be more consistent with FIA procedures. Added sapling status for MIDN.	
3.07	March 2014	Jesse Wheeler	Simplified sapling and shrub methods for MIDN so that woody species are either saplings or shrubs. All shrub species are estimated for % cover, and all saplings are measured for DBH.	3.07
3.08	December 2014	Kate Miller	Added that saplings should be paint-marked at DBH to improve consistency across sample cycles.	
3.09	December 2016	Camilla Seirup	Clarified the procedure for measuring shrub height.	
3.10	January 2018	Camilla Seirup	Clarified that Rhamnus cathartica is assessed as a shrub unless it is >= 10cm DBH and assessed as a tree.	
3.11	February 2019	Camilla Seirup Kate Miller	Added species to the list of shrubs that occasionally reach tree size. Clarified that tree-size shrub species should only be treated as a tree when ≥10cm DBH. All individuals that are smaller than 10cm should be measured as a shrub. Clarified when to use NL status with MIDN saplings.	
3.12	January 2020	Camilla Seirup	Changed SOP number	

SOP 10 - Coarse Woody Debris

Mid-Atlantic Network/Northeast Temperate Network

Version 3.08

Overview

This SOP quantifies coarse woody debris using line intersect sampling along three, 15-m transects at each plot. These data yield information on forest structural diversity, and the availability of habitat for wildlife and fungi.

Definitions

Coarse woody debris (CWD) includes down, dead tree and shrub boles, large limbs, and other woody pieces that are ≥ 10 cm diameter and ≥ 1 m long, are separated greater than 50% from a live tree or a snag, and are touching the ground at some point along the piece. Coarse woody debris includes dead trees leaning > 45 degrees from vertical. Very decomposed logs reduced to slightly elevated 'humps' on the ground without structural integrity are not tallied as CWD. Do not tally CWD pieces that are completely suspended above the ground.

Horizontal distance is the straight line distance between two objects. This contrasts with slope distance which is measured parallel to the ground. Slope distance and horizontal distance are equivalent on flat land. On sloped land, the horizontal distance between two objects is less than the slope distance.

Data Collection

Coarse woody debris transects extend 15 m slope distance from plot center. Transect UP extends upslope or North, parallel to plot sides and extending through the upper boundary midpoint. Transect BL extends through the bottom left plot corner. Transect BR extends through the bottom right plot corner. Transects must be laid out along a straight line to avoid biasing the selection of pieces.

Transect slope should be measured during plot setup. Using the TruPulse, record to the nearest degree the average slope along each CWD transect.

Tally Rules for CWD

Most CWD will be lying on the ground. To be tallied by this protocol, the point of intersection between the transect and the central longitudinal axis of the piece must occur above the ground, and the piece must meet the minimum diameter criteria (≥ 10 cm) at the point of intersection, as shown in Figure S10.1.

All snags leaning > 45º from horizontal should be tallied regardless of height off the ground, as long as the piece is touching the ground at some point along its length (even if the part touching the ground is <10 cm diameter). If the snag is too high to reach, record this fact and estimate diameter and length.

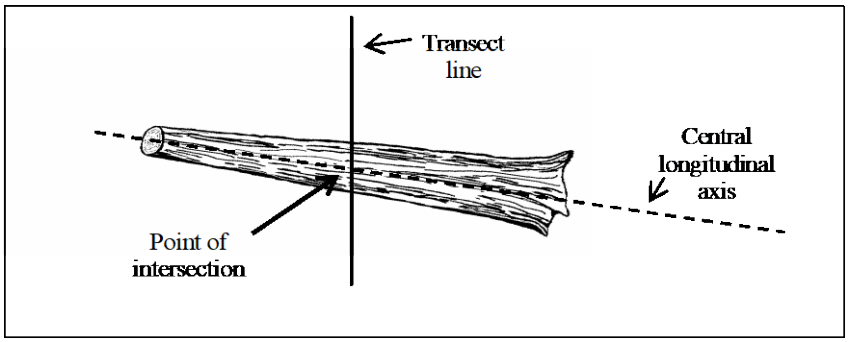


Figure S10.1. Diagram showing the point of intersection along the transect where diameter of the coarse woody debris is measured.

If a piece intersects a transect line more than once or intersects two transect lines, tally the piece each time it intersects and record the same letter for each record of the same piece in the database.

For each piece of CWD to be tallied, record the following:

- **Transect—**Record the letters indicating the transect on which the piece is sampled: transect UP runs upslope or North from the plot center, transect BL runs through the bottom left plot corner, and transect BR runs through the bottom right plot corner.

- **Distance**—Record the slope distance from plot center to the point of intersection to nearest 0.1m.

- **Type**—Record if the piece is coniferous (CON), deciduous (DEC), or unknown (UNK).

- **Species Code**—If species can be quickly and confidently assessed (for example if the piece has a tree tag or is in decay class 1, record species using the first three letters each of the genus and species. If it is not possible to identify the species, record "UNK" for unknown. Do not spend time trying to identify CWD if species is not obvious.

- **Decay Class**—Record the code indicating the predominant decay class (> 50% of the piece) along the length of the pieces as determined from Table S10.1. If no single class dominates, average the decay classes present. For example, a log with sections totaling 15% class 2, 40% class 3, 40% class 4, and 5% class 5 would be classified as Decay Class 3.

- **Diameter at Intersection**—Record the piece's diameter, to the nearest cm, at the point where the transect intersects the longitudinal center of the piece. Take care to measure diameter perpendicular to the piece's length (not along the line of the transect). Diameter of CWD is typically measured by holding a metal tape or ruler above the log. To avoid parallax error, position your eyes directly over each end of the tape in sequence. Other methods include wrapping a tape around the bole (if possible) and using large calipers. If the piece is not round in cross-section, take the average of the smallest and largest diameter measurements to get an accurate diameter of the piece.

- **Multiple Cross**— If a piece crosses the same transect more than once, or crosses multiple transects, record the same letter for each record of the same CWD piece in the multiple cross column. For example if one piece is intercepted twice by the UC transect, record "A" in the multiple column both times it is measured. Likewise if on the same plot another piece crosses both BL and BR transects, record "B" in the multiple column both times it is measured.

- **CWD Length**—Record the length of the piece that qualifies as CWD to the nearest 0.5 m. From the small end, begin measurement at the point that diameter is at least 10 cm and above ground, and measure to the point that the log either ends, goes underground or deteriorates to less than 10 cm diameter. For curved logs, measure along the curve. For forked pieces, consider the main fork to be that with the largest diameter at the fork. For the main fork, length should include the entire length of the piece. For minor forks, length should be measured only to the point of attachment with the main fork. Minor forks do not count as a multiple cross with the major fork. The minimum length recorded by this protocol is 1 m.

- **Hollow**—Record whether piece is hollow (Y) or not (N). A piece is considered hollow if a cavity extends at least 0.5 m along the central longitudinal axis of the piece, and the cavity entrance is at least 1/4 the diameter of the piece.

For each CWD piece that is measured, paint the location that the piece crosses the transect and where the diameter is measured with tree paint.

For pieces that are not round in cross-section because of missing chunks or "settling" due to decay, measure the diameter in two directions and average. Estimate the longest and shortest axis of the cross-section (as shown in Figure S10.2) and record the average value.

Table S10.1. Coarse woody debris decay class definitions, adapted from Pyle and Brown (1998).

Class			Bark	Log Shape and Integrity	Wood Condition
I			Firmly attached	Round and solid	Sound wood covered by intact bark
II			If present, decayed, faded, and not firmly attached	Round and firm	Hard wood—impenetrable with fingernail or pen point, may be case hardened with powder wood beneath
III			Generally absent, except in *Betula* and *Prunus*	Round	Softwood—will spring back if compressed and easily penetrated with fingernail or pen point
IV			Generally absent	Oval or flattened, no longer a solid piece though some hard chunks remain	Very spongy wood—responds to finger pressure and may exude moisture—and powder wood—flows through fingers like coarse sawdust
V	Absent	Quite flat or flat with some rounding	Loosely aggregated powder wood		

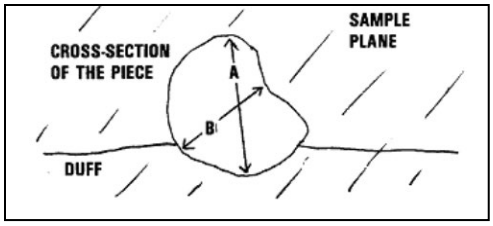


Figure S10.2. Diagram showing how to estimate the longest and shortest axis of the cross-section of coarse woody debris.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version	Date	Revised By	Changes	Justification
1.00	June 2006	Geri Tierney Brian Mitchell	Changed decay classes, increased CWD transect length to 45 m per plot, added measurement of distance from plot center to CWD piece.	Decay classes now adapted from Pyle and Brown 1998 for eastern trees.
2.00	September 2006	Geri Tierney Brian Mitchell	Increased CWD minimum size threshold to 10 cm diameter, adjusted transect names from lower (L) to bottom (B) to match quads, clarified CWD length measurement.	
2.01	April 2007	Geri Tierney Kate Miller Brian Mitchell	Minor editorial changes, added measurement of multiple intersection on a single transect, clarified measurement of length for forked pieces, clarified CWD classes.	
3.00	May 2008	Kate Miller Brian Mitchell	Specified that CWD slopes are taken during plot setup, with the laser rangefinder.	CWD slopes are now measured in degrees, not percent slope.
3.01	December 2008	Kate Miller	Added MIDN to SOP title, added figure and table titles to be consistent with SOP format, minor editorial changes.	
3.02	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.
3.03	December 2009	Kate Miller Andrew Vincello Jim Comiskey	Changed method for dealing with a CWD piece that crosses the same transect more than once or multiple transects.	
3.04	October 2010	Kate Miller	Minor editorial changes	

Revision History Log (continued)

Version	Date	Revised By	Changes	Justification
3.05	January 2013	Kate Miller	Clarified that for pieces that aren't round, crews should take an average of the largest and smallest measurement for diameter. Changed CWD tally rules to exclude pieces that are completely suspended above the ground. Added that a dead branches attached to a snag or live tree only count as CWD if they are >50% severed from the snag/tree.	QA/QC suggested that suspended CWD was often missed. These methods are also more consistent with FIA.
3.06	March 2014	Kate Miller	Replaced LAR with TruPulse	Equipment change.
3.07	December 2016	Camilla Seirup	Added calipers as a diameter measurement option. Added that CWD pieces should be painted at the location where the piece crosses the transect to improve repeatability.	
3.08	January 2020	Camilla Seirup	Changed SOP number	

SOP 11 - Soil Measurements and Sampling

Mid-Atlantic Network/Northeast Temperate Network

Version 4.06

Overview

This SOP will be used to characterize soil depth and chemistry within the rooting zone and provide information on the effects of atmospheric deposition upon the ability of these soils to support forested ecosystems. Soil samples will be shipped to designated facilities for soil chemistry analysis. This SOP also includes a rapid assessment of earthworm presence, used to characterize the spatial extent of earthworms across the network.

Regulations Governing Sample Collection

The National Historic Preservation Act of 1966 (as amended) provides for the protection of historical and cultural artifacts. Due to the random placement of plots, a soil sampling site may be located on a site of prehistoric or historical significance. Park archeologists or cultural resource specialists must be contacted prior to field visits in order to obtain permission to sample. However, if cultural artifacts are encountered at a plot where permission to sample has been granted, do not take a soil sample. Code the site as not sampled and record a note explaining why a soil sample was not taken.

Definitions

Horizons are layers which develop in the soil under the influence of climate, living organisms and other soil forming factors. Major horizons from top to bottom include the O (organic) horizon, A, E (eluviated), B and C horizons.

Forest floor is the top layer of organic matter overlying the mineral soil, consisting of intact and partially decomposed litter and humus, otherwise known as the O (organic) horizon. This protocol will collect forest floor as the consolidated litter and the humus layer only, without unconsolidated litter.

Litter is undecomposed or partially decomposed organic material that can be readily identified as plant leaves, twigs, etc. The upper part of the litter layer is typically unconsolidated and is easily brushed aside. Beneath is a layer of older, compressed litter which has been consolidated.

Peat is partially decomposed organic matter that can accumulate in wet areas under acidic conditions.

Mineral soil is a soil consisting predominantly of products derived from the weathering of rocks (e.g., sands, silts, and clays). As soil develops under the influence of climate, living organisms and other soil forming factors, it typically develops layers or horizons. Typical mineral soil horizons include the A, E and B horizons.

Earthworm burrows are temporary or permanent soil channels made by earthworms for living space and during travel. Burrows can be observed as circular openings in the soil surface. Sometimes burrows are covered by, or surrounded by, casts, litter or organic matter.

Earthworm casts are excreted by earthworms after feeding, and are composed of soil mixed with digested plant residues. Casts appear as distinctive, moist aggregates of rich soil. Cast production is highest during moist spring and fall seasons, but should be visible throughout the summer in areas with established earthworm populations.

Data Collection

Measurements will be taken at the annual soil sampling location. The first time a plot is sampled, the soil measurement location can be found as described here and diagrammed in Figure S11.1. From a position facing upslope at the plot center, turn to face left and travel in a direction parallel to the upper and lower plot boundaries to reach the midpoint of the plot edge, and continue in that same direction 2 m past the plot edge. The first soil sampling location lies within a 2-m radius circle surrounding this point.

During subsequent visits, soil measurement locations will be at 4-m intervals alternating in a diagonal fashion on opposite sides of soil measurement site #1, as shown below in Figure S11.1. To locate the S2 location, stand at ML and face S1. S2 is 5.6 m from ML at 30 degrees (when facing S1).

If the soil cannot be measured or sampled within the designated sampling location due to obstruction (e.g., boulder, tree, standing water), move to the corresponding location off the opposite (right) side of the plot, and attempt to obtain a sample there within a 2-m radius. Note the alternate sampling location in Soil Notes.

Earthworms

Visually assess and record the presence (1) or absence (0) of earthworm casts and burrows at the soil sampling location for the current year. To do so, gently brush aside unconsolidated litter to view casts and burrows at the soil surface. Examine up to three locations within an area approximately equivalent to the 2-m radius available for the soil sample. If examination is inconclusive, record 9, and record a brief note explaining why in Soil Notes.

Soil Sample

Soil samples will be separated and collected by layer whenever possible (Table S11.1). When soil layers are not evident, samples will be separated and collected by depth (Table S11.2 and S11.3). Differences in soils between Acadia NP (ACAD) and the National Historical Parks (NHP) require different methods.

Tables S11.1-S11.3 highlight the methods and data to be recorded in different situations. Detailed procedures follow the tables.

At each plot, sampling of soil in the rooting zone will occur at three places within the current year's sampling location (a 2-m radius circle); samples from the three places will be composited by soil

layer or depth to yield composite samples. Procedures for collecting samples at ACAD differ from **procedures used at the NHPs, as described herein.**

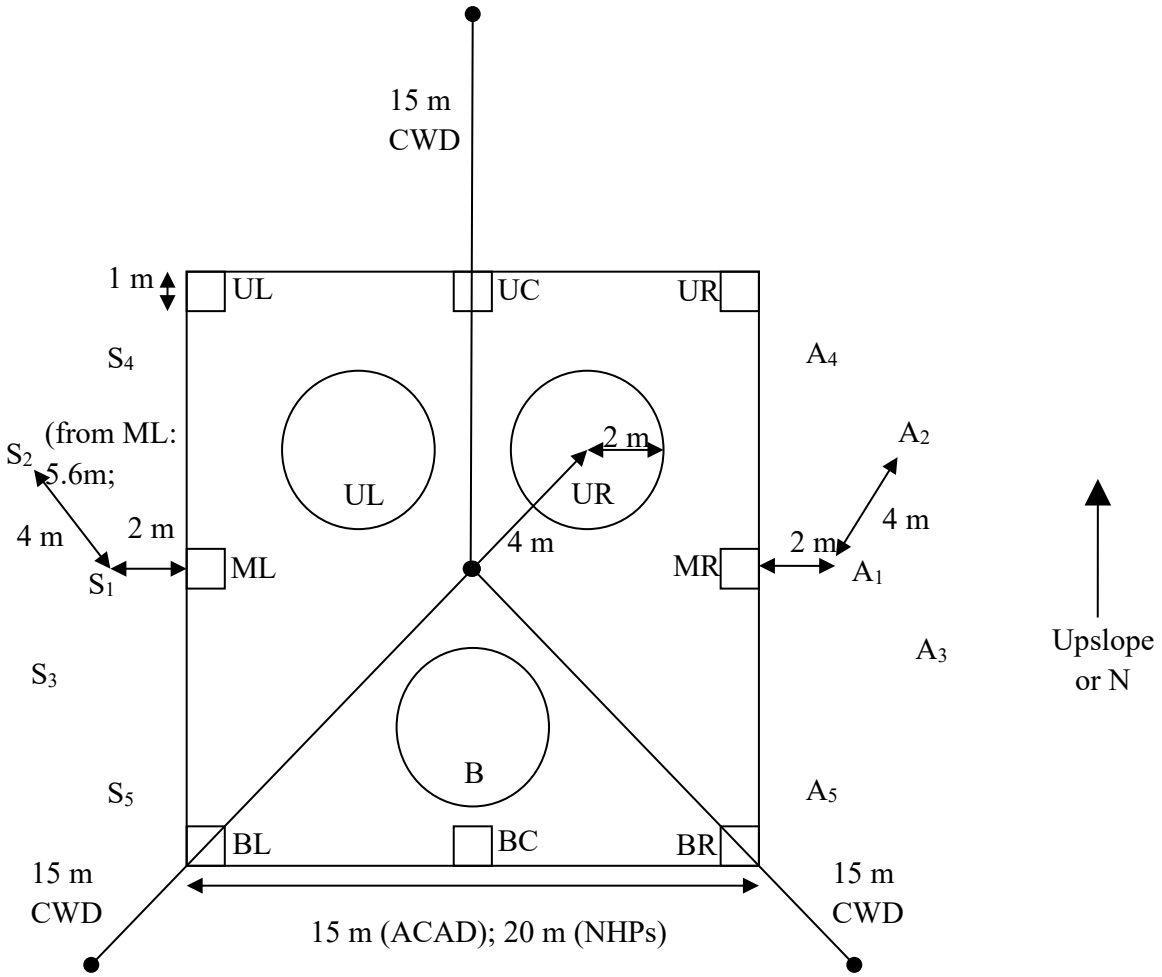


Figure S11.1. Soil sampling location relative to plot. S1 shows location of soil sample during first visit, S2 shows location of soil sample during second visit, etc. (added the alternate soil sample sites to figure on a trial basis).

