

Cumberland Piedmont Network

National Park Service
Inventory and Monitoring Division



Standard Operating Procedure 6

Tree Measurements—Version 1.48

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Overview

This standard operating procedure documents procedures for recording species, diameter, and various measures of condition of all live and standing dead trees greater than 10 centimeters (3.9 inches [in]) diameter at breast height in the entire 20×20 -meter (65.6×65.6 feet [ft]) plot. The data are collected separately for each of the four 10×10 -meter (32.8×32.8 ft) modules. These data will provide information on tree growth through time, mortality, condition, stand structure and stand composition.

***If this is a plot revisit or a QA/QC resampling event, make sure that the list of trees and the map of trees found during the last sampling are taken out into the field to match up present day trees with ones measured previously.*

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Definitions

Trees are woody species with a diameter greater than or equal to 10 centimeters (3.9 in]) at breast height (1.37 meters [4.5 ft]) and capable of attaining heights greater than 7 meters (23 ft). Field teams are provided a list which delineates species classified as trees. This will make it easier to determine whether a species being recorded is considered to be a tree, shrub, or vine. When in doubt, go ahead and record the diameter at breast height since the data on non-trees can always be discarded later.

Diameter at breast height (DBH) is the diameter of the tree trunk (also called bole) at 1.37 meters (4.5 ft) above the ground line on the uphill side of the tree. It is very important that the DBH is measured at the 1.37 meters height. The DBH is measured and rounded to the nearest centimeter for trees greater than 10 centimeters (3.9 in) diameter at breast height. The one exception to rounding is that the Cumberland Piedmont Network does not round up from 9.5 centimeters (3.7 in). In other words, a trunk or bole must be greater than or equal to 10 centimeters in order to count as a tree.

Live trees have living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters [4.5 ft]). Trees that have been temporarily defoliated or are leaning or fallen are considered live trees. Live trees do not have to be self-supported—they may be supported by other trees, branches, or their crown. Pay attention to overtopped evergreen tree species that may appear dead but have green foliage at the very top of the tree that is embedded in neighboring trees or mistaken for brown foliage.

Standing dead trees (also called snags) lack any living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters [4.5 ft]) and lean less than 45° from vertical, as measured along the trunk (bole). Standing dead trees need not be self-supported. Once included, standing dead trees are tracked until they no longer qualify as standing dead. Dead trees leaning greater than 45° from vertical are considered coarse woody debris and are measured according to SOP 8 *Coarse Woody Debris Measurements—Version 1.35* (CUPN 2023a).

Step by Step Instructions

For plot revisits: after reviewing these step by step directions, field teams, particularly those involved in tree data collection, should review the “Notes on Plot Revisits” section at the end of this SOP which highlights common data collection/recording errors during plot revisits.

For new plots, beginning with module one, visually determine your strategy for measuring trees in a coherent pattern so that each tree of greater than 10 centimeters (3.9 in) DBH is recorded on the datasheet. This can be done by measuring the trees starting in one corner of each module and working through the whole module. You can work in a circular or linear pattern depending on the arrangement of trees in a module but do so in a logical manner. In other words, do not skip around from one side of the module to the other. In dense foliage, flagging may be helpful to mark the starting tree and the boundary between trees that have been recorded and those that have not. For plot revisits, start with the first pre-recorded tree on the datasheet (labeled “Tree 1”) and work in order of the pre-recorded trees, keeping an eye out for any newly recruited trees (grown to > greater than 10 cm centimeters since last plot sampling event) as you methodically work through the module.

A tree on the plot boundary will be included only if the center of the tree base lies directly on or within the plot boundary (i.e., at least half of the tree is within the boundary). If a crew is struggling with whether a tree should be in or out, one approach is to measure the horizontal distance from the centerline tape to the front of a crew member, standing adjacent to the tree base center. If the distance from the plot centerline to the center of the tree base is greater than 10.0 meters (32.8 ft), then the tree falls outside the plot and is not tallied. The lean of the tree bole into or out of the plot does not affect whether the tree is tallied. For revisits, if it is obvious the previous field crew included a tree (i.e., assigned a tree number and is mapped) then it should be included for your sampling event as well even if you think a tree may be “mostly” out (over time, a tree may grow to where it appears more “out” than “in,” even though during plot establishment the tree was mostly “in”). Also, if a tree falls just outside the plot, it is good practice to map this tree on the plot’s tree diagram to assist future field crews in plot layout (refer to Tree Map section, below).

For revisit or QA/QC plots, field teams will have the tree map from the previous event. It is critical that teams reference this provided map when mapping and tallying trees. Specifically, your tree 1 should be their tree 1. When resampling a plot for QA/QC, the tree map completed at the end of your sampling event should look like the map produced by the other team (given ± 0.5 meters [1.64 ft] on the exact mapping). This comparison is made for every tree before moving on to the next tree. Do not add or drop trees from plot boundaries as the decision on whether to include was already made by the previous team. This means tapes are laid out to match the previous sample and trees on edges of modules or plot are in the same place for the current sampling event. If the previous team called a tree in or out of a module or plot, do the same unless it is an obvious un-reconcilable error (i.e., entire base is clearly in or out with reasonable margin for error). In those rare instances where you believe the previous team made an egregious error, collect the data as the previous team did and then make detailed notes detailing why it should be done differently, including the “corrected” data as well. A photo showing the tree in question and plot boundary tapes would also be helpful.

For plot revisits, every tree recorded during the previous sampling event and recruited trees (those that are now greater than or equal to 10 centimeters [3.9 in] but were not during the previous five-year cycle) will receive a value for module number, tree number, species, and status. From that point on, recorded values will depend on the tree’s status. Each of the subsequent sections in this SOP will define which trees receive which values. Refer to Table 1 below for an overview of which values are required for which tree statuses, and which values are given only if applicable.

Table 1. Overview of tree values by tree status. X=Required Field. I=If applicable.

Value	Tree Status 0	Tree Status 1	Tree Status 2	Tree Status 3	Tree Status 4
Module number	x	x	x	x	x
Tree number	x	x	x	x	x
Species Code	x	x	x	x	x
Tree Status	x	x	x	x	x
DBH >10 centimeters (3.9 in)	—	x	x	—	—
Crown Class	—	x	—	—	—
Vigor	—	x	—	—	—
Dieback	—	I	—	—	—
Condition/Damage	—	I	—	—	—
Foliage Condition	—	I	—	—	—
Foliage %	—	I	—	—	—
Decay Class	—	—	x	—	—
Snag Height	—	—	x	—	—

Verify Plot Layout

It is highly likely, the trees in your plot have been previously mapped and measured. Therefore, a plot tree map and plot footprint (i.e., which trees are included in which modules) have already been established. This map or footprint should have already been consulted during plot layout, ensuring module boundaries align with the previous event(s). Before beginning data collection do a reconnaissance of each module to ensure all trees that should be in each module can be accounted for and any discrepancies can be accounted for (e.g., fallen tree). If it was discovered that a tape was laid out incorrectly (i.e., included a tree that should not have been included or vice versa), stop data collection for the plot and have the field team correct the error by realigning the tapes.

Species

Once you have reviewed the tree map from the previous sampling event and feel confident module boundaries are correctly delineated, locate tree 1 from the previous sampling event. Tree number is consecutive for the plot beginning with tree 1. For each species, record the 7–8 letter code that corresponds to the scientific name. Refer to park species list provided to field crew. If for some reason the park species list is inaccessible or a species is not included on the list, spell out the **entire** species name, no abbreviations. Unique codes generally consist of the first four letters of genus and first three letters of species of that tree with an extra eighth digit where there would be duplicate seven letter codes. For example, shagbark hickory, (*Carya ovata*) and red hickory (*Carya ovalis*) would have the same seven-letter code, as such the former's eight-letter code is CARYOVAT and the latter's correct code is CARYOVAL. In assigning species names

and uncertainty values, refer to SOP 14 *Recording Species Nomenclature—Version 1.37* (CUPN 2023b). In instances where species identification is not 100% certain, ask the botanist. If for some reason you believe the previous team made a species identification error, consult the botanist before changing the species ID. In all cases, the botanist on the plot is the final authority when making species identification calls.

Diameter at Breast Height (DBH)

Before starting, it is good practice to measure 1.37 meters (4.5 ft) on your chest, using the 1.37 meters (4.5 ft) fiberglass pole in the plot gear or plot meter sticks to aid in consistency of measurement. It is also good practice (and highly encouraged) to periodically have someone else on the field crew re-measure a tree or two within the plot to again check for consistency.

All trees, living or dead, greater than or equal to 10 centimeters (3.9 in) DBH will be recorded on the datasheet. Using a DBH tape, measure DBH, which is 1.37 meters above the ground, on the uphill side of tree (Figure 1). Do not measure from a pit or atop a mound or emergent rock. Use the DBH tape measure and round to the nearest 1 centimeter (0.4 in). In other words, if measured DBH is 10.4 centimeters, then it would be rounded to 10 centimeters. If measured DBH is 10.5 centimeters, it would be rounded up to 11. The one exception to rounding is that a tree must be at least 10 centimeters DBH to be recorded. So, if it measures 9.9 centimeters or less, it should not be rounded up to 10 centimeters. In any case where a tree branches above 1.37 meters (breast height) from its base or more, you will only record the main stem. In contrast, if the tree branches less than 1.37 meters (breast height) from the base, you will measure all stems greater than or equal to 10 centimeters DBH.

Make certain you are reading the correct side of the DBH tape; often one side has standard centimeters and the other side has units calibrated to give the diameter in centimeters when wrapped around the circumference of the tree. Press the hook at the end of the tape into the bark and then run the tape around the trunk, ensuring the tape is straight, pulled tight (no kinks) and perpendicular to the axis of the trunk. Tapes that are not run straight will overestimate the trunk diameter. Read the number where the tape crosses the zero mark at the hook end of the tape. For unusual situations, determine where DBH should be located on the tree, using the guidelines in Figure 1 and “further notes” below. Note the location of the DBH measurement in Tree Notes, using distances and unique tree characteristics.