Table S11.1. Soil sample procedures by horizon.

Soil Layer	ACAD	NHPs
Unconsolidated Litter	Measure depth at two points on frame and remove	Measure depth in core hole
Forest Floor	Excavate using frame and record depth	Collect using core and record layer length in core
A Horizon	Excavate using frame and record total depth. Do not exceed 20 cm total depth of excavation.	Collect using core and record total length of core. Do not exceed 20 cm total length of core.

Table S11.2. No detectable horizons, sample by depth[1].

Soil Layer	ACAD	NHP's
Unconsolidated Litter	Measure depth at two points on frame and remove	Measure depth in core hole
No detectable horizons	Excavate using frame to bottom of fine root penetration or max depth of 10 cm, and record total depth	Collect using core to bottom of fine root penetration or max depth of 10 cm, and record total length of core

[1] In the event of a thick peat layer, exclude litter measurement (record "thick peat" in notes).

TableS11.3. No detectable mineral horizons, hybrid sample

Soil Layer	ACAD	NHP's
Unconsolidated Litter	Measure depth at two points on frame and remove	Measure depth in core hole
Forest Floor	Excavate using frame and record depth	Collect using core and record layer length in core
Mineral soil (no mineral horizons evident)	Excavate up to 10 cm using frame and record total depth. Do not exceed 20 cm total depth of excavation.	Collect up to 10 cm using core and record total core length. Do not exceed 20 cm total length of core.

Begin by visually examining the soil sampling location designated for the current year of measurement. The first sampling place should be the centerpoint of the 2-m radius soil sampling location. If rocks, roots or other obstructions prevent soil sampling at that point, select another location within the 2-m radius circle. If, after 5 attempts, no suitable location exists within that 2-m radius, note this fact in Soil Notes, and move to the corresponding location off the opposite (right) side of the plot and attempt to obtain a sample there.

National Historical Parks and MIDN

Soil will be collected using a soil corer. Gently remove any unconsolidated litter from the soil surface, and drive the soil corer at least 5 cm into the ground. If the core strikes a rock or obstruction before reaching this depth, remove the core and select another location with a radius of 2 m of the original sampling location. The maximum collection depth is 10 cm for an individual sample by depth, and 20 cm for the total excavation. Collect and composite three cores from within this area as follows.

Once a core is exposed, carefully examine the core to identify boundaries between the forest floor, A horizon, and any underlying horizons. The boundary between the **forest floor** and mineral soil can be detected by soil texture and weight. **Forest floor**, comprised of organic matter, will be light in weight and have a greasy feel. Underlying mineral soil may be lighter in color or have a similar dark color to the forest floor, but will contain a mix of organic and mineral particles which will be heavier in weight and may feel gritty. A boundary between the A **horizon** and underlying soil may be identified as the lower extent of fine root penetration, or by changes in soil color or texture. If present, an E horizon would be relatively narrow band that is markedly lighter in color than the overlying A or underlying B horizons.

Use a ruler to measure the thickness of the forest floor (excluding unconsolidated litter), and thickness of the A horizon (up to a total combined thickness of 20 cm). Then, use a knife to separate

the forest floor and A horizon from each other and any underlying horizons. Carefully collect the forest floor (excluding unconsolidated litter), and A horizon in separate plastic bags, clearly labeled with Date of collection, Park, Plot number, and Horizon.

Finally, use a ruler to record the thickness of unconsolidated litter adjacent to the core hole.

If no horizons can be distinguished, use a ruler to measure a) the entire thickness of soil removed, and b) the depth to which fine roots penetrate the core. Then collect soil to the depth of fine root penetration (up to 10 cm) in a plastic bag clearly labeled with Date of collection, Park, and Plot number.

In this manner, collect and composite three cores from this location. Composite corresponding layers (e.g., forest floor) from all three cores into a single bag. This will yield two soil samples per plot (one composite forest floor layer and one composite A horizon); or one undifferentiated sample per plot if no horizons can be distinguished.

Acadia National Park

Soil will be collected using a frame. Place the 10 x 10 cm sampling frame on the ground at the first sampling place carefully to avoid compacting the forest floor. Use small survey flags to mark the approximate midpoints of the upper and lower edges of the frame, and remove the frame. Use a ruler to measure the depth of unconsolidated litter at each flag, to the nearest cm. Some areas may have thick organic layers comprised of peat—partially decomposed organic matter. In this case, omit the litter measurement and note "thick peat" in Soil Notes.

Replace the sampling frame. Using a pair of clippers, carefully remove all live vegetation from the sample area. Living mosses should be clipped at the base of the green, photosynthetic material. Then brush aside all unconsolidated litter (leaves, bark, wood fragments, etc.) and deposit this material outside the sample frame (it may help to clear litter 3-5 cm around the outside of the quad to keep litter from falling into the quad while excavating). Unconsolidated litter will easily be brushed aside by hand. Consolidated litter (leaves, etc.) which has begun to compress and decompose should not be removed, as it is part of the forest floor layer. The maximum collection depth is 20 cm total excavation, and 10 cm for a single sample of undifferentiated soil sampled by depth.

Next, collect the forest floor as follows. Use a sharp knife or keyhole saw and a pair of clippers to carefully cut through the forest floor along the inner surface of the frame to separate it from the surrounding soil. Using inward scooping motions, carefully collect and bag the forest floor layer (excluding unconsolidated litter) within the sampling frame to the depth at which mineral soil is detected. Discard all recognizable woody debris including pine cones, large pieces of bark, and decomposed wood, and any rocks or pebbles. The boundary between the forest floor and the underlying mineral soil can be detected by soil texture and weight as described above. In the case of a thick organic layer comprised of peat, collect to a maximum depth of 10 cm. Collect material in a plastic bag, clearly labeled with Date of collection, Park, Plot number, and Horizon. Now, record the thickness of the forest floor layer (excluding unconsolidated litter) as the distance from the top of the consolidated litter to the bottom of the excavation so far.

After the forest floor layer is collected, identify and collect the A horizon as follows. Expose a soil profile along the inside edge of the frame using a trowel or by taking a soil core just outside the frame. Examine the profile to find the point at which fine roots penetrate no further into the soil, and look for any distinct changes in soil texture and color as described above.

If an A horizon is apparent, carefully collect the A horizon within the sampling frame into a plastic bag (to a maximum total excavation depth of 20 cm). Clearly label the bag with Date of collection, Park, Plot number and Horizon (A). Now, record the total depth reached as the distance from the top of the consolidated litter to the bottom of the excavation.

If the boundary between the forest floor and A layer is difficult to determine or no horizons can be differentiated, collect soil within the sampling frame to the depth of fine root penetration (up to a maximum of 10 cm) in a plastic bag clearly labeled with Date of collection, Park, and Plot number. Record the depth of soil collected.

Alternatively**, if a forest floor layer has been collected but no mineral horizons can be differentiated**, collect mineral soil within the sampling frame to the depth of fine root penetration (up to a maximum of 10 cm for this sample and 20 cm for the entire excavation) in a plastic bag clearly labeled with Date of collection, Park, and Plot number. Record the total depth reached as the distance from the top of the adjacent consolidated litter to the bottom of the excavation.

Next, repeat this entire procedure at two additional places within this year's soil sampling location (2-m radius circle). All three samples should be composited by soil layer (forest floor or A horizon) to yield a total of one or two samples per plot.

Unconsolidated Litter Thickness

Measure the depth of unconsolidated litter to the nearest cm as described above. Gently pat down (do not compress) the litter prior to measurement so that the litter is the same height it was before it was disturbed. Be sure that you are only measuring the unconsolidated litter (i.e., do not sink the ruler into the consolidated litter). Some areas may have thick (> 20 cm) organic layers comprised of peat—partially decomposed organic matter. In this case, omit the litter measurement and write “thick peat” in the soil notes.

Forest Floor Depth

Record to the nearest cm the thickness of the forest floor collected (excluding unconsolidated litter). If the lower boundary cannot be discerned, omit this measurement.

Total Depth Collected

At ACAD, record to the nearest cm the total depth collected (up to 20 cm) as the distance from the top of the consolidated litter to the bottom of the excavation. In the NHPs, record the total length of the core collected (up to 20 cm).

A Thickness

At the NHPs only, measure and record to the nearest centimeter the thickness of A horizon collected. If no distinct A horizon is evident, omit this measurement.

Soil Notes

Note which, if any distinct horizons were evident at this site. If it was difficult to find a suitable soil location, note that here, record the reason, and note if it was necessary to sample on the alternate side of the plot. Record any unusual soil features.

Sample Drying

Upon return from the field, leave soil sample bags open to air-dry in a safe location until soil no longer appears moist. To do so, gently squeeze the soil from the outside of the bag to break up clumps, and arrange the sample so it has maximum exposure to the air (fold back the lip of the bag, move soil out of the corners of the bag, and let the sample lay as flat as possible). In order for this to work properly, soil sampling bags should be flexible plastic bags that are wider at the opening than they are long. Soil sample bags should always be open, unless in transit or completely dry. Bags closed for extended periods of time may grow mold or other fungi, and may impact soil analyses. As the soil dries, **check and mix the sample daily** by gently squeezing from outside the bag. During the soil drying process, do not handle the soils with bare hands or allow contact with any other potential contaminant.

If a **drying oven** is available (such as at ACAD and FRSP), place open sample bags in oven set to 30-35° C (85-95° F) until dry. Arrange sample bags and check as described above for air-drying. Clearly mark the outside of the oven with a note identifying the date, a crew member's name and contact information, and the temperature at which the oven must remain. **If more samples need drying than can fit in the drying oven, keep the extra samples open, and in a safe, dry place.** Monitor samples in the oven and in the alternate location daily.

Record the date each sample finishes drying. Once samples are dried, seal bags and store them in a labeled box until your supervisor directs you to send the set of samples to a designated soil chemistry lab for analysis.

Prior to sending samples to the lab, **prepare a master list of sample information**. Assign each sample a unique number from 1 to n, mark this number prominently on the bag (using a different color ink than other info on the bag and circle this number), and create a list identifying which sample number corresponds to which park, plot number, soil horizon or depth increment, date collected and date finished drying. Print a copy of this list for NETN, and include a copy with the samples when shipped or delivered to the lab.

Sample Analysis

Dried samples should be sent to a designated soil chemistry lab for analysis. The designated lab should have experience analyzing forest soils. Several soil laboratories have sufficient capabilities, including the Analytical Lab at the University of Maine (http://anlab.umesci.maine.edu, contact Sue Erich at erich@maine.edu).

The lab should prepare samples by passing each through a 2 mm sieve to remove larger particles. Analysis must include:

- Total carbon and total nitrogen by dry combustion
- NH_4Cl extractable ions including Ca and Al

Soil Archiving

Once soil samples are returned from the analytical lab, samples may be archived to allow for future analyses. Original soil samples (≥10g) should be archived in 4 mil sealable plastic bags (6” X 6”), filling bag no more than approximately 2/3 full. If original sample is not available, then use the sieved/pulverized sample found in the small Whirl-Paks that were returned from the lab. Remaining soil from the analyzed samples should either be discarded or stored in an additional sample bag. Soil sample labels should be printed on acid-free paper using a pencil and contain: Sample (UMO) number, Park, Plot, Layer, Date collected, Date dry, and Sample Type. Sample type refers to whether the sample is the original unsieved/pulverized sample (label as "original") or the sieved/pulverized sample (label as "sieved"). Labels should be inserted into small (2” X 3”, 2 mL) plastic bags. Label and soil bags should both be kept in 6”X6” bags and stored in an acid-free cardboard box.

Original Sample Type

The original soil sampled in pure form, containing consolidated litter of the organic layer, and/or aggregates of varying size from the A-layer.

Sieved/Pulverized Sample Type

Soil that has been sorted with larger particle sizes removed, or pulverized to create uniform soil particle size. The analytical lab encloses these samples in small Whirl-Paks.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
2.00	June 2006	Geri Tierney Brian Mitchell	Changed soil sample to a composite sample, separated by horizon.	
3.00	September 2006	Geri Tierney Brian Mitchell	Added earthworm and humus measurements from Forest Floor SOP. Included instructions for drying samples. Included specifications for soil analysis. Added soil notes. Revised instructions to separate by depth if soil layers are not identifiable.	
3.01	December 2006	Geri Tierney Brian Mitchell	Altered instructions for separating soil horizons and collecting sample	

Revision History Log (continued)

Version #	Date	Revised by	Changes	Justification
4.00	November 2007	Geri Tierney Kate Miller Brian Mitchell	Clarified need to sample soil from the rooting zone only. Revised instructions for collecting soil in NHPs to use soil corer. Clarified instructions for sites without clear horizons.	
4.01	May 2008	Geri Tierney Kate Miller Brian Mitchell	Clarified litter depth measurement to refer to unconsolidated litter. When using the frame, clear unconsolidated litter for several cm around the frame. Humus thickness excludes unconsolidated litter. Total depth excludes unconsolidated litter. Litter thickness is unconsolidated litter (previously was consolidated + unconsolidated. Specified that litter can be patted down if it has been disturbed. Clarified and simplified terminology for layers. Clarified sample depths and added tables summarizing procedures and depths.	
4.02	December 2008	Geri Tierney Kate Miller Brian Mitchell	Clarified that soil sample bags should always be open, unless in transit or completely dry. Clarified that soil samples should not be handled with bare hands post collection.	
4.03	December 2009	Kate Miller Andrew Vincello	Added location of S2. Clarified unconsolidated leaf litter measurement	
4.04	October 2010	Kate Miller Jesse Wheeler	Added MIDN to National Historic Parks section Added instructions for archiving soil samples Minor editorial changes	
4.05	November 2017	Kate Miller	Clarified labeling for archived soils	
4.06	January 2020	Camilla Seirup	Changed SOP number	

SOP 12 - Quadrat Measurements

Mid-Atlantic Network/Northeast Temperate Network

Version 4.12

Overview

This SOP measures the composition and abundance of understory vascular plants. Lichen genera are also recorded if possible. In Northeast Temperate Network (NETN) parks, species percent cover data are collected in eight 1-m^2 quadrats nested within each plot; in Mid-Atlantic Network (MIDN) parks, the data are collected on twelve 2 x 0.5-m^2 quadrats. This SOP is designed to be conducted by two people, one of which must be a vegetation specialist or crew member familiar with vegetation at the sampled park. This protocol should be used only during the summer months (about June 1 to August 31 in NETN parks, and to September 30 in MIDN parks).

Percent cover classes used for this protocol are: 0, < 1, 1-2, 2-5, 5-10, 10-25, 25-50, 50-75, 75-95, 95-100%.

Notice the exact breakpoints (e.g., 25%) are not included in any class. Classes are either above or below each breakpoint. This is not a mistake—it is to encourage the crew not to waste time trying to decide if the correct value is exactly 25%. The most suitable class should be rapidly assessed and recorded.

Data Collection

In NETN parks, quadrats are nested within each of the four corners of the plot and at the midpoints of each plot edge, for a total of eight quadrats. At plot corners, anchor the quadrat with the corner stake and align the quadrat along plot edges. At midpoints, align the quad edge with the plot edge so that the plot midpoint stake also demarks the midpoint of that aligned quad edge.

In MIDN parks, three quadrats are located at 2 m, 5 m, and 8 m along each of the three coarse woody debris (CWD) transects, and one quadrat is at the center of each microplot. For the quadrats located along these transects, the bottom of the quadrat is placed at the defined distance with half the quadrat stretching to either side of the transect. The top of the quadrat will therefore be located at 2.5 m, 5.5 m, and 8.5 m respectively. For the microplot quadrats, the quadrat base is placed at the middle of the microplot and oriented so the quadrat sides face the plot center (Figure S12.1). The top of the quadrat will therefore be located at 6.5 m from the plot center. MIDN quadrats should be sampled as soon as plot setup is complete to minimize trampling.

A useful quadrat frame can be made from PVC pipe and pipe joints—the joints are detachable to improve maneuverability. The quadrat should be placed so that it follows the contour of the ground. Level the quadrat, if necessary, by propping up the quadrat corners. In areas of thick vegetation, quadrat sides should be slid through the vegetation. Carefully mark the midpoints of each quadrat frame edge with a permanent marker in order to accurately line up the quad frame with plot markers.