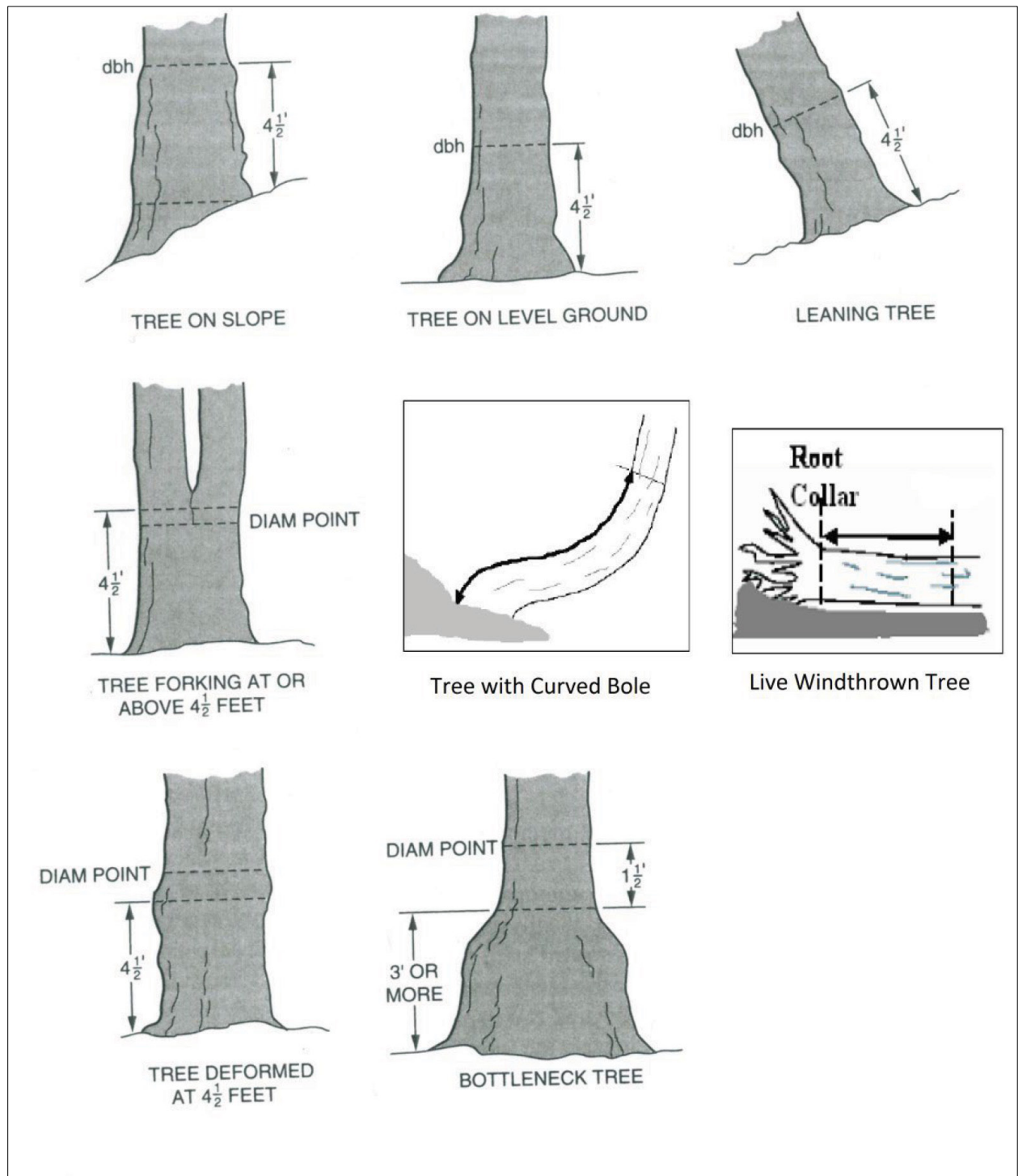


Figure 1. Irregularities in DBH measurement.

Further notes on measuring DBH:

Trunk abnormality: If a trunk abnormality occurs at breast height (1.37 meters [4.5 ft]): Take the diameter measurement just below the abnormality if possible. If the abnormality extends far below breast height (1.37 meters), then take the measurement just above breast height (1.37 meters). Put the height where measured in the Tree Notes.

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 as the tree is and note that wood or bark was missing in Tree Notes.

Leaning tree: Diameter is always measured perpendicular to the bole axis. Find the point equivalent to breast height (1.37 meters) by measuring along the uphill side of the tree. Measure diameter perpendicular to the tree trunk (bole) as shown in Figure 1. If a living tree is leaning more than 45°, find the point equivalent to breast height (1.37 meters) by measuring along the uphill side of the tree starting with the root collar and measure diameter perpendicular to the bole. Note that a dead tree leaning more than 45° is not counted or measured as a tree but is counted as coarse woody debris.

Curved bole: Find the point equivalent to breast height (1.37 meters) by measuring along the curvature of the bole on the uphill side of the bole as shown in Figure 1 and measure diameter perpendicular to the bole.

Live windthrown tree: Find the point equivalent to breast height (1.37 meters) by measuring along the uphill side of the tree starting with the root collar and measure diameter perpendicular to the bole (Figure 1).

Swollen base: Trees with swollen bases rising higher than 0.91 meters (3 ft) are measured 0.46 meters (1.5 ft) above the top of the swelling. Trees with swelling below 0.91 meters are measured at standard DBH. Make a note in Tree Notes about the swelling and diameter location.

Independent trees that grow together: If two or more 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 (1.37 meters) are tallied and measured as one tree. Diameter is measured below the point at which forking affects DBH (Figure 1). For trees that fork below breast height (1.37 meters), each stem greater than or equal to 10 centimeters (3.9 in) is tallied as a separate tree. Measure the diameter of each stem at breast height unless the fork affects the diameter of the stem, in which case measure above breast height where the fork does not affect the diameter of the stem and make a note in Tree Notes of measurement location. For consistency, multiple stems are recorded from left to right when facing the trees from plot center, and a single dot on the map should never be used to represent multiple trees, including forks. Note the spatial relationship of forked trees to each other in Tree Notes and on tree map. Record any unusual tree features or the relative position of each of the stems of a clumped tree or copse if applicable.

Trees with vines: It is imperative that trees with vines climbing the bole at breast height have the DBH measured underneath the vines. The easiest way to remove the vine is by prying it away from the tree with the hammer to get underneath it. Be especially careful when handling poison ivy vines (use gloves) because the hairs on the vine can cause a reaction similar to the leaves. Note there is not enough precision using the Biltmore stick to estimate DBH for this method to be recommended.

Tree Status

Determine the tree status of each recorded tree (see below). In differentiating whether a tree is alive or dead, refer to the definitions at the beginning of this SOP. If the tree in question is determined to be dead, move on to Decay Class. Information on decay class is found near the end of this SOP.

0. No status: Previously tallied tree is no longer in sample because the tree: (a) shrunk below 10 centimeters (3.9 in) DBH (e.g. tree damage or bark sloughing), (b) was incorrectly tallied last time, or (c) a change in procedure now excludes this tree. Record the reason in Tree Notes, along with DBH if measurable. If a missing tree is likely fallen dead then it should be given a status of 4, even if you cannot locate the tree (see below).
1. Live tree: New live trees in revisit plots are assumed to be in-growth. If a tallied new tree was obviously missed during a previous inventory, note this in Tree Notes. New trees will be given the next tree number available. For example, if there are already 25 trees documented in the plot, then a new tree would be assigned tree number 26. Live trees have living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters).
2. Standing dead tree: Tree lacks any living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters), and is straight up and down or leans less than 45° away from vertical.
3. Removed: Previously tallied tree has been cut and removed by humans during harvest, forestry treatment, hazard tree removal, or land clearing. Signs of cut or destroyed tree such as stump or chips can be found.
4. Fallen dead tree: Previously tallied tree has fallen and will no longer be tracked as a live tree. This includes standing dead trees leaning greater than 45° from vertical, as well as fallen dead trees that have decayed past the point of being relocatable. It also includes dead trees that have snapped where the bole is still present but shorter than 1.37 meters, and the rest of the tree above 1.37 meters has fallen.

If tree is alive, follow the steps below to pick the appropriate codes for crown class and tree vigor. All live trees will receive a crown class and vigor code. Additional codes are added for trees that exhibit dieback, damage, foliage problems, or other various conditions. It is important to thoroughly inspect each tree by looking up and down the tree from multiple angles using binoculars, as well as around the entire bole.

Crown Class

Every live tree will receive a crown class code. Assign the crown class code describing tree crown position in canopy and amount of sunlight received (Figure 2). If there is any uncertainty in assigning a canopy class to a tree, make a note in Tree Notes about why.

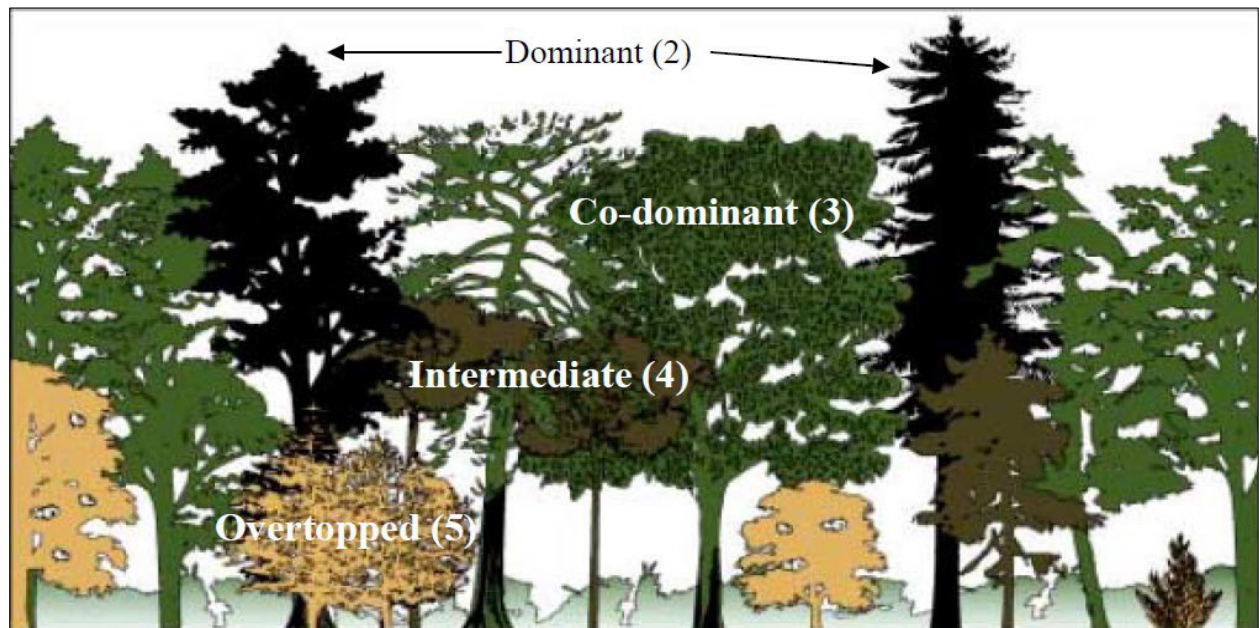


Figure 2. Crown class examples for classes 2–5.

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. Open-grown trees may be present at different positions within the general canopy but are identified by their form. They are much older and larger than all the other trees in the plot, with unusually spreading branches indicative of a past that included growing in a full-sun, low competition environment. This results in a much more rounded (as opposed to linear) crown.
2. Dominant—crown extends above canopy, receiving full light from above and some light from sides. Taller than the average tree in stand and has well-developed crown.
3. Co-dominant—crown at the general level of the canopy, receiving full light from above but little direct light from sides. 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. Overtopped—crown is entirely below the general level of the canopy.

Vigor

Every live tree will receive a vigor code. Vigor is a measure of overall tree health and vitality. This measure compares the subject tree to an “ideal” healthy specimen of that species. Several factors should be considered when assessing vigor:

- How much of the crown is missing or damaged from recent or long past disturbances? Old injuries should be considered in the vigor assessment until the tree builds a new crown that makes the old injury largely invisible.

- How much of the crown is composed of dead snag branches? Snag branches are large branches without small twigs less than 2.5 centimeters (1.0 in) in diameter, usually with the bark absent or with dead bark peeling away.
- How much of the crown contains foliar discoloration or dwarfed or misshapen leaves?

Current defoliation should **not** be considered in the vigor assessment. A defoliated tree does not necessarily have low vigor. Vigor is difficult to assess for trees currently undergoing partial or severe defoliation. For those trees, make the best assessment possible by considering crown structure, snag branches, and any intact foliage that may remain.

Vigor should be assessed using species-specific concepts for “ideal tree specimens.” For example, a healthy Virginia pine (*Pinus virginiana*) has a very different growth form than a healthy eastern hemlock (*Tsuga canadensis*). The same is true for deciduous trees; the growth forms are very different between sourwood (*Oxydendrum arboreum*), and scarlet oak (*Quercus coccinea*), for example. Crew members must be familiar with “healthy” specimens of the tree species found in CUPN parks and must use these concepts as reference points when assessing vigor.

Record the general overall health of the tree using the codes below. Estimate vigor before estimating dieback or recording tree or foliage conditions.

1. Healthy. Tree appears to be in reasonably good health with less than 10% missing or damaged crown, branch or twig mortality, discoloration, or dwarfed leaves present.
2. Light Decline. Less than 25% of the crown is missing or damaged. Branch mortality, twig dieback, foliage discoloration, or dwarfed leaves are present on 10–25% of the crown.
3. Moderate Decline. Branch mortality, twig dieback, foliage discoloration or dwarfed leaves on 25–50% of the crown. Between 26 and 50% of the crown is missing or damaged.
4. Severe Decline. More than half of the crown is missing, damaged, or contains branch mortality, dieback, discoloration or leaf dwarfing, but foliage is still present to indicate that the tree is alive.
5. Functionally Dead. There may be a few epicormic shoots on the bole, but the vast majority of the crown branches are missing or dead and leaf-less.