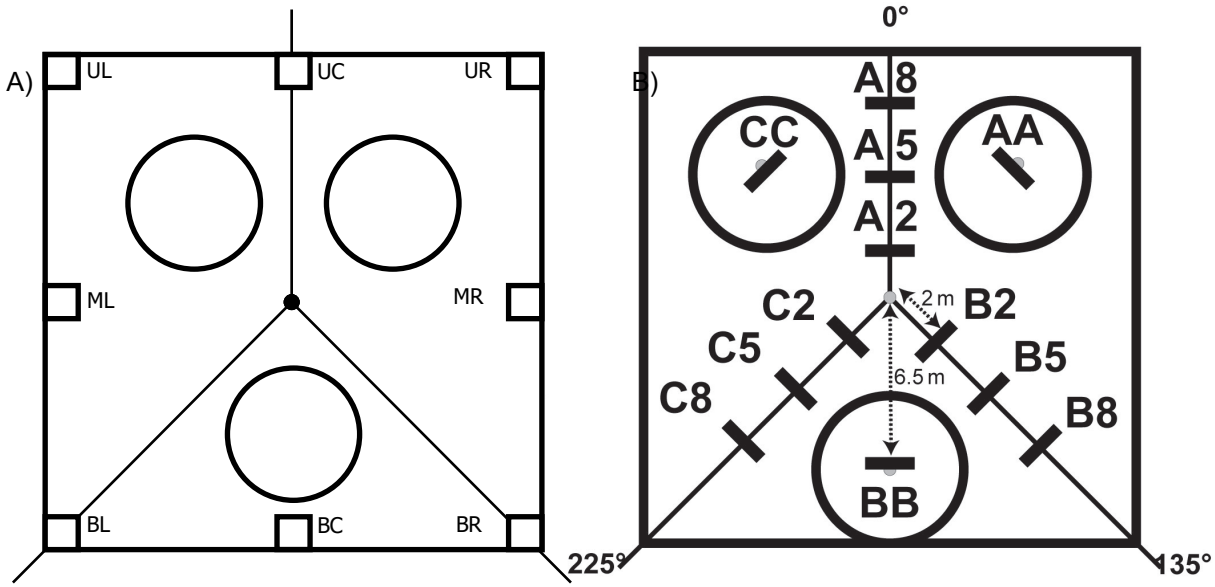


Figure S12.1. Layout and naming of quadrats in A) NETN parks, and B) MIDN parks.

Quadrat Code

Record the code(s) corresponding to each quadrat within which the species was found: Codes in NETN are upper-center (UC), upper-right (UR), mid-right (MR), bottom-right (BR), bottom-center (BC), bottom-left (BL), mid-left (ML), and upper-left (UL). For the MIDN the quadrat codes are shown in Figure S12.1.

Quadrat Sampling Status

Record whether each quadrat was sampled (1) or not (0). If a quadrat was not sampled, record the reason in Quad Notes. This might occur if no vascular plants are rooted in or overhanging the plot, or if a safety hazard exists.

Quadrat Trampling

Examine each quadrat prior to sampling and record "1" if more than 10% of the ground surface of any quadrat appears trampled. If not, record "0". Trampling is defined as damage to plants or disturbance of the ground layer by humans, livestock, or wildlife. Include trampling caused by the field crew, and note this in Quad Notes.

<u>The next six measurements of Quadrat Characteristics are made to determine the % of quadrat area unavailable to vascular plants.</u> Note that distinguishing between wood and stem are less important than making sure the same non-plant area is only included in one cover estimate.

% Stem

Record % cover of vertical (less than 45 degrees from vertical) woody stem ≥ 1 cm DRC within the quad using the cover classes listed above.

% Wood
Record % cover of live or undecomposed dead wood (large root or coarse woody debris ≥ 5 cm diameter) within the quad using the cover classes listed above. Wood suspended above the ground should not be included in this estimate. Wood is greater than 45 degrees from vertical.

% Rock
Record % cover of exposed rock within the quad using the cover classes listed above. If rock is visible beneath unconsolidated litter include that area as rock. If consolidated (aggregated) litter, moss or non-crustose lichens cover the rock surface, do not include that area as rock.

% Cover Bare Soil
Record % cover of bare soil within the quad using the classes listed above. Bare soil is defined as exposed mineral soil with no leaf litter or duff layer (i.e., O horizon) present.

% Sphagnum
Record % cover of sphagnum moss within the quad using the cover classes listed above.

% NS Bryophyte
Record % cover of non-sphagnum bryophytes within the quad using the cover classes listed above.

% Lichen
Record % cover of lichens "rooted" in the substrate within the quad using the cover classes listed above. Lichens that have fallen from the canopy or are attached to recently fallen branches should not be included in the % cover estimation.

Quadrat Species—NETN
Each quadrat is examined for vascular plant species found rooted in or overhanging within 1.5 m above the ground by a team of two people, one of which must be familiar with vegetation at this park (i.e., a crew member familiar with flora of that park or a contract botanist). A list of species is recorded, including vines and epiphytes as long as they are vascular plants and are overhanging within 1.5 m above the ground. Then, % cover of the foliage of each species is jointly estimated and recorded by the team of two people. Use the cover classes listed above. Cover is based on a vertically-projected polygon described by the outline of the foliage, ignoring any normal spaces occurring between leaves, up to a maximum height of 1.5 m. The 1.5 m height should follow the contour of the ground.

New germinants of woody species receive special treatment because cover of these germinants fluctuates greatly within and among years. For each woody species, record and estimate cover of this year's germinants separately from more established specimens. Specify records for germinants by checking the "germinant" box in the database. The germinant category only refers to seedlings that have germinated from seed within the current growing season. These seedlings typically are very small (< 5 cm tall), and will display cotyledons (rudimentary seed leaves) and possibly one-two true leaves or a single whorl of fine needles.

If a plant cannot be identified to species quickly and confidently, assign the species a specimen number, record genus or family, if possible, and give a short descriptive name. If the unknown plant

is not locally sparse, collect a specimen away from the quadrat as described below. Do not collect any plants that are represented by five or fewer individuals (i.e., locally sparse) in the general vicinity of the plot. Do not collect if plant occupies less than 1% canopy cover on subplot *and* no mature foliage or reproductive parts are present; these plants would be too difficult to identify. Any time it is not possible to collect a specimen, collect a photograph as described in the **Unknown Species Photos** section below

If lichen genus is known, record percent cover of genus that is "rooted" in the plot substrate (e.g., rock, soil, CWD, or tree stem). Lichens that have fallen from the canopy or are attached to recently fallen branches should not be included in the % cover estimation. If lichens are present, but genus is unknown, record total % lichen cover in quadrat characteristics section only.

Quadrat Species—MIDN

A similar process is used in the MIDN parks with the following differences. A select group of herbaceous species are targeted for estimation of % cover in the quadrat. These include invasive exotics and some native species (Table S12.1). For other herbaceous species in the quadrat, their total cover is estimated and recorded as a single value. Starting in 2019, % cover of all woody species (mature trees, saplings, seedling, shrubs, and woody vines) rooted or hanging over the quadrat will be assessed by species. All growth stages of a tree species should be included in the % cover estimation and be recorded in the Quadrat Species tab of the database or datasheet. In other words, follow the same procedures for woody species in MIDN that are done in NETN for Quadrat Species. In addition, % cover of tree seedlings will continue to be assessed separately and recorded on the MIDN Quadrat Seedling datasheet to maintain continuity with historical data (see below).

Tree seedlings are measured using the protocols outlined for the regeneration plots in SOP 10 - Microplot; seedlings are identified and assigned to a height class category. For each tree seedling species the total cover within the quadrat, including seedlings rooted outside with foliage overhanging inside the quadrat, are also estimated. For seedlings that are smaller than 15 cm (5 cm in VAFO), no height measurement is taken, but the total cover within the quadrat is estimated. Starting in 2017, deer browse is assessed for each tree seedling that is >15cm (>5cm VAFO) tall and rooted in the quadrat. Browse is recorded as a tally of browsed seedlings by species per quadrat. The presence of deer browse is only recorded if the browse is determined to have occurred within the last four years. Pay careful attention to differentiate between deer and rabbit browse (see SOP 7 Stand and Site Measurements: Deer Browse Index).

Plot Species

In NETN parks, a time-constrained search for additional species is conducted on the whole plot by the vegetation specialist or crew member familiar with vegetation at this park. Record all additional species rooted within or overhanging the plot, searching for no more than 15 minutes (not including time spent identifying or looking up species). If portions of the plot are wet, only emergent plants are recorded. Epiphytes and vines are recorded as best as possible as seen from the ground level. For MIDN parks, the time constrained search is limited to the presence of target species that were not found in the quadrats and all woody species found in the plot.

Quad Notes

Record any note-worthy observations, including reason quadrat was not sampled, or trampling of quadrat by the field crew.

Plant Collection

Do not collect any plant that is locally sparse as described above. Use a digging tool to extract the entire plant, including any underground portions, flowers, fruits, and leaves. Collected unknown specimens should be transported from the field in zip-lock bags. Bag must be labeled with day of collection, plot, and specimen number. It is essential that each specimen be assigned a number to allow accurate matching of identified species with field measurements. Promptly identify collected plants, present plants to your supervisor for identification, or press specimens for later identification.

Unknown Species Photos

Photos of unknown plants must be taken on the digital cameras provided by the NETN and MIDN. If the digital cameras are unavailable, the smartphones provided to the crew may be used. Personal phones and cameras should never be used.

To ensure identifying information is attached to all unknown photos, fill out the Unknown Plant Photo Card included in the Field Notecards using a dry erase marker. Take a photo of the completed photo card before taking the rest of the documentation photos. If a photo card is not available, write the Park, Plot, Date, and UNK# on a piece of paper. Place a ruler in at least one of the photographs for scale and allow the camera to automatically select the appropriate aperture for the given light conditions. Close-up photos should be taken using the macro lens setting. Photos should be downloaded at the end of the field day to a folder devoted to photos of unknowns. Name the file using the following format (UNK# is the name in database/ datasheet):

4-character park code _3-digit plot code _UNK#_Date (YYYYMMDD)

Example: ACAD_121_001_20100713.jpg

Table S12.1. List of targeted herbaceous species measured in the quadrats in MIDN parks. The list is consistent with protocols used by the National Capital Region Network. Note that species have been added to this list over time. For a history of these changes, refer to Table S17.4 in the Summary of Major Protocol Changes and Deviations for the Northeast Temperate Network Long-term Forest Monitoring Protocol.

Species	Common Name	Synonyms
Exotic Species		
Akebia quinata	Five-leaved akebia	
Alliaria petiolata	Garlic mustard	
Ampelopsis brevipedunculata	Porcelain berry	
Berberis thunbergii	Japanese barberry	
Cardamine impatiens	Narrowleaf bittercress	
Celastrus orbiculatus	Oriental bittersweet	
Centaurea stoebe	Spotted knapweed	*Centaurea biebersteinii*
Cirsium arvense	Canada thistle	
Clematis terniflora	Yam-leaf clematis	
Dioscorea oppositifolia	Chinese yam	
Duchesnea indica	Mock strawberry	

Species	Common Name	Synonyms
Euonymus fortunei	Creeping euonymus	
Fallopia japonica	Japanese knotweed	*Polygonum cuspidatum*
Glechoma hederacea	Ground ivy	
Hedera helix	English ivy	
Hemerocallis fulva	Common daylily	
Lespedeza cuneata	Chinese lespedeza	*Sericea Lespedeza*
Ligustrum spp.	Privet	
Lonicera japonica	Japanese honeysuckle	
Lonicera maackii	Amur honeysuckle	
Lonicera spp. (exotic)	Bush honeysuckles	
Microstegium vimineum	Japanese stiltgrass	
Oplismenus hirtellus spp. *undulatifolius*	Wavy-leafed basketgrass	
Persicaria longiseta	Oriental lady's thumb	*Polygonum caespitosum, Persicaria posumbu*
Persicaria perfoliata	Mile-a-minute	*Polygonum perfoliatum*
Pueraria montana	Kudzu	
Ranunculus ficaria	Lesser celandine	
Rosa multiflora	Multi-flora rose	
Rubus phoenicolasius	Wineberry	
Vinca minor	Periwinkle	
Wisteria spp.	Wisteria vine	
Native Species		
Aralia nudicaulis	Wild sarsaparilla	
Arisaema triphyllum	**Jack in the pulpit**	
Cyperaceae spp.	Sedges	As a group
Dennstaedtia punctilobula	Hayscented fern	
Eurybia divaricata	White wood aster	
Ferns (not including those below)		As a group
Gaylussacia spp.	Huckleberry	
Impatiens capensis	Jewelweed	
Laportea canadensis	Canadian woodnettle	
Lilium spp.	Lilies	As a group
Lonicera spp. (native)	Native honeysuckles	
Maianthemum racemosum	False Solomon's seal	*Smilacina racemosa*
Medeola virginiana	Indian cucumber	
Orchids		As a group
Poaceae spp.	Grasses	As a group
Podophyllum peltatum	Mayapple	
Polygonatum biflorum	Smooth Solomon's seal	
Polygonatum pubescens	Hairy Solomon's Seal	
Polystichum acrostichoides	Christmas fern	
Rubus spp.	Blackberries	As a group
Sanguinaria canadensis	Bloodroot	
Thelypteris noveboracensis	New York fern	
Trillium spp.	Trilliums	
Uvularia perfoliata	Perfoliate bellwort	
Uvularia sessilifolia	Wild oats; Sessile-leaf bellwort	
Vaccinium corymbosum	Northern highbush blueberry	
Vaccinium stamineum	Deerberry	

Species	Common Name	Synonyms
Vaccinium spp.		As a group except *V. corymbosum* and *V. stamineum*
Vines		
Campsis radicans	Trumpet creeper	
Parthenocissus quinquefolia	Virginia creeper	
Smilax glauca	Cat greenbrier	
Smilax rotundifolia	Common greenbrier	
Smilax spp.	Greenbrier	Other; as a group
Toxicodendron radicans	Poison ivy	
Vitis spp	Grape vine	

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
2.00	June 2006	Geri Tierney Brian Mitchell	Number of quads per plot increased to eight. Percent cover class of species is now recorded in quads. % cover class of ground unavailable for plants is now recorded in quads by category. % cover class of both sphagnum and non-sphagnum bryophytes now recorded in quads. Upper boundary for veg quad sampling decreased from 2 m to 1 m.	
3.00	September 2006	Geri Tierney Brian Mitchell	Added additional stakes to mark all veg quads. Use team of 2 people to assess veg quads. Adjusted upper height boundary of veg quad sampling from 1 m to 1.5 m. Emphasized proper labeling and numbering of unknown plants collected. Included trampling by field crew in trampling measurement. Changed names of lower quads (L) to bottom (B). Clarified reason for % rock, wood, and stem measurement in quads. Added quad notes.	To avoid confusion with left (L).
3.01	December 2006	Geri Tierney Brian Mitchell	Included clarification regarding breakpoints and cover classes. Clarified epiphytes and vines are included only if vascular and overhanging quad within 1.5 m.	
3.02	April 2007	Geri Tierney	Minor editorial changes.	
3.03	November 2007	Kate Miller Geri Tierney Brian Mitchell	Noted that quad frame midpoints must be marked with permanent marker for accuracy. Changed % Stem DRC cutoff to 1 cm. Changed % Wood diameter cutoff to 5 cm. Minor editorial changes. Revised lichen % cover. Added separate woody germinant record.	
4.00	May 2008	Brian Mitchell Jim Comiskey Kate Miller Geri Tierney	Incorporated MIDN procedures.	

Revision History Log (continued)

Version #	Date	Revised by	Changes	Justification
4.01	December 2008	Kate Miller Jim Comiskey Brian Mitchell Geri Tierney	Changed name of SOP from Vegetation Diversity to Quadrat Measurements Added % Lichen to the Quadrat Characteristics section. Updated list of target species in Table S12.1. Minor editorial changes.	Instead of recording Lichen in the quadrat species section. If lichen genus is known, it will be included in the quadrat species section. Added notation to track when species was included for monitoring.
4.02	April 2009	Kate Miller	Minor editorial changes.	
4.03	May 2009	Sarah Lupis Kozlowski	Minor editorial changes, formatting.	Conform to NPS standards.
4.04	December 2009	Kate Miller Jim Comiskey Brian Mitchell	Clarified that the quadrat should follow the contour of the ground. Added that % wood only includes wood on the ground. Clarified MIDN microplot location Added bare soil definition Minor editorial changes Addition and modification to MIDN target species list	
4.05	October 2010	Kate Miller Jesse Wheeler	Clarified that seedling percent cover in MIDN is estimated for seedlings rooting or overhanging. Clarified that % rock doesn't include non-crustose lichens. Minor editorial changes	
4.06	January 2013	Kate Miller	Added that quadrats in MIDN should be sampled as soon as plot setup is complete to minimize trampling. Clarified that the 15min. plot search does not include time spent keying or looking up plants.	
4.07	March 2014	Jesse Wheeler	Split Vaccinium spp. and Gaylussacia spp. on the indicator species list.	
4.08	February 2016	Aaron Weed	Updated deer browse monitoring for MIDN seedlings.	
4.09	January 2017	Camilla Seirup	Updated deer browse monitoring protocol to reflect 2017 implementation.	
4.10	January 2018	Jim Comiskey Camilla Seirup	Modifications to indicator species list for MIDN.	

Revision History Log (continued)

4.11	February 2019	Camilla Seirup Kate Miller	Added all woody species to quadrat species data collection in MIDN. Added that unknown species photos should have an ID card filled out and photographed along with the plant. Clarified that only NPS-provided cameras can be used for unknown photos. Removed dates added from Table S12.1. Information now captured in Table S17.4. Changed *Trillium cernuum* to *Trillium* spp. and *Wisteria sinensis* to *Wisteria* spp. to include the other possible species and to accomodate the crew's inability to differentiate late in the season. No historical data was affected.
4.12	January 2020	Camilla Seirup	Changed SOP number

SOP 13 – Collecting and Aging Tree Cores

Mid-Atlantic Network/ Northeast Temperate Network

Version 1.01

Overview

This SOP details the process of collecting and reading tree core samples. Many of the methods are adapted without citation from Maeglin (1979), which is a U.S. Forest Service technical report that details methods for collecting and processing tree cores.

Definitions

Increment borer is used to core trees, and consists of a handle, auger and extractor (Figure S13.1).

Pith is the central core of the tree.