Dieback

Only live trees displaying dieback will receive a dieback code. Branch and fine twig dieback is defined as branch mortality that begins at the terminal portion of a limb and progresses downward (Figure 3). This measurement is an estimate of the proportion of the crown silhouette involved in dieback. Assume the perimeter of the crown is a two-dimensional outline from branch-tip to branch-tip. Then estimate the amount of the outline that includes dieback.

Record the proportion of the crown with crown dieback using the following categories:

(1) 1–10%, **(2)** 10–25%, **(3)** 25–50%, **(4)** 50–75%, **(5)** 75–100%.

The following should be **excluded** from the dieback percentage:

- **Snag branches** (large branches without small twigs less than 2.5 centimeters (0.9 in) in diameter, usually with the bark absent or with dead bark peeling away). Snag branches are assumed to have died much earlier and should not be included in the dieback percentage.
- **Large holes or gaps in the crown** where branches never developed.
- **Branch mortality at the base of the crown**, assumed to be the result of shading.

Dieback should ideally be estimated when leaves are mature, but before the appearance of fall color. One crew member is required to make the estimate of dieback from two different sides of each tree, standing at a minimum of a 90° angle apart around the tree. The diagram below (Figure 3) illustrates what to include and exclude when assessing dieback.

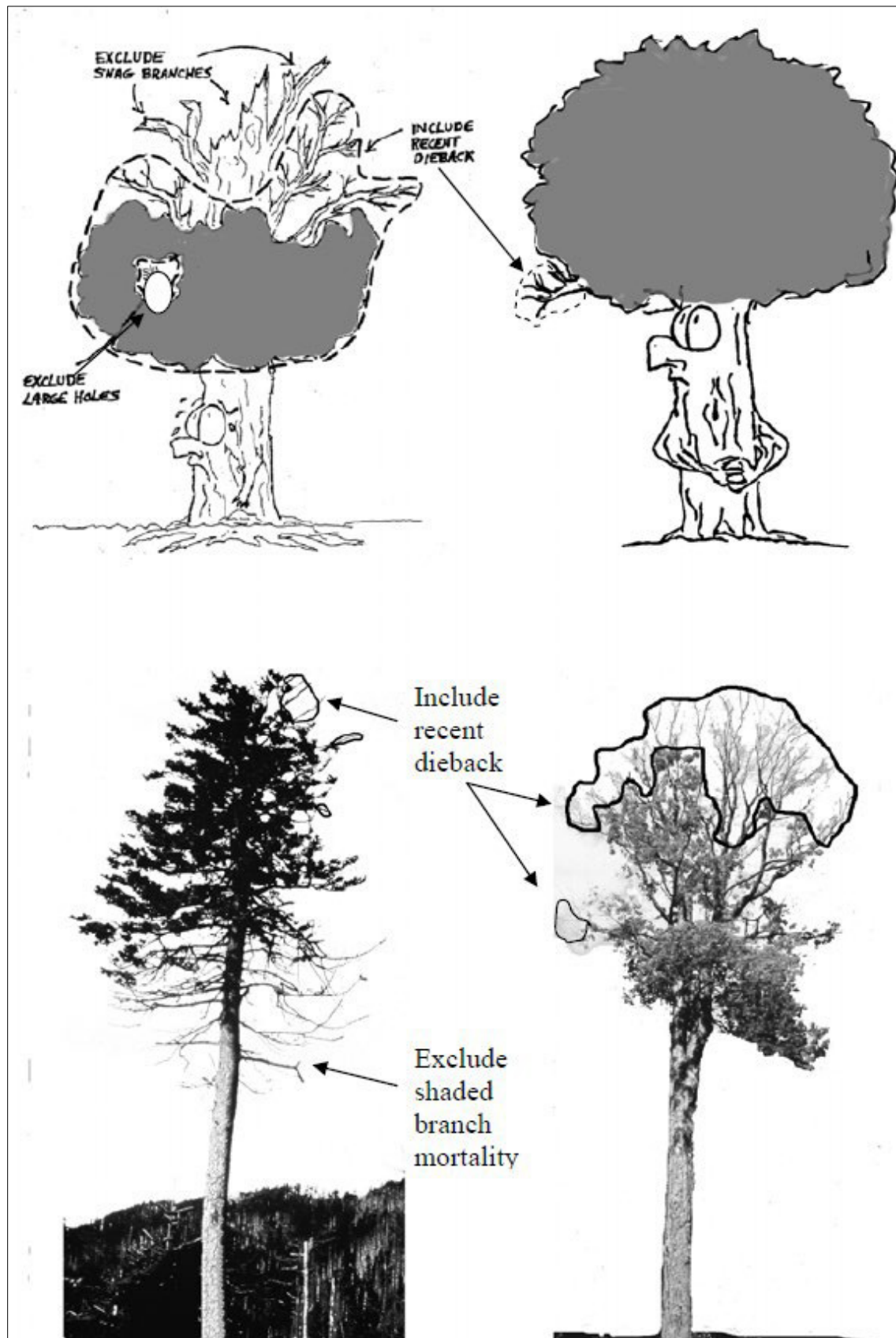


Figure 3. Examples of tree dieback (USFS 2005a).

Condition/Damage

Only live trees exhibiting conditions/damages listed below will receive a code. Field teams need to have some familiarity with the identification of these codes before assessing. Specific tree damage types will be indicated by placing the appropriate three- or four-letter code in the “tree condition/damage codes” column. You can add up to three codes in this column (if you need to write more than three codes, add the additional codes in the “Tree Notes” section). Forest pest and pathogen codes (three-letter code) can be found below in Table 2. Photographic evidence of any suspected forest pest or pathogen, as well as notes describing damage, should be collected as in many cases these will need additional verification.

Table 2. Tree pest and pathogen list for CUPN forest vegetation monitoring [mm=millimeters].

Forest Pest	Species Impacted	Signs and Symptoms
Asian Longhorned Beetle (ALB)	<i>Fraxinus</i> , <i>Betula</i> , <i>Ulmus</i> , <i>Aesculus</i> , <i>Platanus</i> , <i>Acer</i> , <i>Albizia</i> , <i>Populus</i> , <i>Salix</i> with maple the most commonly infested in NA, followed by elm and willow	Visible beetle 0.75 to 1.5" long, shiny black with white spots and very long striped antennae; chewed round depressions in bark or pencil-sized, perfectly round holes; sawdust (frass) buildup near base; unseasonable yellowed or drooping leaves
Beech Bark Disease (BBD)	<i>Fagus grandifolia</i>	Visible beech scale insect 0.5-1.0mm long, elliptical, becoming covered in wooly white wax; bleeding spots followed by reddish-brown fluid and perithecia from fungus; small, sparse and yellowed foliage with weak crown; cracking bark, cankers, and trunk snap from weakness
Chestnut Blight (CHB)	<i>Castanea</i> spp., can rarely be found on oaks, hickories, red maple, and staghorn sumac	Yellowing and dying of leaves; yellowish-to-red cankers around branch crotches; swelling and cracking bark
Dogwood Anthracnose (DWA)	<i>Cornus</i> spp., mainly <i>C. florida</i>	Necrotic lesions on leaves surrounded by dark zones; necrotic "shot holes" on sepals; cankers with epicormic shoots on trunks
Emerald Ash Borer (EAB)	<i>Fraxinus</i> , possibly <i>Chionanthus virginicus</i>	Visible beetle 1/3" long, metallic green with bright red upper abdomen under wings and wing covers; yellow, thin or wilted foliage; unusual woodpecker presence and pecking holes; D-shaped exit holes; Shoots growing from roots or a tree's trunk, often with larger than normal leaves
Spongy Moth (SGM)	Prefers oaks but will also feed on maple, birch, alder, hawthorn, apple, beech, cherry, and basswood	visible adult moths-males are brown, and females are white and much larger; caterpillars are hairy with yellow and black heads, followed by five pairs of blue spots and 6 pairs of red spots; egg masses are tan to orange and visible on tree trunks and branches and can cause defoliation with large amounts of frass at bottoms of trees
Hemlock Woolly Adelgid (HWA)	<i>Tsuga canadensis</i> and <i>Tsuga caroliniana</i>	Visible nymphs with white "wool" on twigs at base of needles; premature needle drop and discoloration; twig and crown dieback to complete defoliation

Forest Pest	Species Impacted	Signs and Symptoms
Laurel Wilt Disease (LWD)	Laurel family, most notably <i>Sassafras albidum</i> and <i>Lindera benzoin</i>	Tiny visible beetle ~2 mm in length; small strings of compacted sawdust protruding from entry holes in bark; dark discoloration of outer sapwood and wilted foliage with reddish or purplish discoloration
Spotted Lanternfly (SLF)	Any woody species with a smooth trunk, prefers grapes, stone fruits, apples, crabapples, and most preferred host is <i>Ailanthus altissima</i>	Visible adult planthopper about 25 mm long and 12 mm wide with black head, gray-brown forewings with black spots, and crimson hindwings; nymphs also brightly colored black with white spots/red and black with white spots; buildup of sticky fluid (honeydew) on plants and on the ground underneath infested plants; sooty mold on infested plants where honeydew was secreted
Oak Wilt Disease (OWD)	Red and white oaks, but red oaks more susceptible	Often occurring in later spring or summer, symptoms include: discoloration of leaves, wilted or curled leaves, complete leaf drop that occurs by mid summer, dead crowns (upper portions of the trees), suckering at the base of the tree
Thousand Cankers Disease (TCD)	<i>Juglans nigra</i>	Visible walnut twig beetle-tiny (1.5-2 mm long) and reddish- brown; thinning foliage and yellowing of leaves in the upper crown to entire branch dieback; bark may not exhibit symptoms of cankers in phloem but can crack and become dark and stained above a canker; tiny beetle entrance and exit holes on dead and dying branches

The Cumberland Piedmont Network began implementing an Invasive Species Early Detection (ISED) protocol in 2014 (Keefer et al. 2014). The protocol contains early detection lists for both plants and pests for each of the 14 CUPN parks. Historically, these lists were updated annually. However, the protocol is undergoing a substantive revision which started in 2021. In the interim, any suspected evidence of a pest or pathogen should include a specimen of the pest, or a photo of the pest or symptoms Blank “Incidental Observation” forms (Figure 4) must also be completed as part of the ISED protocol and accompany the evidence of the forest pest. These vouchers are provided as quickly as possible to:

Clare Bledsoe, Biologist Mammoth Cave National Park
P.O. Box 8
Mammoth Cave, KY 42259
clare_bledsoe@nps.gov

This information will then be used to help with the early detection of forest pests.

☐ Invasive Exotic Plant	☐ Forest Pest	☐ Rare/ Tracked Species	☐ Other														
Species: _____ Observer(s): _____ Park: _____ Date: _____																	
ID Confidence: certain probable uncertain		Evidence Collected: photo voucher other _____															
<i>plant only</i> Infested Area (ft ² /m ² /acre/ha): _____ (if dense) Gross Area (ft ² /m ² /acre/ha): _____ (if scattered) Canopy Closure: Trace Low Med High (<1%) (1-5%) (5-25%) (25-100%) Abundance: Single Scattered Dense Patches Dense monoculture Linear Pattern Description: In Flower In Fruit Seedlings/Rosettes Dormant/Dead Bolting Unknown Stem Count: _____		<i>forest pest only</i> <table style="width: 100%;"> <tr> <td style="width: 50%;">Host Species</td> <td style="width: 50%;">Type of Evidence</td> </tr> <tr> <td>_____</td> <td>crown dieback</td> </tr> <tr> <td></td> <td>foliar injury (chlorosis/necrosis...)</td> </tr> <tr> <td>DBH _____</td> <td>sawdust</td> </tr> <tr> <td><i>(if tree)</i></td> <td>exit holes</td> </tr> <tr> <td></td> <td>other _____</td> </tr> <tr> <td colspan="2">Host Species Stem Count: _____</td> </tr> </table>		Host Species	Type of Evidence	_____	crown dieback		foliar injury (chlorosis/necrosis...)	DBH _____	sawdust	<i>(if tree)</i>	exit holes		other _____	Host Species Stem Count: _____	
Host Species	Type of Evidence																
_____	crown dieback																
	foliar injury (chlorosis/necrosis...)																
DBH _____	sawdust																
<i>(if tree)</i>	exit holes																
	other _____																
Host Species Stem Count: _____																	
Field UTM X _____ m E		Field UTM Y _____ m N															
Datum _____		Zone _____															
How were coordinates obtained (e.g. phone, GPS, etc.)? _____		GPS error _____ m															
Location Description: _____																	
Habitat Description (e.g. forest edge, mixed forest, open field): _____																	
Other comments: _____																	

Figure 4. Blank “Incidental Observation” form which must be completed if an early detection plant or pest is found during vegetation monitoring.