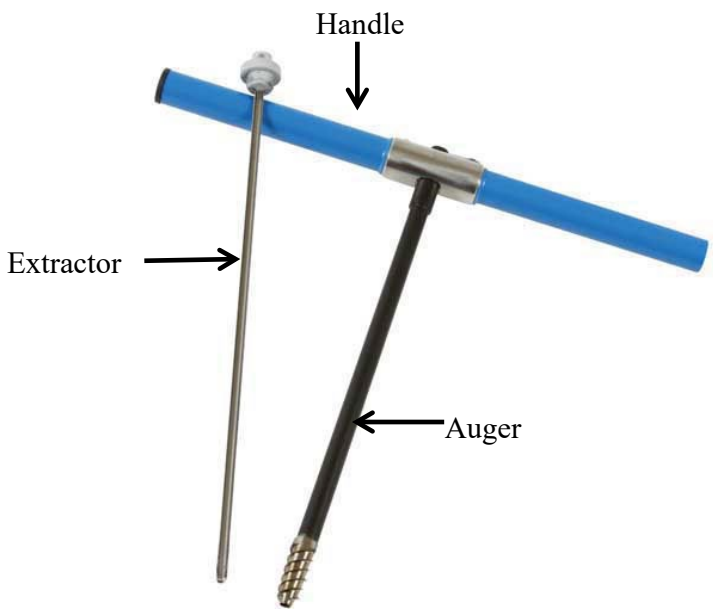


Figure S13.1. Parts of the increment borer.

Procedure

Coring the Tree

At each plot, select two co-dominant and two intermediate trees outside the plot and within 10 m of the boundary. Selected trees should be as representative of the trees in the plot as possible. For example, core only species that are well-represented in the plot.

Select an area on the bole that is at DBH, is free of wounds, branch stubs, unusual swellings, etc. If possible, collect the core along the longest bole radius to the pith, as this will minimize anomalies such as missed rings (Figure S13.2).

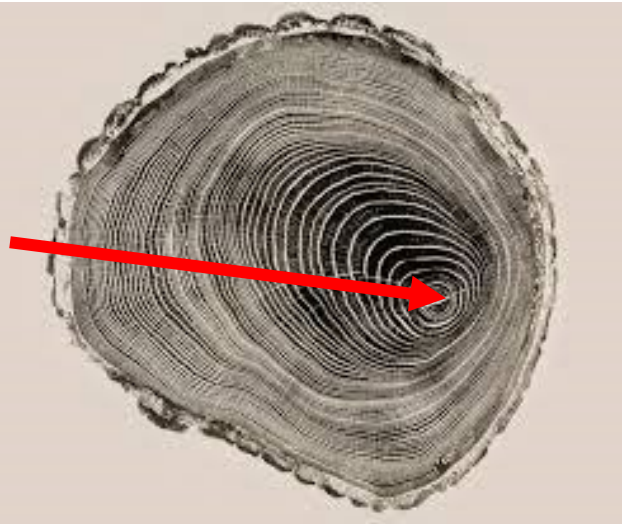


Figure S13.2. Cross section of tree bole to show arrangement of borer along the longest axis (red line).

Align the borer as straight as possible, and make every effort to hold the borer auger steady. Allowing the borer auger to wobble upon penetration will cause the tip of the core sample to break into many pieces.

1. Use the smallest borer that will reach the pith as possible, and check that the borer you are using will reach the pith by lining up the extractor. A smaller borer will allow for better leverage and easier penetration into the tree.

2. Borer starters may also be used in order to steady the borer shaft. Starters consist of a plate that is pressed against one's chest, which allows for both hands to rotate the borer and stabilizes the pivot points of the barrel.

3. If a borer starter is not used, begin coring by steadying the threaded tip end with one hand and rotating the borer clockwise with the other hand. Once the threaded bit has fully penetrated the wood, use both hands to rotate the borer.

Pay special attention to the alignment of the borer to ensure it is heading into the pith of the tree, otherwise multiple annual rings may be missed. Although the pith is not always located directly in the geometric center of the tree, this is generally the best location to aim. Branch stubs point towards the pith of the tree, and can also be helpful for aligning the borer. To estimate if the center of the tree has been reached, hold the core extractor next to the borer. The borer and extractor are similar lengths, and thus the end of the extractor provides a good estimate of where the end of the borer is in the stem. Notable situations include:

1. Forked trees, which are crowded on one side, and add more wood to the opposite side. This causes the pith to be shifted toward the fork. Avoid coring forked trees.

2. Leaning trees form “reaction wood” which is difficult to interpret and not representative of the true age. If possible, do not bore leaning trees. If you must, take the core along the contour of the slope (i.e. neither on the upslope nor downslope side of the tree).

When the pith is reached, gently insert the core extractor inside the borer. Rotate the borer two full turns in a counter-clockwise direction and remove the extractor and the core. Be particularly careful removing the extractor so the core is not dropped. Discard cores that are rotten at the center or are broken in more than two pieces from the pith to the outside of the core, and select another tree to core. Repeat this process until you have four good cores, but do not core more than eight trees total for a plot.

Store the core sample in a slotted plastic tray, and be consistent with the direction you store the bark end of the core. Store the tray in a zipper-locked plastic bag inside a metal clipboard to protect it.

Immediately after the core is completed, remove the borer from the tree by turning it in a counter-clockwise direction. Compressed wood surrounding the auger will rebound and cause the borer to become stuck if left in the tree for long. Once the borer is removed, check that the tip is clear; often a small piece of core will remain jammed in the tip of the borer. To dislodge this piece, use a small hardwood peg or dowel. Center the peg on the jammed wood, and gently tap it out with a rubber mallet. If possible, avoid hammering the core out with a metal tool, as this will inevitably chip the cutting edge of the borer. Do not plug the hole in the stem left by the core.

For each core collected, record:

1. Plot #
2. Core tray #
3. Core slot #
4. Tree species
5. Crown class (co-dominant or intermediate)
6. DBH
7. Corer initials
8. Notes

Increment Borer Maintenance

Common issues such as broken, ragged, and stained cores can be easily minimized by following basic maintenance procedures to keep the increment borer in good condition.

<u>Cleaning the Borer</u>

Wrap a piece of tissue paper or cloth patch around the extractor tip, and spray with WD-40. Rub the paper along the inside of the borer. Spray WD-40 directly onto the borer barrel and extractor and wipe clean. Alternatively, a .22 caliber gun cleaning kit also works well.

<u>Sharpening the Borer</u>

Sharpening the borer will require a flat sharpening stone, a round sharpening stone, and cleaning oil. Begin by adding a few drops of oil to the flat stone and place the tip of the cutting edge on the stone

at a 45° angle. Move the cutting edge up and down along the stone, while rotating the tip continuously clockwise and counter-clockwise between your fingers. Continue until the cutting edge appears sharp. Next, add a drop of oil to the rounded stone, and insert about three-fourths of the way into the cutting edge hole. Align the stone until it is in contact with the inside wall of the hole. Rotate the borer shaft a few times until sharp.

In general, a borer that is cleaned more often will require sharpening less often, because keeping the cutting edge clean will reduce rust and corrosion. Avoid metal-to-metal contact with the tip of the borer. Such preventative care will keep the borer in better condition for a longer period.

Analyzing Tree Cores

Preparation

Allow cores to air dry outside the plastic bag for 1 or 2 days before attempting to sand. If possible, orient the cores so the xylem vessels are facing vertically. The xylem vessels are small vertical tubes in the wood that are important for water transport along the stem, and appear as small oval to circular-shaped holes in the core. Sand the core by hand using progressively finer grits, finishing with at least a 320 grit. Dampen a paper cloth with water and rub along the length of the core in order to remove the sawdust clogging the vesicles. As an alternative, buffing the core with a lamb's wool pad may achieve the same result.

Distinguishing rings can be particularly difficult for diffuse-porous hardwoods (especially aspens). Several staining methods are available, though they vary in effectiveness and some involve using hazardous chemicals. Fehling's Solution, which is a solution of copper sulfate, potassium sodium tartrate, and sodium hydroxide, is a common staining option for distinguishing between heartwood and sapwood, but may not help distinguish early and late wood within rings (Asherin and Mata 2001). Fluorescent markers may help distinguish early and late wood, especially if a black light is available. Phloroglucinol may be most effective but is also most hazardous, as the process involves soaking the core in 50% HCl solution (Maeglin 1979).

Reading

Rings can be counted using a 10x dissecting microscope. The use of a dissecting needle is beneficial for keeping track of counted rings.

Because specific annual rings are not being assigned specific years, and because only living trees are being cored, the process of cross dating is not necessary for the purpose of this SOP. Simple ring counting will generally provide a reasonably accurate stand age. QA/QC procedures should be implemented in order to assess the reliability of ring counts, such that a random sample of 10% of the cores should be counted by a second person. QA/QC counts that are within 5% of the original count are considered acceptable.

In some situations, the core may not include the pith of the tree, either because the core was too short, or because it was taken at an improper angle. If a core was taken at an improper angle, and the arcs of the inner rings are visible, it may be possible to estimate the distance to the missing pith and estimate the number of missing rings. There are numerous geometric and graphical methods for

achieving this estimation. A pith locator designed by Applequist (1958) is a commonly used method, particularly for research designed to simply determine general stand age. At the risk of being slightly less precise than other methods, a pith locator is far more time efficient while still giving a good estimate of the missing number of rings.

The pith locator is designed as a series of concentric half-circles of various widths that are printed on transparent film (Figure S13.2). For example, circles can be arranged every 1mm, 2mm, 3mm, etc. To use, match one of the half-circles with the ring width of the inner arc of the core. Superimpose the locator over a similar ring on the core, so that multiple rings match. When an adequate match is found, the location of the pith is indicated, and the number of missing rings can be easily counted. This method assumes a constant growth rate between the rings near the center of the pith and the missing rings at the pith. If the 10 innermost rings near the center of the pith are not roughly equal in thickness, then this method will be less accurate.

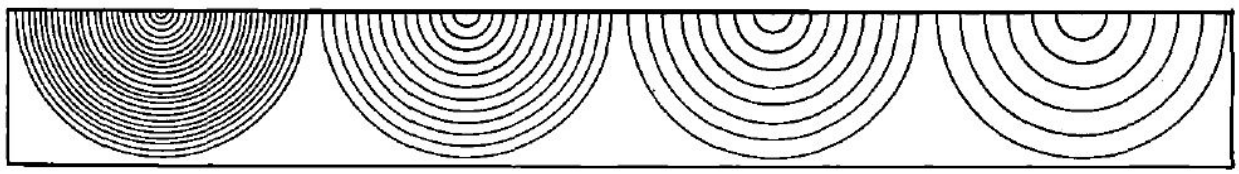


Figure S13.2. Example of a pith locator from Applequist 1958.

References

Applequist, M. B. "A simple pith locator for use with off-center increment cores." Journal of Forestry 56.2 (1958): 141.

Asherin, Lance A., and Stephen A. Mata. "Basic tree-ring sample preparation techniques for aging aspen." Sustaining Aspen in Western Landscapes, Proceedings RMRS-P-18. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO (2001): 347-351.

Maeglin, R.R. 1979. Increment Cores: How to collect, handle and use them. U.S. Department of Agriculture Forest Service General Technical Report FPL-25. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr25.pdf

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.0	March 2014	Patrick Curtin Jesse Wheeler Kate Miller	New SOP	
1.01	January 2020	Camilla Seirup	Changed SOP number	

SOP 14 – Limiting Exotic Species Transport (LEST)

Mid-Atlantic Network/ Northeast Temperate Network

Version 1.01

Overview

This SOP provides instructions for cleaning clothing and field equipment in order to limit the spread of exotic species by the vegetation monitoring crew members. The introduction and spread of exotic insects, diseases, and plants is a serious threat to the parks' vegetation and other natural resources. Therefore, crew members shall be responsible for taking reasonable actions to limit the spread of exotic species between plots and especially between parks.

When to Implement LEST

The crew is always encouraged to limit species transport in the parks, but certain situations will require following the LEST protocol. These situations include:

- Any time an early detection species is encountered that is setting seed or has probably set seed in previous years.
- After leaving a site with any abundant invasive species that is currently dispersing seed.
- Before leaving a park, boots and equipment must be cleaned and clothing must be washed before starting work at a new park.
- Before the start of the work week, if one has been hiking in other places over the weekend.

Materials Needed

- 5-gallon drywall bucket
- Wire brushes
- Coarse fibered brushes

These materials will be stored in the field vehicle for use after visiting a site where exotic species or their propagules were present.

Removing Exotic Species

After leaving a site that requires following LEST protocol, the crew shall return to the vehicle and remove the 5-gallon drywall bucket. Use the coarse fibered brush to brush any seeds off of pants and boots and into the bucket. Remove any material that is stuck in treads of boots with the wire brushes and drop it into the bucket. It may be necessary to unlace and clean out seeds that are trapped under boot laces.

Field equipment that is contaminated should also be cleaned into the bucket using the brushes. Equipment that needs to be cleaned includes, but is not limited to: packs, soil trowel, DBH tape, and any other potentially contaminated equipment.

The contents of the bucket should be placed into a plastic bag and thrown into the trash. If large quantities of material are being collected in the bucket, the crew should investigate safe manners in which to burn the material once it is dried.

If there is a possibility that a forest pest or pathogen that is not already widespread within the park has been in contact with your clothing, your clothes must be washed at the end of the day.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.00	March 2014	Doug Manning	Initial version. Adopted from ISED Protocol	.
1.01	January 2020	Camilla Seirup	Changed SOP number	

SOP 15 - Landscape Context

Mid-Atlantic Network/ Northeast Temperate Network

Version 3.06

Overview

This SOP describes procedures for calculating landscape context metrics. These landscape metrics are indicative of the influence of adjacent landuse and stressors on the ecological condition of the plot. Change over time will be monitored using Digital Orthophoto Quarter-Quadrangles (DOQQs) or alternatively the USGS National Land Cover Database.

This SOP is specific to the landscape condition of forested plots; the Northeast Temperate Network (NETN) will develop metrics for overall Landscape Dynamics as a separate protocol. However, it may be most efficient to bundle an analysis of forest plot landscape condition together with the large Landscape Dynamics analysis.

Sources of Spatial Data

Vegetation maps of NETN parks are being developed as one of the Inventory and Monitoring (IM) base inventories by the U.S. Geological Survey (USGS)/NPS Vegetation Mapping Program (http://biology.usgs.gov/npsveg/) and distributed in digital and paper format. These maps will show National Vegetation Classification (NVC) vegetation communities within and surrounding each park using a minimum mapping unit of 0.5 ha. The NVC polygons can be grouped to show NatureServe Ecological Systems. These maps also designate human land use and cultural vegetation areas to standard land use/land cover (LUC) classification Level II.

While these USGS/NPS Vegetation maps provide a useful starting point for analysis, new spatial data will be needed for reassessment of landscape metrics. NETN should monitor change over time by periodically acquiring and analyzing high-resolution Digital Orthophoto Quarter-Quadrangles (DOQQs)—digital images of aerial photographs that have been rectified to remove distortion from terrain and filming. A standard DOQQ is a grayscale or color-infrared image with 1-meter ground resolution, covering an area 3.75’ longitude by 3.75’ latitude—an area equivalent to one-quarter of a USGS quadrangle—plus 50 to 300 meters additional edge to facilitate mosaicing of adjacent images. DOQQs should be referenced to the North American Datum of 1983 (NAD83) and cast on the Universal Transverse Mercator (UTM) projection. For this analysis, we recommend color infrared images be used, and that imagery be photographed during the growing season when leaves are on trees.

Every 10 years, NETN should acquire recent (< 5 years old) DOQQs. High resolution DOQQs may be available from the U.S. Department of Agriculture (USDA) National Agricultural Imagery Program (NAIP; http://165.221.201.14/NAIP.html) or the National Digital Orthophoto Program (NDOP; http://www.ndop.gov/). If updated DOQQs photographed during the growing season are not available from these sources every 10 years, NETN may need to contract to have DOQQs created.

Acquisition of DOQQs should be done in conjunction with NETNs Landscape Dynamics protocol.If DOQQs are unavailable, it may be possible to use the USGS National Land Cover Database (NLCD) for some analysis. In addition, periodically updated digital spatial data showing the location of roads, carriage roads and trails will be needed. These data can be acquired directly from the parks in some cases. For parks that do not maintain GIS data, road data should be available from state GIS clearinghouses.

Spatial Analysis

The forest patch size analysis is performed at the scale of the park, while the anthropogenic land use analysis is performed separately for each plot. This analysis will be performed only on forest plots that have already been established, and not the pre-selected plot locations. Spatial analysis should be performed using ArcGIS 9.x, FRAGSTATS, or a program with similar capabilities. It may not be possible to identify woodland patches and neighborhood cover for woodland plots using DOQQs; however, woodland plots only occur at ACAD and are a small percentage of total plots there.

Forest Patch Size

Calculate average size in hectares of the forested patches within each park as described below. When patches extend beyond the park boundary, use the actual area rather than clipping patches to the park boundary. Patch size should be digitized at the 1:6,000 scale or finer, and patch size should be at least 0.5 ha.

Step 1: Identifying a Patch

For this analysis, a patch is considered to be an area of continuous medium to high-canopy (≥ 8 m height) forest vegetation or plantation. The area should have at least 60% canopy closure overall to qualify as forest rather than woodland. Examine recent DOQQs and establish polygons representing continuous patches of forest vegetation including plantations. Adjacent natural areas lacking forest (e.g., shrub wetlands or early successional areas, open woodlands) are not included. It may be helpful to first delineate the patch at a broader scale, such as 1:8,000. Once patch is delineated, zoom in to a finer scale (1:6,000 or finer) to check that the polygon is accurate.

NOTE: "Continuous" forest or plantation vegetation still needs to be defined. As a first cut, if two regions are separated by more than 30 m, with a connecting corridor less than 30 m, they may be separate patches (among other things, this would be simple to implement in FRAGSTATS with the NLCD). The literature should be consulted regarding how far "edge" typically extends into a forest patch to help make this judgment call. Another option would be to use a visible break in the orthophotography (for any feature, not just roads). For a narrow or small connection, we still need a defined breakpoint—30 m or 50 m width may be too low.

Step 2: Roads as Breaks

Roads wide enough to register on orthophotography as a visible break in the tree canopy present a barrier to many organisms living within a forested patch. Overlay road data upon polygons created in Step 1, and compare road data with aerial photography to identify areas where roads cause a break in the tree canopy. Bisect polygons along these breaks accordingly.

Step 3: Record Area

Record the size to the nearest 1/10 hectare of each forest polygon in the park, and calculate the average polygon area.

Alternative Calculation Method

An alternative calculation method based on the NLCD would use FRAGSTATS to calculate the average area of forested patches within the park.

- Prepare the layer by reclassifying forest habitat types so that they all have the same value (1), and classifying all other types to a different value (0).
- Clip the NLCD to the park (taking care to include forested patches that extend beyond the park boundary; this will require digitizing an appropriate boundary to use in the clipping operation).
- Rasterize the park roads layer, assigning roads a value of 0 and the rest of the grid a value of 1.
- Multiply the road and modified NLCD layers (forest will retain a value of 1, and roads will be assigned a value of 0, while non-forest remains 0).
- Calculate patch area statistics using FRAGSTATS.

Neighborhood Anthropogenic Land Use

Calculate the percentage of anthropogenic land use found in the specified buffer (Table S15.1) surrounding each plot center. Examine recent DOQQs to determine presence of recognizable anthropogenic land use on a pixel-by-pixel basis or delineated polygon basis within this circle. Polygons should be delineated at the 1:6,000 scale or finer.

Table S15.1. Buffer radius for neighborhood anthropogenic land use calculations for each park.

Park	Buffer (m)
ACAD	400
ELRO/HOFR	200
MABI	200
MIMA	200
MORR	200
SAGA	100
SARA	200
WEFA	100
VAMA	100

Plantations of exotic species and active agricultural lands should be considered anthropogenic land use. Designation of native species plantations and early-successional areas should consider current management; actively managed areas (e.g., mowed fields, new plantations) should be considered anthropogenic land use, but areas which are no longer actively managed (e.g., old fields, older, unmanaged native plantations) should be considered natural land use.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version	Date	Revised by	Changes	Justification
1.01	Sept 2006	Geri Tierney Brian Mitchell	Minor text edits	To reflect larger changes to overall protocol.
1.02	Dec 2006	Geri Tierney Brian Mitchell	Included possibility of using USGS NLCD if DOQQs are unavailable. Changed interior forest patch size to forest patch size (unbuffered).	
2.00	June 2007	Brian Mitchell Geri Tierney	Adjusted rule for determining if polygon is bisected by road. Adjusted size of window for neighborhood landuse calculations. Clarified height and closure criteria for closed canopy forest. Clarified anthropogenic landuse status of exotic plantations and agricultural fields.	
2.01	August 2007	Brian Mitchell Geri Tierney	Clarified natural landuse status of native plantations and early-successional areas.	
3.00	May 2008	Geri Tierney Kate Miller Brian Mitchell	Changed the forest patch size metric, and included methods for calculating this metric based on DOQ's and based on the NLCD (using FRAGSTATS).	The original metric (area of patch that plot resides in) was subject to positive bias due to multiple plots occurring in the same large patch. For example, if there is a 1,000 and a 100 ha patch in a park, with 10 plots in the first patch and one in the second, average patch size was 918 ha using the original metric. The new metric will produce an average patch size of 550 ha.
3.01	Jan 2009	Kate Miller Jim Comiskey Brian Mitchell	Removed reference to ArcView GIS. Added note about the need for criteria to assess "continuous" cover. Clarified this analysis will be done every 10 years Added NAIP as source of DOQQS.	
3.02	April 2009	Kate Miller	Clarified that the spatial analysis will only take place on plots that have already been established. Minor editorial changes.	
3.03	May 2009	Sarah Lupis Kozlowski	Minor editorial changes.	Conform to NPS standards.
3.04	Oct 2010	Kate Miller Jesse Wheeler	Clarified that polygons be digitized at 1:6,000 or finer scale	

Version	Date	Revised by	Changes	Justification
			Clarified that the minimum patch size is 0.5ha. Added that it may be useful to digitize at a coarser scale, then to check at 1:6,000 or finer. Added table of buffer distances to match EI metric calculations	
3.05	March 2014	Kate Miller	Changed SOP number; added MIDN to SOP	
3.06	January 2020	Camilla Seirup	Changed SOP number	

SOP 16 - Analyzing and Reporting Ecological Integrity

Northeast Temperate Network

Version 3.12

Overview

This SOP describes how ecological integrity is assessed and reported from field data collected by the NETN forest protocol. NETN will use data, models and expert opinion from the scientific literature to evaluate levels of ecological integrity as "Good", "Caution" or "Significant concern" for specific metrics of forest structure, composition and function based on assessment points derived from natural or historic ranges of variation for each metric. The interpretation of ecological integrity is a useful but developing conservation application, and ratings should be reviewed and updated as new information becomes available. A scorecard format will be used to clearly and concisely report the integrity of NETN forests to multiple audiences including park managers and decision-makers.

Ecological Integrity

The concept of "ecological integrity" is increasingly being used as a measuring tool to assess the state of ecosystems and the effectiveness of land management actions upon those ecosystems. Building upon the related concepts of biological integrity and ecological health, ecological integrity is a broader and more useful conceptual endpoint for ecological assessment and reporting (Czech 2004). "Integrity" is defined as the quality of being unimpaired, sound, whole or complete. To have integrity, an ecosystem should be relatively unimpaired and complete across a range of characteristics and scales (DeLeo and Levin 1997). "Ecological integrity" has been defined as a measure of the composition, structure and function of an ecosystem in relation to the system's natural or historical range of variation and the perturbations imposed upon it by natural or anthropogenic agents of change (Karr and Dudley 1981, Parrish et al. 2003).

Assessment of ecological integrity is a challenging undertaking (NAS 2000). One promising approach builds upon the well-known Index of Biological Integrity (IBI). The original IBI interpreted stream integrity from twelve metrics reflecting the health, reproduction, composition and abundance of fish species (Karr 1981). Each metric was rated by comparing measured values with values expected under relatively unimpaired conditions, and the ratings were aggregated into a total score. Related biotic indices have sought to assess the integrity of other aquatic and wetland ecosystems primarily using faunal assemblages. Building upon this foundation, others have suggested interpreting the ecological integrity of ecosystems by developing suites of indicators or metrics comprising key biological, physical and functional attributes of those ecosystems (Andreasen et al. 2001). The Nature Conservancy has developed this approach into a framework for measuring conservation effectiveness upon targeted ecosystems (Parrish et al. 2003). This approach is well-suited to the needs of the NPS Vital Signs Monitoring Program, which seeks to improve understanding of the condition of park ecosystems by monitoring the status and trends of a selected group of indicators.

Selecting Metrics

The first step in determining ecological integrity is identifying a limited number of key attributes or metrics of an ecosystem that best distinguish a highly impacted, degraded or depauperate state from a relatively unimpaired, complete and functioning state. Key attributes may be properties that typify a particular ecosystem (Keddy and Drummond 1996, Parrish et al. 2003) or attributes that change predictably in response to anthropogenic stress (Karr and Chu 1999). The suite of attributes selected should be comprehensive enough to incorporate composition, structure and function of an ecosystem across a range of spatial scales (Andreasen et al. 2001).

A conceptual ecological model delineating linkages between key ecosystem attributes and known stressors or agents of change is a useful tool in identifying and interpreting metrics. NETN developed a simple conceptual model identifying important stressors and agents of change acting upon terrestrial ecosystems in NETN parks, and identifying key attributes of these systems. This model is presented within the Conceptual Ecological Model Appendix of the NETN Vital Signs Monitoring Plan (Mitchell et al. 2006). Key stressors acting upon NETN forested ecosystems include climate change, atmospheric deposition, ozone pollution, invasive exotic species including forest pests and pathogens, overbrowsing by white-tailed deer (*Odocoileus virginianus*), landscape change including fragmentation, visitor use, and on-site land management including agriculture and silviculture. Justification for the selection of each metric is included below within the Metrics and Ratings section.

Rating Metrics

A second step in determining ecological integrity is determining assessment points for each metric that distinguish acceptable or expected conditions from undesired conditions which warrant concern, further evaluation or management action (Bennetts et al. 2007). Assessment points for rating ecological integrity will be based upon natural or historic variability. Estimates of historical or natural variation in ecosystem attributes provide a reference for gauging the effects of current anthropogenic stressors, while at the same time recognizing the inherent natural variation in ecosystems across space, time, and stages of ecological succession (Landres 1999).

Of course, current knowledge of historic or natural conditions is limited. Insight into natural or historic conditions comes from historical studies and records, paleoecological reconstructions of past conditions, current studies of relatively pristine ecosystems, and efforts to model ecosystem dynamics. While all these efforts provide useful insight, our understanding of historic or natural conditions in many ecosystems relies on a limited number of key studies, and care must be taken when applying data from these studies to other sites. For these reasons, ratings should be reviewed and updated as our knowledge of the historic or natural variation and ecosystem response to perturbation increases over time.

Following the NPS national Vital Signs rating system, three ratings are used – Good, Caution and Significant Concern. “Good” represents acceptable or expected conditions; “Caution” indicates a problem may exist; “Significant Concern” indicates undesired conditions that may need management correction. For several metrics, we have not defined conditions that merit “Significant Concern” because current knowledge is insufficient to justify this rating.

Scorecard

NETN will use a scorecard format to clearly and concisely report ecological integrity to a wide audience. A successful ecological scorecard should transparently convey status and trend in key ecological parameters in a way that is meaningful to the public, managers and other stake-holders (Harwell et al. 1999).

We have developed a scorecard reporting framework to visually convey status and trends in each metric of forest integrity using the NPS "stoplight" symbology. This symbology uses color to convey integrity rating—Good, Caution and Significant Concern are conveyed respectively as green, yellow or red circles—and uses an embedded arrow to convey the direction of trend observed across sampling intervals (increasing, stable or decreasing). For transparency, actual data values will be reported in addition to ratings. An example Forest Integrity Scorecard based on data collected in 2005 is shown in Appendix D.

Some ecological integrity reporting efforts have developed simple or elaborate point-based indexes to aggregate information describing integrity of individual metrics into overall scores for the ecosystem (Karr 1981). Successful aggregation of individual metrics will require an understanding of the relative importance of individual metrics in determining the overall integrity of an ecosystem. Such an approach relies on a subjective understanding of what is important in a particular ecosystem, and can unintentionally "hide" information about ecosystem components in need of attention. This forest scorecard attempts to concisely convey information on each individual metric, and provide summary information only on the number of metrics classified as good, caution and significant concern in each park. We recognize that NPS will need to aggregate this information at higher levels (such as by Vital Sign) for reporting at the national level. For that reason, this scorecard adheres to NPS Vital Signs reporting conventions, and should provide NPS with the necessary information for aggregation.

Metrics and Ratings

Metrics and ratings are summarized in Table S16.1. The text that follows provides an overview, justification, calculation description, scaling rationale, and suggested level of confidence for each metric. Throughout this SOP, we define "tree" as any woody stem greater than 10 cm diameter at breast height (1.37 m); if an individual woody plant forks below 1.37 m and both stems are greater than 10 cm diameter, they are tallied as two separate trees. This definition is similar to the one used by the U.S. Forest Service's Forest Inventory and Analysis (FIA) program, and will facilitate comparisons with FIA data.

Table S16.1. Metrics and ratings for evaluating the ecological integrity of forest ecosystems.

Metric type	Metric	Metric Ranking		
		Good	**Caution**	**Significant Concern**
Landscape structure	Forest patch size	> 50 ha	10-50 ha	< 10 ha
	Anthropogenic landuse	< 10%	10-40%	>40%
Structure	Structural stage	≥ 70% (MABI, SAGA), 50% (ACAD), and 25% (MIMA, MORR, ROVA, SARA and WEFA) late-successional structure	< 70% (MABI, SAGA), 50% (ACAD), and 25% (MIMA, MORR, ROVA, SARA and WEFA) late-successional structure	< 70% (MABI, SAGA), 50% (ACAD), and 25% (MIMA, MORR, ROVA, SARA and WEFA) combined mature *and* late-successional structure
	Snag abundance	≥ 10% standing trees are snags and ≥10% med-lg trees are snags[1]	< 10% standing trees are snags or <10% med-lg trees are snags	< 5 med-lg snags/ha
	Coarse woody debris volume	> 15% live tree volume	5- 15% live tree volume	< 5% live tree volume
Composition	Tree regeneration	Seedling ratio ≥ 0	Seedling ratio < 0	Stocking index outside acceptable range[2]
	Tree condition	Foliage problem < 10% *and* no priority 1 or 2 pests[3] *and* BBD ≤ 2	Foliage problem 10-50% *or* priority 2 pest *or* BBD > 2	Foliage problem >50% *or* priority 1 pest
	Biotic homogenization	No change	Increasing homogenization	
	Indicator species: invasive exotic plants	< 0.5 key species per plot	0.5 to < 3.5 key species per plot	3.5 or more key species per plot
	Indicator species: deer browse	No decrease in frequency of most browse-sensitive species	Decrease in frequency of most browsed species *or* increase in frequency of browse-avoided species	Decrease in frequency of most browsed species *and* increase in frequency of browse-avoided species
Function	Tree growth and mortality rates	Growth ≥ 60% mean *and* Mort ≤ 1.6%	Growth < 60% mean *or* Mort > 1.6%	
	Soil chemistry: acid stress	Soil Ca:Al ratio > 4	Soil Ca:Al ratio 1-4	Soil Ca:Al ratio < 1
	Soil chemistry: nitrogen saturation	Soil C:N ratio > 25	Soil C:N ratio 20-25	Soil C:N ratio < 20

[1] Med-lg trees are ≥ 30 cm diameter-at-breast-height.

[2] Tree regeneration stocking index varies by park.

[3] Priority 1 pests are Asian long-horned beetle, hemlock woolly adelgid, emerald ash borer and sudden oak death. Priority 2 pests are balsam woolly adelgid, butternut canker, elongate hemlock scale, and beach bark disease (BBD).

Forest Patch Size

Overview

Forested areas in the northeastern U.S. exist within a matrix of managed, rural, and suburban habitat that limits the ability of species to freely forage, interbreed and disperse, and that creates "edge" habitats which differ from forest interior in environmental conditions, structure, composition and disturbance.

Metric Justification

A large and growing body of scientific literature documents the negative impacts of habitat fragmentation on biodiversity in a wide variety of ecological systems (Fahrig 2003). The impacts of fragmentation have been especially well documented upon avian communities, and population declines of a variety of forest interior avian species are linked to habitat fragmentation (Austen et al. 2001, Boulinier et al. 2001). In general, large forest patches tend to support larger populations of fauna and more native, specialist, and forest interior species (Harris 1984, Forman 1995).

Calculation and Scaling Rationale

Average forested patch size for each park is calculated in hectares using GIS as described in SOP 16 – Landscape Context.

Kennedy et al. (2003) reviewed the literature on minimum patch area for a variety of taxa and found minimum patch areas ranged up to 1 hectare for invertebrates, up to 10 hectares for small mammals, up to 50 hectares for the majority (75%) of birds species, and up to over 200,000 ha for large mammals. The relatively small parks for which this protocol was designed cannot independently support large mammal populations, thus our ratings are based on the needs of birds, small mammals and invertebrates. In other areas, it will be necessary to consider the needs of large mammals which require substantially larger forest patches.

Good: More than 50 hectares.

Caution: 10-50 hectares.

Sig. concern: Less than 10 hectares

Confidence

Medium. While patch size and fragmentation impacts on particular species have been well documented, developing an overall rating for an ecosystem or group of ecosystems is more complex, and may be refined over time.

Anthropogenic Land Use

Overview

This metric assesses the percentage of land in anthropogenic versus natural land use in the local or immediate neighborhood surrounding each forest or woodland plot.

Metric Justification

Habitat loss and fragmentation have synergistic, cumulative impacts upon remaining natural areas. As habitat is lost, the remaining fragments become more important to wildlife populations, and are

more likely to be isolated and impacted by surrounding anthropogenic land use. The Heinz Center (2002) calculated similar neighborhood statistics on immediate (2 ha), local (65 ha) and larger neighborhoods (5,000 ha).

Calculation and Scaling Rationale

We will use GIS to calculate the percentage of anthropogenic versus natural landuse within the local or immediate neighborhood surrounding each plot, as defined below. Northeast Temperate Network parks vary substantially in size, and the "neighborhood" considered will be scaled to park size. For ACAD (>14,000 ha. in size), the neighborhood analyzed will be a 400-m radius circle (equivalent to about 50 ha.). For NHP greater than 100 ha in size (i.e., MABI, MIMA, MORR, ELRO/HOFR, SARA), the neighborhood will be a 200-m radius circle (equivalent to about 12.5 ha). For NHPs less than 100 ha in size (i.e., SAGA, VAMA and WEFA), the neighborhood analyzed will be a 100-m radius circle (equivalent to about 3 ha.). Plantations of native species will be considered natural land use, while plantations of primarily exotic species will be considered anthropogenic land use. Likewise, mowed fields will be considered anthropogenic land use. See SOP 15 - Landscape Context for additional details on calculation.

Theoretical models offer a framework for assessing the combined impacts of habitat loss and fragmentation. Simulations show a marked increase in the likelihood of continuous habitat existing in a landscape that has more than 60% natural cover (McIntyre and Hobbs 1999, O'Neill et al. 1997).

Good: Less than 10% anthropogenic land use.

Caution: 10-40% anthropogenic land use.

Sig. concern: More than 40% anthropogenic land use.

Confidence

Medium.