In addition to specific pests and pathogens listed above, the field teams will also be called upon to record various characteristics of the tree, indicative of past or current stressors which may impact or provide insight into the tree’s health and longevity (see Table 3 below for damage/condition codes, excluding pests and pathogens). For instance, epicormic or basal sprouting can be a symptom of stress in a tree as it attempts to increase leaf surface available for photosynthetic activity, whereas a conk is indicative of fungal infection. Just like when recording tree vigor, this evaluation requires crew members to have some knowledge or experience observing “healthy” individuals of the species under evaluation. It is anticipated that if a tree receives a low vigor than one or more condition codes will be recorded. However, the presence of one of these conditions does not always mean a tree is currently exhibiting low vigor. For instance, a tree may have bird “damage” present on the bole but still appear quite healthy.

A special note on vines. Vines are only recorded if present in the tree’s canopy and the vine species should be recorded in the “Tree Notes” field. During a revisit, if a vine was present during the previous sampling event this note will still be retained in the tree notes field on the revisit form (e.g., Vine = *Vitis* sp.). If the vine is no longer present, cross off the old note to avoid confusion during future sampling events.

Table 3. List of tree damage codes, excluding pests and pathogens.

Damage Code	Description of Damage
ABGR	Abnormal growth pattern for the species. This category would include a range of physical deformities not included in the remainder of the damage codes.
BIRD	Bird damage such as woodpecker or sapsucker holes.
BLIG	Blight is generally defined as any plant disease or injury that results in general withering and death of the plant without rotting. Blight can result from a wide variety of needle, cone, and stem rusts, as well as canker diseases, and is often species- or genus- specific.
BROK	Broken top of the tree.
BURL	A hard often rounded outgrowth on a tree that is made up of woody material. This occurs naturally in some tree and shrub species and is a sign of an internal infection or disease in other species.
CONK	The knobby fruiting body of a tree fungal infection visible on a tree bole, such as a shelf fungus.
DECY	Advanced decay of bole and limbs.
DTOP	Dead top.
EPIC	Epicormic sprouting for species in which this is uncharacteristic, adventitious shoots arising from suppressed buds on the stem.
FIRE	Fire scar or cambial damage due to fire.
GALL	Galls found on stems, leaves, or roots. Galls are formed by infection of the plant by bacteria or fungi, or by an attack by certain mites, nematodes, or insects, most notably wasps.
HOLW	Hollowed-out trees. Repeated hot fires can burn through the bark and the tree's core may then rot out, especially in trees with tough bark, but soft heartwood. These hollowed-out trees are sometimes called "goose pens" because early settlers kept poultry in them.
INSE	Visible insects in the tree bole or the canopy, or their sign, such as frass, pitch tubes or bark beetle galleries.
LIGT	Lightning scar or other damage to the tree caused by lightning.
MAMM	Damage caused by mammals, such as bear claw marks, porcupine or beaver chewings, and deer or elk rubbings.
OZON	Ozone damage. Ozone injury is often seen in the form of stippling or speckling on the leaves or needles of trees. This discoloration varies among species and ranges in color from red or purple to yellow or brown. Susceptible species often drop their leaves prematurely.
ROOT	Large, exposed roots.
SPRT	Basal sprouting; new shoots arising from the root collar or burl.
UMAN	Human-caused damage such as axe marks, embedded nails or fence wire, or vandalism.
VINE	Vines present in canopy. List vine species or genus in the Notes section of the paper data sheet or the Vine Species section of the database. Vine should reach the tree canopy to be counted.

Damage Code	Description of Damage
WOND	A wound to a tree that cannot be identified by one of the other damage codes, including wounds or cracks of unknown cause.

Foliage Condition and Foliage Percentage

Only live trees displaying foliage conditions will receive a code. Visually assess canopy foliage and record up to three (3) problems: chlorosis (C), necrosis (N), holes (H), small leaves (S), wilting (W), leaf loss (L), or other (O—describe in Tree Notes). Chlorosis is a condition where leaves produce insufficient chlorophyll and instead appear ghostly white. Necrosis is the premature death of cells and can occur in some leaves, which appears as dark watery spots on leaves to dry papery spots that may be tan or black. Holes are actual widespread perforations in the leaves caused by insect or other factors. Wilting is the loss of turgor in leaves, which appear shrinking and withered. Leaf loss is the consistent condition of branches and stems lacking leaves. Only record L (leaf loss) for needle loss if fine twigs in the canopy are affected—disregard lower branches and large dead branches. Current defoliation should also be recorded under foliage conditions. If the defoliating pest is known and recorded under Tree Conditions, record O (other) for Foliage Conditions. If the defoliating pest is unknown or not listed under Tree Conditions, record L (leaf loss). Other can also be used to describe foliar conditions that cannot be accounted for with the other foliage condition codes and describe the condition in Tree Notes. Estimate amount of crown affected for each foliage condition using the following classes:

(1) 1–10%, **(2)** 10–25%, **(3)** 25–50%, **(4)** 50–75%, **(5)** 75–100%.

Decay Class and Snag Height (Dead Trees Only)

If the tree is a dead standing tree (see definitions at beginning of this SOP), then collect information on the decay class and snag height (visual estimate in meters). If tree is dead, you are not required to name the species, though if you can determine it based on bark and twigs, then please do so. Recording genus only on snags is also helpful but it is important to be right—do not simply guess. For each standing dead tree, record the code indicating the tree’s stage of decay (see Table 4 below).

Table 4. List of decay class codes.