Structural Stage Distribution

Overview

This metric assesses the structural stage distribution of forest plots in relation to the expected distribution under natural disturbance regimes. It provides an indicator of altered disturbance regimes, and habitat availability for species dependent on specific structural stages. Structural stage is calculated from tree size and canopy position measurements in forested plots, and distribution is assessed at the level of the park.

Metric Justification

At landscape scales, forest structural stage affects the maintenance of biological diversity, particularly of species dependent upon specific structural stages. As multiple stressors including global change and exotic pest and pathogen outbreaks alter disturbance regimes (Dale et al. 2001), structural stage distributions are likely to shift.

Calculation and Scaling Rationale

Structural stage distribution is assessed for each park based on calculations from canopy trees in forested plots (woodlands are excluded). We use a method similar to that of Frelich and Lorimer (1991) but substitute basal area for exposed crown area (Goodell and Faber-Langendoen 2007). Plots are classified as pole, mature, late-successional stage or mosaic based on relative basal area of live canopy trees within pole, mature and large size classes. For the NHPs, size classes are 10-25.9 cm DBH (pole), 26-45.9 cm DBH (mature) and ≥ 46 cm DBH (large). Dominant trees of coastal Maine (balsam fir and red spruce) are typically smaller in size than dominant trees at the NHPs, and ACAD size classes have been adjusted to be 10-19.9 cm DBH (pole), 20-34.9 cm DBH (mature), and ≥ 35 cm DBH (large).

To calculate this metric, first exclude all woodland plots (treed areas with open or patchy tree cover ≤60%). Woodland associations occur at ACAD and may be dominated by jack pine (*Pinus banksiana*), pitch pine (*P. rigida*), northern red oak (*Quercus rubra*), red spruce (*Picea rubens*), white cedar (*Thuja occidentalis*), and/or aspen-birch (*Populus* spp.-*Betula* spp.) (Lubinski et al. 2003). Woodland plots are classified onsite (stand structure = 6). However, woodland plots are not always recognized by field crews. Thus, plots at ACAD with canopy closure ≤ 50 % (code 1, 2 or 3) and dominated by one of the woodland species noted above are likely to be woodland plots. These plots should be verified as forest or woodland during remeasurement; in the meanwhile they are removed from this analysis.

Next, calculate basal area (*BA* in m^2) for each live canopy tree in a forest plot from DBH (diameter-at-breast-height in cm) using the formula below. Canopy trees are identified onsite (i.e., dominant, sub-dominant or intermediate crown class). Open-grown, sub-canopy, and gap-exploiter trees are not used in this calculation. Trees within the open-grown crowns are excluded to avoid mis-interpreting early-successional plots dominated by a few, large open-grown trees as late-successional. However, open-grown trees in early successional or mosaic plots sometimes are mis-classified onsite as "dominant." Thus, it is useful to compare categorization using these calculations with stand structure classifications made onsite.

$$BA = \pi * \left(\frac{dbh}{2*100} \right)^2$$

Next, relative basal area per size class is calculated for the plot by summing the BA of canopy trees within each DBH size class (pole, mature and large as defined above), and then dividing by the total basal area of the plot. Structural stage is assigned to the plot based on the relative basal area distribution as follows:

Pole stage: ≥ 67% BA in pole plus mature sizes, with more basal area in pole than mature size.

Mature stage: ≥ 67% BA in pole plus mature sizes, with more basal area in mature than pole size or ≥ 67% in mature plus large size, with more basal area in mature than large size.

Late-successional stage: ≥ 67% BA in mature plus large sizes, with more basal area in large than mature size.

Mosaic: Any plot not meeting the above criteria.

Frelich and Lorimer (1991) and Lorimer and White (2003) have compiled data and modeled the distribution of old growth stands under natural disturbance regimes for several northeastern forest ecosystems. Northern hardwood and hemlock hardwood forests historically experienced low frequency of natural disturbance (dominated by windstorms) and 70-90% of stands across the landscape are estimated to have historically existed as late-successional. Upland and montane spruce-hardwood forests of northern New England and the Adirondacks may have had similar historical late-successional landscape distribution to northern hardwoods, estimated as 75-80% of stands as late-successional. However, the swamp, flatland and rocky spruce-hardwood forests typical of coastal Maine are more susceptible to coastal storms, windthrow, fire and other disturbances, and only 50% of stands may have existed as late-successional. Less data are available describing oak-hickory forests, but Lorimer and White (2003) suggest that multi-cohort stands may have occupied 25-40% of the landscape. The overall park rating is interpreted from ratings of dominant ecosystems in the park.

Ratings are assigned to each park using assessment points based on the matrix forest ecosystem at each park (Acadian Low-Elevation Spruce-Fir-Hardwood Forest at ACAD; both Appalachian Hemlock-Northern Hardwood Forest and Laurentian-Acadian Northern Hardwood Forest at MABI; Appalachian Hemlock-Northern Hardwood Forest at SAGA; both Appalachian Hemlock-Northern Hardwood Forest and Northeastern Interior Dry-Mesic Oak Forest at ROVA and SARA; and Northeastern Interior Dry-Mesic Oak Forest at MIMA, MORR, and WEFA. At parks with more than one matrix forest ecosystem type, assessment points are based on the type with lower late-successional structure.

Good: At least 70% (MABI, SAGA), 50% (ACAD), and 25% (MIMA, MORR, ROVA, SARA and WEFA) late-successional structure across the park

Caution: Less than 70% (MABI, SAGA), 50% (ACAD), and 25% (MIMA, MORR, ROVA, SARA and WEFA) late-successional structure across the park

Sig. concern: Less than 70% (MABI, SAGA), 50% (ACAD), and 25% (MIMA, MORR, ROVA, SARA and WEFA) combined mature and late-successional structure across the park

Note: Consider adding sapling/seedling or "small" stands to metric calculation to reflect overall distribution of structural stages across the park.

Confidence

Medium. Metric can be fine-tuned over time as more data become available.

Snags and Coarse Woody Debris

Overview

Dead wood, in the form of standing dead trees (snags) and fallen coarse woody debris (CWD), is an important structural feature of forest stands that provides habitat for wildlife and fungi. This metric assesses the density of snags and volume of CWD in relationship to live tree density and volume. Since NETN plots are not designed to pick up rare features such as snags, snag abundance should be evaluated at the scale of the park only.

Metric Justification

Snags and CWD provide important habitat for arthropods, herptiles, birds, small mammals and fungi. Snags are particularly important for cavity-nesting birds, and the density and size of snags is indicative of habitat availability for those species (Zarnowitz and Manuwal 1985, Schreiber and deCalesta 1992). Coarse woody debris is particularly important for herptiles and small mammals (DeGraaf and Rudis 1986, Petranka et al. 1994). Coarse woody debris continues to be used by wildlife as it breaks into smaller pieces over time, thus CWD volume can be a useful indicator of habitat availability. Large diameter snags persist longer than smaller diameter snags (Morrison and Raphael 1993, Garber 2005) and provide habitat for a greater number of vertebrate species (Cline et al. 1980, DeGraaf and Shigo 1985). Silviculture, land management and hazard tree removal can reduce the quantity or quality of these features; however, thoughtful land management can maintain or enhance snags and CWD (Keeton 2006).

Calculation and Scaling Rationale

Density of snags and volume of CWD in mature and late-successional stands varies substantially across ecosystems and with site conditions (Tyrrell et al. 1998). However, positive relationships between live and dead tree density and volume can be used to indicate expected snag and CWD levels (Sippola et al. 1998, Ferugson and Archibald 2002, Stewart et al. 2003).

For snags, Nillson et al. (2003) have calculated a ratio of 1:9 standing dead:live trees for the boreal forest, while Ferguson found about 15% of standing trees were dead in the boreal forest. Goodburn and Lorimer (1998) report that 11% and 16% of standing trees were dead, respectively in Michigan/Wisconsin northern hardwood and hemlock northern hardwood stands. Since larger diameter snags tend to persist longer than smaller diameter snags (Garber 2005) and some studies report snag diameter distributions in late-successional stands which meet or exceed live tree diameter distributions (Goodburn and Lorimer 1998, Spetich et al. 1999, Nilsson et al. 2003), we can expect that these relationships should hold for large snags. Thus we can suggest both overall (>10 cm DBH) and medium-large (≥ 30 cm DBH) snag density should be at least 10% of overall and medium-large live tree density.

To develop a minimum snag density requirement, we reviewed recommendations based on land management and wildlife needs. The USFS recommends 5-10 medium or large (≥ 30 cm DBH) snags per hectare on some Wisconsin and Michigan national forests (USFS 1980). Keddy and Drummond (1996) suggest at least 4 large (> 50 cm) snags per 10 hectares for temperate deciduous forest. Other recommendations range from 0.35 to 2.5 large (> 45 cm) snags per hectare to support

wildlife (Tubbs et al. 1987). These recommendations suggest a minimum of at least five medium or large snags per hectare.

To calculate snag density, the number of snags within a plot is summed, and converted to a per hectare basis as:

$$\frac{Snags}{Plot_size}$$

where *Snags* is the number of snags in a plot and *Plot_size* is the plot size in hectares (0.0225 or 0.04, respectively, for a 15-m or 20-m square plot). For snags:

Good: At least 10% of all standing trees in a park or group of plots are snags and at least 10% of all medium-large (≥ 30 cm DBH) standing trees in a park or group of plots are snags.

Caution: Less than 10% of standing trees in a park or group of plots are snags or less than 10% of all medium-large (≥ 30 cm DBH) standing trees in a park or group of plots are snags

Sig. concern: Fewer than 5 medium-large snags (≥ 30 cm DBH) per hectare, calculated for the park or a group of plots.

Huber's formula can be used to estimate CWD volume from line intersect transect data using the diameter of each CWD piece measured at the point of intersection with the transect line (Marshall et al. 2000). This formula can be simplified to calculate CWD volume per hectare (m^3/ha) as:

$$\frac{\pi^2}{8 * Horiz_length} * \sum_i^n Diam_i^2$$

where *Horiz_length* is the horizontal length of the transect in meters and $Diam_i$ is the recorded diameter in centimeters of each piece of coarse woody debris. Please note that conversion factors for length (10,000) and areal units (also 10,000) have canceled out of this simplified equation and thus are not shown.

However, this calculation must be slope-corrected by converting the slope-length of each line intersect transect (15 m) to its equivalent horizontal distance (Van Wagner 1982). Inserting a correction factor into the formula above allows calculation of CWD volume per hectare (m^3/ha) as:

$$CWD = \frac{\pi^2 \sqrt{1 + \left(\frac{\%Slope}{100}\right)^2}}{8 * Slope_length} * \sum_i^n Diam_i^2$$

where *%Slope* is slope percent of the transect rounded to the nearest 5%, and *Slope_length* is the slope length of the transect in meters (i.e., 15 m). If slope angles are collected rather than slope

percents, slope percent is tan (slope angle)*100. Note that the tan function in Microsoft products uses radians, so a conversion (angle*pi/180) may be needed.

This calculation must be made for each of the three transects in a plot. Then, CWD volume per hectare at each plot is calculated as the average from all three transects in a plot.

For comparison and rating, a simple, conservative estimate of live tree (stem and branches ≥ 10 cm DBH) volume will be made from individual tree measurements and stand height using the geometric formula for a paraboloid. This calculation is conservative because volume from both stem and branches (≥ 10 cm diameter) should exceed paraboloid volume; this will provide additional confidence that ratings of caution or significant concern are warranted. While more nuanced equations exist for calculating stem volume from DBH and height measurements for different species, those equations do not include volume of large branches. Thus, those more complex calculations are unlikely improve accuracy in this case.

Tree volume (v in m^3) is calculated for each *live tree* in the plot as:

$$v = \frac{\left(\pi * DBH^2 * h_c\right)}{80{,}000}$$

where DBH is the DBH of the tree (cm), and h_c is an estimate of tree height (m) from stand height adjusted for tree canopy position. For codominant trees, h_c is equivalent to measured stand height. For dominant trees, intermediate and sub-canopy or gap-exploiter trees, respectively, h_c will be estimated as 1.1, 0.8 and 0.5 stand height, respectively. Open-grown trees could potentially be larger or smaller than stand height, so no correction factor will be used.

Volume of all live trees in the stand is then summed and converted to a per hectare basis to yield an estimate of stand volume (V in m^3/ha):

$$V = \frac{\sum_{i=1}^{n} v_i}{plot_size}$$

where *plot_size* is the plot size in hectares (0.0225 or 0.04, respectively, for a 15-m^2 or 20-m^2 plot).

Volume of dead wood in boreal stands has been reported to range from about 20-40% of total (live and dead) wood volume (Linder et al. 1997, Kuuluvainen et al. 1998, Siitonen et al. 2000, Sippola et al. 1998, Karjalainen and Kuuluvainen 2002), of which about 70% is downed CWD (Siitonen et al. 2000, Sippola et al.1998). Stewart et al. (2003) found dead wood to be 20-28% of live tree volume in late-successional hemlock-spruce-pine and northern hardwood stands, of which about 70% was downed CWD.

Forested systems within NETN parks are relatively young, and may fall short of late-successional CWD and snag benchmarks for some time.

Good: CWD volume > 15% of live tree volume.

Caution: CWD volume is 5-15% of live tree volume.

Sig. concern: CWD volume < 5% of live tree volume.

Confidence
Medium.

Tree Regeneration
Overview
This metric assesses the quantity and composition of advance tree regeneration in the forest understory. Established tree seedlings (>15 cm tall) are quantified by species and size class in three circular 2-m radius microplots (12.57 m^2) per plot. This metric should be used for forest sites only; it has not been adapted for use on woodland sites.

Metric Justification
Shade tolerant forest trees typically regenerate from seedling banks of advance regeneration present in the forest understory prior to disturbance. The quantity and species composition of advance regeneration will impact future canopy structure and composition. Regeneration can be affected by a variety of stressors, including air pollution and climate change. Most notably, sustained, selective browsing by a historically high population of white-tailed deer is currently impacting seedling establishment, growth and composition in parts of the midwest and northeast U.S. (Rooney 2001, Cote et al. 2004). Significant impacts on forest tree regeneration are associated with deer densities ≥ 8.5 per km^2, well above presettlement estimates of 3-4 deer per km^2 in the northeastern U.S. (Russell et al. 2001, Augustine and DeCalesta 2003).

Calculation and Scaling Rationale
In northeast temperate forests, deer selectively browse seedlings of preferred species that are at least 30 cm and less than 75 cm tall (Gill 1992, Kay 1993, Cornett et al. 2000). Sweetapple and Nugent (2004) developed a simple ratio of seedling richness in browsed and unbrowsed size classes to assess ungulate impacts of forest understories. Adapting this approach for NETN forest monitoring, a simple ratio of seedling species richness in heavily browsed size classes (30-100 cm tall) versus shorter size classes (15-30 cm tall) of preferred species will serve as an indicator of impacts on tree regeneration. Browse impacts on tree regeneration vary with species tolerance to browsing, and also with deer browse preference which varies seasonally and regionally. Potential deer browse impacts on northeastern tree species are estimated as High, Medium, Medium/Low and Low in Table S16.2. Most species rated Medium/Low are not preferred, but can be heavily browsed when other choices are not available. Using only species with High to Medium/Low deer impact ratings, the ratio is calculated as:

$$\frac{tall - short}{tall + short}$$

Table S16.2. Potential deer browse impact to northeastern tree species.

Species	Common Name	Potential Deer Impact	Cite[1]	Note
Acer rubrum	red maple	High	2	
Acer saccharum	sugar maple	High	2	
Cornus florida	flowering dogwood	High	1	
Liriodendron tulipifera	tulip poplar	High	2	
Magnolia acuminata	cucumbertree	High	2	
Prunus pensylvanica	pin cherry	High	2	
Sassafras albidum	sassafras	High	1	
Sorbus americana	mountain ash	High	1	
Thuja occidentalis	northern white cedar	High	1	
Tilia americana	basswood	High	1	
Tsuga canadensis	eastern hemlock	High	2	
Betula alleghaniensis	yellow birch	Medium	2	High preference but medium browse tolerance
Betula lenta	black birch	Medium	2	High preference but medium browse tolerance
Carya spp.	Hickories	Medium	2	High preference but medium browse tolerance
Fraxinus spp.	Ashes	Medium	2	High preference but medium browse tolerance
Hamamelis virginiana	witch hazel	Medium	1	
Juglans cinerea	butternut	Medium	1	
Juglans nigra	black walnut	Medium	1	
Nyssa sylvatica	black gum	Medium	3	Sprouts have medium to high palatibility
Quercus spp.	Oaks	Medium	2	High preference but medium browse tolerance
Ulmus spp.	Elm	Medium	1	
Abies balsamea	balsam fir	Medium/Low	1	Low choice but heavily browsed if needed
Acer pensylvanicum	striped maple	Medium/Low	2	Medium preference but high browse tolerance
Fagus grandifolia	American beech	Medium/Low	2	Medium preference but high browse tolerance
Pinus resinosa	red pine	Medium/Low	1	Low choice but heavily browsed if needed
Pinus rigida	pitch pine	Medium/Low	1	Low choice but heavily browsed if needed
Pinus strobus	white pine	Medium/Low	1	Low choice but heavily browsed if needed
Pinus sylvestris	Scotch pine	Medium/Low	1	Low choice but heavily browsed if needed
Alnus spp.	Alder	Low	1	
Betula papyrifera	paper birch	Low	1	
Betula populifolia	gray birch	Low	1	
Carpinus caroliniana	musclewood	Low	1	
Crataegus spp.	Hawthorn	Low	1	
Juniperus virginiana	red cedar	Low	1	

Table S16.2. Potential deer browse impact to northeastern tree species (continued).

Species	Common Name	Potential Deer Impact	Cite*	Note
Larix laricina	tamarack	Low	1	
Ostrya virginiana	hop hornbeam	Low	1	
Picea spp.	Spruces	Low	1	
Populus spp.	Aspens	Low	1	
Prunus serotina	black cherry	Low	2	
Rhamnus cathartica	buckthorn	Low	1	
Robinia pseudoacacia	black locust	Low	1	

[1]1 — New York State Department of Environmental Conservation (NYS DEC). A Preference List of Winter Deer Foods (www.dec.state.ny.us/website/dfwmr/wildlife/deer/foodlist.html); 2 — USFS 2003. Forest Inventory and Analysis. Northeast Field Guide, Version 1.7, App. 12; 3 — USFS Fire Effects Information System tree description. (www.fs.fed.us/database/feis/plants/index.html).

where *tall* and *short* are species richness, respectively, of tall (30-100 cm) and short seedlings (15-30 cm) of browsed species.

While this seedling ratio approach can be useful in detecting moderate impacts due to deer browsing, it will be less effective at detecting severe browsing impacts, which are likely to affect even seedlings < 30 cm tall, as well as impacts on tree regeneration from other stressors, such as air pollution and climate change. An alternative approach by McWilliams et al. (2005) quantifies whether current seedling quantities are sufficient to restock a forest stand with canopy trees. Their index, developed for hardwood stands in Pennsylvania, awards and sums points for seedlings by size class within 2-m radius circular microplots as follows: one point for each seedling 15-30 cm, two points for each seedling 30-100 cm, 20 points for each seedling 100-150 cm, and 50 points for each seedling or sapling > 150 cm tall but less than 10 cm DBH. Only seedlings of native species that typically form the high canopy in northeastern forested sites are counted; this excludes striped maple (*Acer pensylvanicum*), mountain maple (*Acer spicatum*), Allegheny serviceberry (*Amelanchier arborea*), gray birch (*Betula populifolia*), musclewood (*Carpinus caroliniana*), flowering dogwood (*Cornus florida*), hop hornbeam (*Ostrya virginiana*), pin cherry (*Prunus pensylvanica*), chokecherry (*Prunus virginiana*), and black willow (*Salix nigra*), in addition to shrubs such as alders (*Alnus* spp.), hawthorns (*Crataegus* spp.), witchhazel (*Hamamelis virginiana*), and exotic species such as Norway maple (*Acer platanoides*), glossy buckthorn (*Frangula alnus*), and common buckthorn (*Rhamnus cathartica*).

Good: Seedling ratio ≥ 0.

Caution: Seedling ratio < 0.

Sig. concern: Stocking index < 25 at MORR, ROVA, WEFA; must be refined for other parks.

Confidence

Medium. Metric should be tested and fine-tuned. Many regeneration plots at Acadia NP will have few if any preferred browse species, thus the seedling ratio may not be useful at that park. McWilliams et al. (2005) developed their stocking index for Pennsylvania hardwood stands subject

to harvest, so it must be refined for other NETN systems. NETN will continue to refine this metric so that it effectively monitors deer herbivory in all NETN parks across a broad range of deer herbivory impacts.

Tree Condition

Overview

Qualitative observation of specific tree health problems and canopy foliage condition can provide an early warning indicator of problems or decline in canopy trees of a particular species or region.

Metric Justification

Several exotic pests and pathogens are seriously impacting northeastern forest composition or structure. The hemlock woolly adelgid (Adelges tsugae; HWA) has caused widespread and rapid mortality of hemlock across the eastern U.S. since introduction here in the 1950s, and threatens to rapidly and substantially reduce or eliminate eastern hemlock (Tsuga canadensis) throughout much of its range (Orwig et al. 2002). Hemlock woolly adelgid is currently moving northward into Vermont, New Hampshire and Maine. The elongate hemlock scale (*Fiorinia* externa; EHS) is often found with HWA, and can contribute to increased hemlock mortality rates. The balsam woolly adelgid (*Adelges piceae*; BWA) is another damaging exotic aphid. Introduced in the northeastern U.S. in the early 20th century, this insect has damaged balsam fir in New England and New York, and is decimating Fraser fir (*Abies fraseri*) in the southern Appalachians (Schooley 1976, Smith and Nicholas 2000). An exotic scale insect has caused the widespread occurrence of beech bark disease (BBD) throughout the northeast. Caused by the interaction of this insect and a native fungus, BBD has caused substantial mortality to American beech (*Fagus grandifolia*) throughout the region, though most immature and some mature trees have some resistance to the disease. In areas of high beech mortality, increased sprouting of beech suckers can dramatically alter forest structure (Le Guerrier et al. 2003). Butternut (*Juglans cinerea*) is being killed throughout its range by an exotic fungus that causes butternut canker (BC) (Furnier et al. 1999). Butternut is far less common in NETN forests than hemlock, balsam fir or American beech, but the threat across its native range is still cause for concern. Less destructive but still impacting northeastern forests is the European gypsy moth (*Lymantria dispar*). Repeated outbreaks of this pest can lead to reduced growth rate and some mortality to preferred tree species.

Several other species pose enormous threats if they advance into the region. The Asian longhorned beetle (*Anoplophora glabripennis*;*ALB*) poses an enormous threat to maples (*Acer* spp.) and other species if it spreads from its current documented occurrences in and near New York City (Haack et al. 1997), and more recently, in Worcester, Massachusetts. Likewise, the emerald ash borer (*Agrilus planipennis*; EAB) is of high concern, and has been found in Canada (near the Vermont border), and several mid-Atlantic states. This insect quickly kills all native species of ash (*Fraxinus* spp.), and could have dramatic impacts if it arrives in this region (BenDor et al. 2006). Finally, the fungal pathogen that causes sudden oak death (SOD) could have dramatic impacts on oaks (*Quercus* spp.) and other trees if it spreads across the east coast (Venette and Cohen 2006).

This metric also assesses canopy foliage in canopy trees (e.g., dominant, co-dominant or intermediate crown class). As the season progresses, most trees will develop minor foliage problems (e.g., insect

damage, chlorosis, etc.). However, more extensive damage to canopy foliage is indicative of tree health problems within a species or across a region.

Calculation and Scaling Rationale

Specific tree health problems and the condition of canopy foliage are qualitatively observed. For each tree, the amount of canopy foliage affected by various foliar problems (insect damage, chlorosis, etc.) is visually estimated within broad classes (0-1, 1-10, 10-50, 50-90 and 90-100%). Beech bark disease severity is visually assessed using a four-point scale. To assess EI, specific health problems are tallied per plot, and foliage condition class is averaged across trees in a plot, as well as by species within the plot. Good condition is defined as minor foliage problems averaged across a plot and within individual species (represented by at least two individuals), minor damage from BBD, and no evidence of damage by the other specific invasive exotic pests and pathogens noted. More extensive foliage problems (10-50%), or BBD damage, or evidence of damage by one of several invasive exotic pests and pathogens already widespread in the NETN region (BWA, BC, EHS) indicate cause for concern. Foliage damage above 50% averaged across a stand or within an individual species (represented by at least two individuals) indicates a more serious problem. Likewise, evidence that certain invasive exotic pests and pathogens of high concern for extensive mortality to trees (ALB, EAB, HWA,SOD) have reached NETN forests indicates a significant concern which might still be controlled by management action.

Good: Average foliage problem < 10% <u>and</u> no HWA, BWA, BC, ALB, EAB or SOD <u>and</u> average BBD severity ≤2.

Caution: Average foliage problem 10-50 % for plot or species (represented by at least two trees) <u>or</u> evidence of BWA or BC <u>or</u> average BBD severity > 2.

Sig. concern: Average foliage problem > 50% for plot or species (represented by at least two trees) <u>or</u> evidence of ALB, EAB, HWAor SOD.

Confidence

Medium. New exotic pests and pathogen threats to northeastern forests arise with increasing frequency. This list of key health problems should be regularly reviewed and updated. Seasonal staff will likely recognize some specific health problems (e.g., HWA, BBD) with training, but will be less likely to detect others (e.g., ALB, EAB and SOD). Analysis must consider that foliage damage will typically increase as the field season progresses.

Note: Consider adding sirex woodwasp (*Sirex noctiliobe*) for potential to kill jack pine (*Pinus banksiana*). Currently present in New York, Vermont, and Pennsylvania, this species may be hard to see/identify.

Note: Consider adding Asian gypsy moth (*Lymantria dispar*), a voracious pest of many tree species. This moth is not yet established in the northeastern U.S.

Note: Consider adding winter moth (*Operophtera brumata*), a pest for oaks, maples, American basswood (*Tilia americana*), and ash. This moth is present in Massachusetts and eastern Canada.

Note: Consider using USFS I-PED software for pest detection and identification. Contact is Daniel Twardus, dtwardus@fs.fed.us, 304-285-1545.

Biotic Homogenization

Overview

Biotic homogenization is the process by which regional biodiversity declines over time due to the addition of widespread exotic species as well as the loss of native species (Olden & Rooney 2006). This metric assesses homogenization of forest and woodland biotas by calculating a similarity index.

Metric Justification

Recognition of the extent, magnitude and implications of biotic homogenization due to human activities is growing (Lockwood & McKinney 2001, Olden 2006). Homogenization occurs when regional floras become more similar due to the addition of wide-spread exotic species as well as the extirpation of endemic species. While this process has occurred in the geologic past, most notably when previously separate land masses have become contiguous, activities of modern humans have dramatically increased the rate of biotic homogenization (McKinney & Lockwood 1999). This process is driven both by the spread of invasive exotic species associated with human activity, as well as by physical and environmental habitat modification by humans including landuse and climatic change. Tracking the extent and magnitude of biotic homogenization over time provides a useful metric indicative of the effect anthropogenic change is having upon regional biological diversity.

Calculation and Scaling Rationale

NETN will use a similarity index to compare plant species composition between plots. Among a group of sites, biotic homogenization can be calculated between each site pair as a simple ratio of species present at the two sites over the total species present at either site (Jaccard's Similarity Index; Olden & Poff 2003). Biotic homogenization for the group of sites would then be:

$$BH_1 = \frac{\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{shared_{i,j}}{total_{i,j}}}{n*(n-1)/2}$$

And the change in biotic homogenization between two time periods is:

$\Delta BH = BH_2 - BH_1$

Alternatively, species' relative abundance can be included within a more complex similarity metric (Bray-Curtis Distance; Rooney et al. 2004).

We will calculate metrics of similarity both for all species and for native species only, to better understand the causes and implications of change.

NETN will continue to develop this metric, since the approach described here may be too simple, and not sensitive enough to detect increasing biotic homogenization.

Good: No change or decrease in homogeneity.

Caution: Increasing homogeneity.

Confidence

Medium. Metric should be assessed for sensitivity and fine-tuned when trend data are available. NETN may also consider developing additional metrics for understory species dynamics that include plant guilds and species traits.

NOTE: Consider analyzing this metric using G-Test developed by Sarah Johnson and Waller lab at the University of Wisconsin at Madison (Rooney et al. 2004).

Indicator Species—Invasive Exotic Plants

Overview

This metric assesses the presence of key invasive exotic plant species within NETN forested, woodland and successional ecosystems.

Metric Justification

The effects of invasive exotic species on the structure, composition and function of natural systems have become a chief concern of ecologists and land managers over the last 20 years due to the growing number of species successfully exploiting and altering non-native habitats (Drake et al. 1989).

Calculation and Scaling Rationale

Presence of key invasive exotic species (Table S16.3) is inventoried within eight 1-m^2 vegetation quadrats per plot, followed by a 15 minute time-constrained search for additional species within the plot. Additional detections in the microplots and any tree-sized individuals are also included. The average number of key invasive exotic plant species present is summed by plot, then averaged across the park. Indicator species were selected based on the threat they pose as invaders of northeastern forest, woodland and successional habitats, as documented by the Invasive Plant Atlas of New England (IPANE, http://nbii-nin.ciesin.columbia.edu/ipane), the NatureServe Explorer database (http://www.natureserve.org/explorer) or by studies within NETN parks (Ehrenfeld 1999, Greene et al. 2004). Included species are those that may dominate and/or persist under shaded conditions (i.e., in forest or woodland), or that may disrupt succession to forest or woodland. Two species of exotic knapweed (*Centaurea biebersteinii* and *C. jacea*) are not included as indicator species herein because they do not threaten forested or wooded habitats or inhibit succession. However, these and other exotic species of interest may be tracked separately due to their prevalence in early-successional or other habitats at NETN.

Good: Average of less than 0.5 invasive exotic species present per plot.

Caution: Average of 0.5 to < 3.5 invasive exotic species present per plot.

Sig. concern: Average of 3.5 or more key invasive exotic species present per plot.

Table S16.3. Key invasive exotic species of forest, woodland and successional ecosystems in the northeastern U.S.

Latin name	Common name	Habitat
Acer platanoides	Norway maple	Open and forest habitats
Ailanthus altissima	Tree-of-heaven	Edges and successional habitats
Alliaria petiolata	Garlic mustard	Open and forest habitats
Berberis thunbergii	Japanese barberry	Open and forest habitats
Berberis vulgaris	European barberry	Open and wooded habitats
Cardamine impatiens	Narrowleaf bittercress	Open and wooded habitats
Celastrus orbiculata	Oriental bittersweet	Edges and successional habitats
Cynanchum louiseae	Black swallow-wort	Open, successional and wooded habitats
Cynanchum rossicum	European swallow-wort	Open, successional and wooded habitats
Euonymous alatus	Winged burning bush	Open, successional and wooded habitats
Frangula alnus	Glossy buckthorn	Wetland and successional habitats
Ligustrum spp. (obtusifolium, vulgare)	Privet	Successional and forest habitats
Lonicera japonica	Japanese honeysuckle	Edges and successional habitats
Lonicera spp. (morrowii, tatarica, x bella)	Exotic honeysuckles	Open and successional habitats
Luzula luzuloides	Forest woodrush	Open and wooded habitats
Microstegium vimineum	Japanese stiltgrass	Open and forest habitats
Polygonum caespitosum	Oriental ladysthumb	Open and successional habitats
Polygonum cuspidatum	Japanese knotweed	Riparian, open and successional habitats
Rhamnus cathartica	Common buckthorn	Riparian, open and successional habitats
Rhodotypos scandens	Jetbead	Open, successional and wooded habitats
Rosa multiflora	Multiflora rose	Open and successional habitats
Rubus phoenicolasius	Wineberry	Open, successional and wooded habitats

Confidence

Medium. The list of key invasive exotic species should be reviewed and updated periodically by NETN staff and park natural resource managers. NETN may consider using a more comprehensive list of invasive species and may add a metric that looks at relative proportions of native and exotic species and may be adjusted for abundance. It is important to note that the forest vital sign protocol was designed to monitor status and trend of invasive species, and is not appropriate for early detection of new invasions.

Indicator Species—Deer Browse

Overview

This metric assesses the frequency of selected understory species preferred, browsed or avoided by deer to infer severity of deer browse impacts.

Metric Justification

Sustained, selective browsing by a historically high population of white-tailed deer is currently impacting understory species composition in parts of the northeast US (Russell et al. 2001, Cote et al. 2004). Severe impacts on herbaceous species are associated with deer densities ≥ 20 per km^2, well above presettlement estimates of 3-4 deer per km^2 (Augustine and DeCalesta 2003). Several studies have attempted to identify indicator plants for deer browse pressure using plant population structure

(Anderson 1994, Webster et al. 2001, Augustine and deCalesta 2003, Rooney and Gross 2003), and relative plant abundance (Balgooyen and Waller 1995, Fletcher et al. 2001).

Following the approach of Balgooyen and Waller (1995), NETN will monitor the frequency of common, highly-visible, herbaceous species preferred or browsed by deer, concentrating on species which have been shown or predicted to be intolerant of deer browsing due to life history traits (Augustine and deCalesta 2003). NETN will also monitor the frequency of species considered unpalatable to deer that have been shown to increase in abundance under heavy deer browse pressure. Frequency will be calculated for each species based on presence or absence in eight herb quads per plot. Selected species are shown in Table S16.4. Canada mayflower (*Maianthemum canadense*) and Jack in the pulpit (*Arisaema triphyllum*) are not included as indicator species because of conflicting results about deer impacts on populations of those species (Balgooyen & Waller 1995, http://www.pitt.edu/~kalisz/Research.html). These species may be included later based on additional evidence that plant population size predictably responds to deer pressure.

Calculation and Scaling Rationale

Frequency of these common species will vary regionally, so ratings will be assigned based on a change in frequency between time periods. Historical park records of species abundance or frequency may be useful in assessing the degree to which deer browse impacts had already occurred prior to the implementation of NETN monitoring. For each park, only species known to occur in that park will be assessed; thus "browse-sensitive species" refers to the species present in that park, not all known browse-sensitive species. For each species recorded within herb quads in the park, successive observations are compared to determine if the species has increased, decreased or remained unchanged in frequency within the park. Frequency will be calculated for each park (or group of plots within a given habitat type) from quad data as:

$$\frac{\#_quads_present}{total_quads}$$

where *#_quads_present* is the number of quadrats in which the species was found and *total_quads* is the total number of quadrats measured in the park or group of plots (i.e., usually 8 times the number of plots).

Good: No decrease in frequency for more than half the browse-sensitive species.

Caution: Decrease in frequency of more than half browse-sensitive species <u>or</u> increase in frequency of browse-avoided species.

Sig. concern: Decrease in frequency of more than half of browsed species <u>and</u> increase in frequency of browse-avoided species.

Table S16.4. Understory indicator species of deer browse pressure in northeastern U.S. forests.

Latin name	Common Name	Deer Preference	Citations
*Ageratina altissima var altissima (*formerly *Eupatorium rugosum)*	White snakeroot	Avoided	Augustine and Jordan 1998
Aralia nudicaulis	Wild sarsaparilla	Preferred	Balgooyen and Waller 1995
Aster divaricatus	White wood aster	Preferred	Williams et al. 2000
Carex spp.	Sedge	Avoided	Williams et al. 2000, Augustine and deCalesta 2003, Horsley et al. 2003
Clintonia borealis	Blue bead lily	Preferred	Balgooyen and Waller 1995
Dennstaedtia punctilobula	Hay-scented fern	Avoided	Horsley et al. 2003
Maianthemum (Smilacina) spp. (racemosum, stellatum)	Canada mayflower and false Solomon's seal	Browsed	Fletcher et al. 2001, Augustine and deCalesta 2003
Polygonatum spp. (biflorum, pubescens)	Smooth Solomon's seal	Browsed	Augustine and deCalesta 2003, Webster et al. 2005, Kraft et al. 2004
Sanguinaria canadensis	Bloodroot	Browsed	Augustine and deCalesta 2003
Thelypteris noveboracensis	New York fern	Avoided	Williams et al. 2000, Horsley et al. 2003
Trillium spp. (cernum, erectum, grandiflorum, undulatum)	Trillium	Preferred	Anderson 1994, Augustine and Frelich 1998, Rooney 2001, Augustine and deCalesta 2003, Webster et al. 2005
Uvularia spp. (grandiflora, perfoliata, sessifolia)	Bellwort	Preferred	Fletcher et al. 2001, Augustine and deCalesta 2003, Webster et al. 2005

Confidence

Medium. While most indicator species have been noted as currently or historically present at most NETN parks, browse-preferred species may be too rare at some parks to detect change over time. Species list may be tested and fine-tuned over time. A more rigorous statistical analysis would be needed to account for the likely lack of independence of quad data within each plot.

Tree Growth and Mortality Rates

Overview

Canopy tree growth and mortality rates provide an integrative, quantitative metric of tree health and vitality. Relative basal area growth rate (% basal area/year) of canopy trees is calculated from repeated bole DBH measurements; annual mortality rate (% stems/year) of canopy trees is calculated from repeated observation. Rates will be calculated only on canopy trees in stands that have succeeded to a mature or late-successional stage as defined by the structural stage metric described earlier in this document. Rates in parks will be compared to regional and species means from the larger FIA dataset.

Metric Justification

Tree growth rates can decline in response to environmental factors or anthropogenic stress, and tree mortality is often preceded by some years of reduced tree growth (Ward and Stephens 1997, Pedersen 1998, Dobbertin 2005). Tree basal area stem growth is affected by stress sooner than more critical growth of foliage or roots (Waring 1987), and is more straightforward to measure. Decreased growth or elevated mortality rate in trees of a particular species can indicate a particular health

problem for that species, such as sugar maple decline (Duchesne et al. 2003, Hyink and Zedeker 1987); while altered vital rates for multiple species across a region may indicate a regional environmental stress (Steinman 2004, Dobbertin 2005).

Calculation and Scaling Rationale

Typical growth and mortality rates vary by site, stand structural stage and by tree species, size and crown class (i.e., tree position in the canopy). For this reason, vital rates will be calculated by species and plot using only canopy trees (e.g., dominant, co-dominant or intermediate crown class) in stands that have succeeded to a mature or late-successional stage (see structural stage metric).

Relative basal area growth rate (% basal area/year) has been shown to be a useful predictor of tree mortality risk (Bigler and Bugmann 2003, Bigler et al. 2004). It will be calculated from successive DBH measurements as the percent change in basal area converted to an annual basis. For each live canopy tree, growth rate (*GR*; % basal area / year) is calculated as:

$$GR = \frac{(BA_{t2} - BA_{t1}) * 100}{BA_{t1} * Time}$$

where BA_{t2} and BA_{t1} are, respectively, basal area (m^2) for the present cycle and the previous cycle, and *Time* is the duration (years) between measurements. For each canopy tree, basal area (*BA* in m^2) is calculated from DBH (cm) as:

$$BA = \pi * \left(\frac{dbh}{2 * 100} \right)^2$$

Growth rate is then averaged for canopy trees across the plot, and also by species within the plot.

Choosing an appropriate reference for tree growth rate is complicated by variation in growth rate across regions, stand structural stages, species and tree crown class. Steinman (2004) reported net growth rates for forests in the northeastern U.S. from the FIA data, using 5 categories: > 2, 2.0-1.6, 1.5-1.1, 1.0-0.6, and < 0.6 %, with the first class considered good and the lower classes indicating cause for concern. However, this FIA net growth rate differs from that calculated herein by including ingrowth of new trees, and subtracting out mortality and cull increment (rough or rotten trees) in addition to the stem accretion calculated by NETN. NETN will consider the statistical distribution of growth rate to mean rates by region and/or species from the larger FIA dataset in order to interpret ecological integrity. Studies comparing tree growth in declining or recently dead trees vs. healthy trees report growth rates in the former to be reduced 40-50% (Pederson 1988, Standover and Somogyi 1998).

Annual mortality rate (*MR*; % stems/year) is calculated from successive observations as the percent of stems that died during an interval converted to an annual basis. This rate should be calculated for each plot, and also for individual species within a plot as:

$$MR = \frac{Stems_died_{t1-t2} * 100}{Stems_alive_{t1} * Time}$$

where $Stems_died_{t1-t2}$ is the number of stems that died during a measurement interval, and $Stems_alive_{t1}$ is the number of stems that were alive during the measurement prior to the interval.

Typical annual tree mortality rates in old-growth forest range from 0.3% to 1.6% (Busing 2005, Runkle 2000, Woods 2000).

Good: Growth rate ≥ 60% of mean for region (based on FIA data for state or smaller region, like coastal Maine) or species and mortality rate ≤1.6%; for park and all individual species.

Caution: Growth rate < 60% of mean for region (based on FIA data) or species or mortality rate > 1.6%; for park or any individual species.

Confidence

Medium. Variation in the location of DBH measurements can yield inaccurate growth rates, particularly for trees with forked or misshapen boles. NETN will mark location of DBH on bole in these situations. Ratings should be reassessed for suitability when data are available.

Soil Chemistry—Acid Stress

Overview

The molar ratio of calcium to aluminum (Ca:Al) in soil or soil solution has been developed as an indicator of acidification stress to forest vegetation. We will assess soil chemistry from composite samples within the rooting zone only, as an indicator of stress upon vegetation.

Metric Justification

Acidic deposition acidifies soil, leaching important base cations (e.g., Ca^{2+}, Mg^{2+}, K^{+}) from the soil and increasing availability of aluminum; this deprives vegetation of necessary nutrients, and increases availability of a toxin (Al). Broad-scale patterns of wet deposition across the northeast are well characterized and are most substantial at high elevations and in the southern and western parts of the region, diminishing to the northeast (Driscoll et al. 2001). However, substantial additional acidity can result from dry and occult deposition, and these patterns of deposition are not well characterized. Within NETN, coastal fog at Acadia NP may deposit substantial acidity as occult deposition (Weathers et al. 1986).

Calculation and Scaling Rationale

Ca:Al ratio is calculated as the molar ratio of NH_4Cl-extractable ions (Ca^{2+} and inorganic charged Al). Ca and Al data are typically reported as mg/kg of sample or mg/L of extractant; data reported thus will need to be converted to molar concentrations by dividing each concentration by the molar mass of the element in question (40.08 g/mol for CA; 26.98 g/mol for Al). The Ca:Al ratio is then calculated as the simple ratio of the molar concentrations.

Cronan and Grigal (1995) critically reviewed the literature to determine the utility of Ca:Al ratio in soil solution as an ecological indicator of acid stress to vegetation. Based on this review, they

estimated a 50% risk of adverse impacts on growth or nutrition across a wide range of tree species when the soil solution Ca:Al ratio is as low as 1.0. However, sensitivity to acid stress varies among species, and Cronan and Grigal (1995) note impacts have been reported at higher Ca:Al ratios for red oak (4-5), sugar maple (2.5), and several conifers (> 1); Decker and Boerner (1997) reported a Ca:Al ratio of 4.0 depressed growth, production and nutrient uptake in tulip poplar (*Liriodendron tulipifera*). Driscoll et al. (2001) suggest that Ca:Al ratio can recover over time if acid deposition levels are reduced, and Ca:Al ratio can be used to judge ecosystem recovery.

For practicality, NETN will assess exchangeable Ca:Al from soil samples rather than directly sampling soil water. The former is related but not identical to the latter (David and Lawrence 1996) and soil exchangeable Ca:Al ratio been used as a surrogate indicator (Lyon and Sharpe 1999, Wargo et al. 2002). Calcium and aluminum vary substantially through the soil profile (Yanai et al. 2005). Vegetation will be most affected by the Ca:Al ratio of soil in contact with fine roots, the bulk of which are found in the O and A horizons (or in the upper soil depth if not separated by horizon).

Park ratings will correspond to median values for all park samples in O and A horizons or in the upper 10 cm of soil. Median values are used, rather than means, due to the high variation typical in soil chemistry sampling.

Good: Ca:Al ratio > 4.0 in O and A horizons or in upper depth.

Caution: Ca:Al ratio from 1-4 in O or A horizon or in upper depth.

Sig. concern: Ca:Al ratio < 1.0 in O or A horizon or in upper depth.

Confidence

Medium. Spatial and temporal variation in soil properties are typically quite high and may impede detection of significant trends. Yanai et al. (2005) have shown that small differences in separation of soil layers between years are likely to impact Ca:Al ratios. NETN has adopted a protocol that samples by soil layer when layers are evident, and by depth when layers are not evident. Our SOP specifies compositing samples from each plot to reduce spatial variation.

Soil Chemistry—Nitrogen Saturation

Overview

Changes in the carbon to nitrogen (C:N) ratio in soil are a primary indicator of forest nitrogen status and the impacts of atmospheric deposition.

Metric Justification

Nitrogen (N) is a limiting nutrient necessary for plant growth that has historically been retained within northeastern forested ecosystems. As atmospheric deposition has increased N inputs by five- or 10-fold in the northeastern U.S., concern has arisen that excess N may “saturate” forested ecosystems, causing excess nitrification and N leaching which in turn would exacerbate the effects of acidification (Aber et al. 1998).

Calculation and Scaling Rationale

C:N ratio is calculated as the simple ratio of total C to total N (assessed from dry combustion).

Aber et al. (2003) compiled and analyzed data from sites across the northeastern U.S. to find that nitrification increased sharply below a C:N ratio of 20-25. Soil C:N ratios are typically lower beneath deciduous than coniferous stands, and in mineral than organic soil horizons. The Indicators of Forest Ecosystem Functioning (IFEF) database was compiled to evaluate the utility of C:N ratio in the organic horizon as an indicator of nitrate leaching. This effort compiled and analyzed data from 181 forest sites across Europe and found that below a C:N ratio of 25, overall nitrate leaching was significantly higher and more strongly correlated to N deposition (MacDonald et al. 2002). This assessment found no significant differences in these relationships between deciduous and coniferous forest.

As above, park ratings will correspond to median values for all park samples in O and A horizons or in the upper 10 cm of soil. Median values are used, rather than means, due to the high variation typical in soil chemistry sampling.

Good: C:N ratio > 25 in O and A horizon or in upper depth.

Caution: C:N ratio from 20-25 in O and A horizon or in upper depth.

Sig. concern: C:N ratio < 20 in O and A horizon or in upper depth.

Confidence

Medium. These ratings were developed from a robust body of literature. However, as with Ca:Al ratio, soil spatial and temporal variability is high.

NOTE: Dr. Ivan Fernandez recommends that soil rating be based on "…a suite of variables 'related to' acidification concerns that could include % Ca saturation, C/N,...adsorbed SO4..., and of course pH," rather than on single measurements. NETN is working to refine the soil chemistry metrics by incorporating multiple soil variables to address whether acid deposition may be affecting forest ecological integrity.

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Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version	Date	Revised By	Changes	Justification
2.01	January 2007	-	Calculations included. List of non-high canopy species included in regeneration metric.	-
3.00	June 2007	-	Clarified that "natural" ecological conditions may not be realistic at some cultural parks. Clarified that some metrics are not rated Sig Concern due to lack of information or need for flexibility at NHP Altered regeneration ratio and based on species richness rather than quantity. Clarified only native species count for stocking index. Added separate regeneration stocking for ACAD. Corrected basal area formula in growth rate. Based growth rate rating on statistical distribution, and added additional rationale. Added text describing tree condition foliage calculation. Removed CWD Sig Concern rating pending further review. Added formula to estimate live wood volume per plot. Removed exotic species ratio in favor of exotic indicator species metric. Updated indicator species lists. Adjusted and clarified indicator calculations and ratings. Added biotic homogenization metric. Removed forest patch size rating for Sig Concern—may not be feasible for small cultural parks. Altered Anthropogenic landuse window size Added calculation for stand structure Changed "old-growth" language to "late-successional."	-
3.01	September 2007	-	Changed version number to NETN standard. Formatted document to NPS standards. Minor edits and grammatical corrections. Updated Table S16.1 to include metric type and corrected typo in stand structure metric. Clarified snag rating. Reinserted SC rating for CWD and Forest patch size. Corrected tree volume formula. Adjusted text to clarify intent to rate based on EI, not management goals. Updated Goodell citation. Changed version number to NETN standard.	-
3.02	November 2007	-	Adjusted *Carpinus caroliniana* and *Ostrya virginiana* common names. Added scientific names to Table S16.2.	-

Revision History Log (continued)

Version	Date	Revised By	Changes	Justification
3.03	March 2008	-	Clarified rating breakpoints. Adjusted ACAD tree size classes for stand structural class. Adjusted tree regeneration metric. Clarified that FIA data will be used to establish means for Tree growth rate metric. Adjusted biotic homogenization metric. Adjusted confidence in C:N ratio. Minor editorial changes.	-
3.04	May 2008	-	Adjusted version numbers to meet new NETN standard. Mowed field were classified as anthropogenic land use. Added check for miscategorization of early-successional and mosaic plots. Clarified height correction factors for gap-exploiter and open-grown trees. Defined “tree” in the “Metrics and Ratings” section. Added formulas for biotic homogenization. Clarified cutoffs for invasive exotic species metric. Revised deer browse metric to be a simple proportion of quads with each indicator species, rather than aggregating data per plot (which decreases sensitivity) or calculating on a plot basis (where sample size was small). Minor edits.	-
3.05	October 2008	-	To structural stage distribution, added assessment point for all ecosystem types not specified. Minor edits.	-
3.07	April 2009	Kate Miller	Note for considering adding sapling/seedling or "small" stands to metric calculation to reflect overall distribution of structural stages across the park. Added that NETN is continuing to refine the deer herbivory metric. Added that NETN is working to refine the soil chemistry metric to incorporate a suite of variables to examine impacts of acid deposition. Clarified that the forest vital sign protocol is not appropriate for early detection of new invasions. Added that NETN may consider adding another metric the looks at relative proportion of native and exotic species. Added that NETN may consider additional metrics for understory species dynamics in the biotic homogenization section.	-
3.08	May 2009	Sarah Lupis Kozlowski	Minor editorial changes	Conform to NPS standards
3.09	December 2009	Andrew Vincello, Kate Miller, and Brian Mitchell	Minor editorial changes. Revised Invasive Plant metric to include detections in microplots and as tree-sized individuals.	

Revision History Log (continued)

Version	Date	Revised By	Changes	Justification
3.10	January 2011	Kate Miller	Changed Hemlock Woolly Adelgid to a Priority 1 Pest in Tree Condition Metric.	
3.11	March 2014	Kate Miller	Changed SOP number	
3.12	January 2020	Camilla Seirup	Changed SOP number	

SOP 17 - Protocol and Database Revision

Mid-Atlantic Network/Northeast Temperate Network

Version 1.02

Overview

This SOP outlines the procedures and deadlines for making changes to the forest protocol and the forest database.

Revision Process

There are several approaches to revising the forest protocol and database, and the ideal approach is to discuss changes at the annual protocol review. However, all protocol changes require approval by the lead authors of this protocol, and all changes to the database must be approved by the MIDN and NETN data managers.

Review Panel

A review panel consisting of NETN and MIDN staff and cooperators will meet annually within a few months after the completion of the forest field season. Several weeks prior to the review panel, the NETN plant ecologist will distribute a draft outline of discussion topics to each panel member to revise. The plant ecologist will incorporate the panel members' comments and distribute a final version of the outline no later than the day before the review. This outline will serve as the framework for the discussion during the meeting. Discussion topics should cover lessons learned during the field season, forest crew feedback, and potential protocol and database changes that came up during the field season. After the review the NETN plant ecologist will revise the protocol based on the review discussions, and send the revised protocol to panel members for approval. NETN and MIDN data managers will revise the forest database, which will also be sent to panel members for approval.

Revision Timeframe

While not ideal, it is possible to make changes to the forest protocol and/or database after they have gone through the annual revision process. However, protocol changes must be made and approved by the review panel no later than 3 weeks before the crew is scheduled to begin training. If the protocol change also requires the database to be changed, then changes must be proposed no later than 6 weeks prior to the start of training to allow time for the data managers to modify the database and NETN and MIDN staff to prepare the database materials covered during training. Proposed changes to the protocol or database that arise after this timeline will be added to the list of discussion topics at the following year-end panel review.

Database Tracker

Network program managers or plant ecologists should send a list of proposed database changes to their corresponding data manager using the Database Tracker spreadsheet. Network staff should provide at a minimum a description of the change request and why it is needed. NETN and MIDN

data managers will meet to compare change requests and develop a strategy for handling write access to the master database.

Revision History

Version numbers will be incremented by a whole number (e.g., Version 1.30 to 2.00) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.06 to Version 1.07) when there are minor modifications that do not affect requirements or procedures included in the protocol. Add rows as needed for each change or set of changes tied to an updated version number.

Revision History Log

Version #	Date	Revised by	Changes	Justification
1.00	October 2009	Kate Miller	New SOP	
1.01	March 2014	Kate Miller	Changed SOP Number	
1.02	January 2020	Camilla Seirup	Changed SOP Number	