Snag decay class	Bark	Log shape and integrity	Color of exposed wood	Texture of rotten portions	Primary surface substrate	Branches and twigs
1	Firmly attached	Round and solid. Freshly fallen, intact logs	Fresh color, not stained by weathering	Intact, no rot or conks. Stem decay absent.	Sound, tight bark	Branches retain many small twigs
2	If present, decayed, faded and not firmly attached	Round and solid	May be bleached and relatively smooth (like driftwood)	Mostly intact, sapwood partly soft and starting to decay, but can't be pulled apart by hand	Decayed bark and hard wood - impenetrable with fingernail or pen point	Branches retain some small twigs, often with peeling bark
3	Generally absent, except in <i>Betula</i> and <i>Prunus</i>	Round and firm, piece supports its own weight	Reddish-brown, or original color	Hard, large pieces of sapwood can be pulled apart by hand.	Soft wood - will spring back if compressed, easily penetrated with fingernail or pen point	No small twigs, but branch stubs will not pull out
4	Absent	Oval or flattened, no longer a solid piece, though some hard chunks remain. Piece does not support its own weight, but maintains its shape	Reddish or light brown	Soft, small blocky pieces, a metal pin can be pushed into heartwood	Very spongy wood - responds to finger pressure and may exude moisture. Powder wood flows through fingers like coarse sawdust	No small twigs, branch stubs pull out
5	Absent	Quite flat or flat with some rounding. Piece no longer maintains its shape, but spreads out on the ground	Red-brown to dark brown	Soft, powdery when dry	Loosely aggregated powder wood	No small twigs. Branch stubs and pitch pockets have usually rotted down

Tree Map

All recorded trees (live or dead) should be mapped on the tree diagram, included in the plot datasheets (see Figure 5 for an example). The tree diagram is gridded in 1-meter (3.3 ft) increments. It is important that trees are mapped correctly, this will give future monitoring teams an easy way of determining whether the tree they are measuring is the same as the one you measured or a different one. To plot the trees, use the meter marks on the tape measures surrounding the module. Also, make sure you know which direction is north and that you have the tree diagram oriented correctly before marking trees on the map. It is also helpful to map trees that lie just outside the plot, as this can aid in future plot layout during revisits.

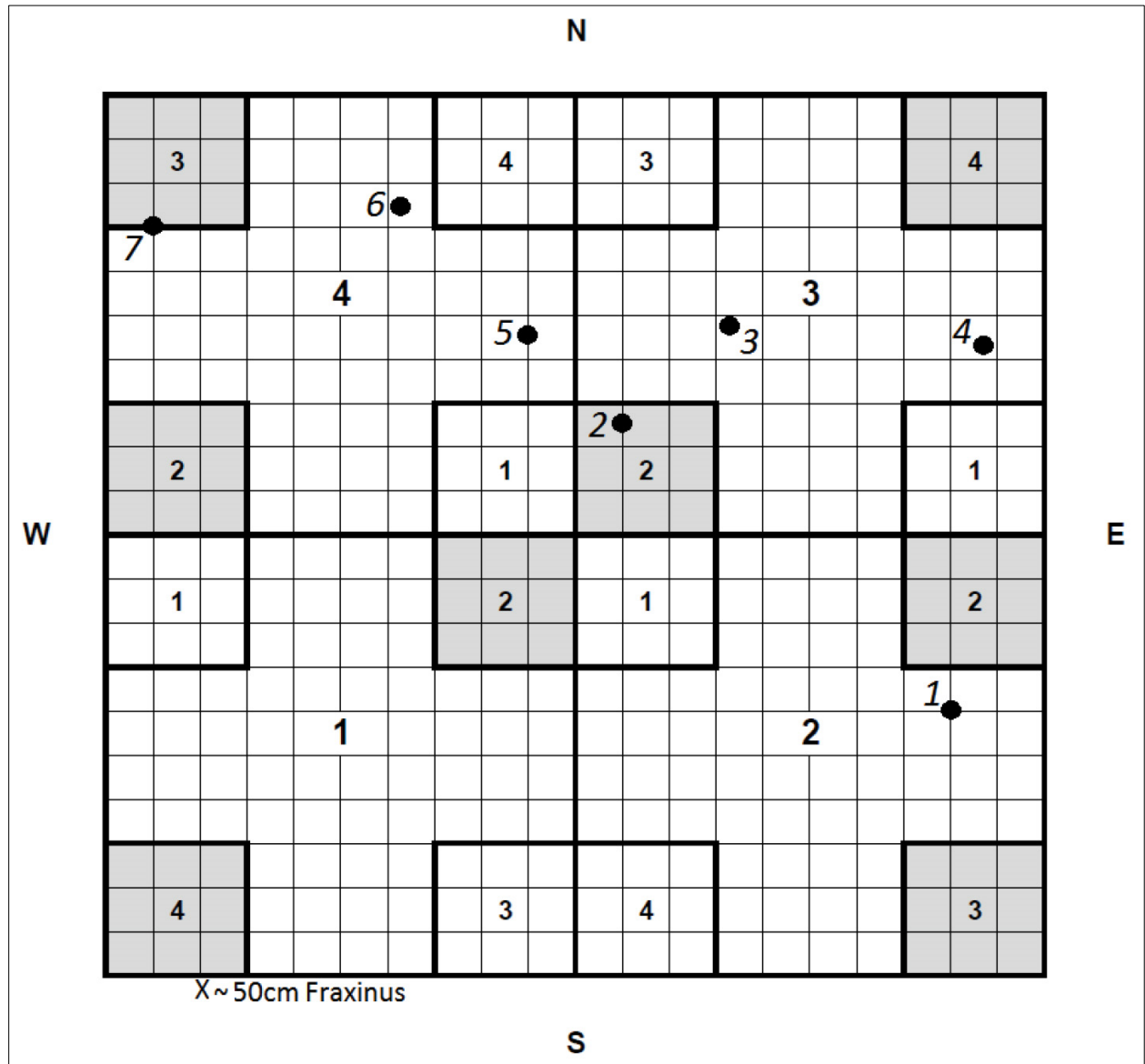


Figure 5. Example of a tree diagram with all trees (live or standing dead) over 10 centimeters (3.9 in) DBH mapped. Note large Fraxinus in bottom left mapped on boundary but outside plot to aid the next survey team in plot layout.

Notes on Plot Revisits

For plot revisits, there are several notes to keep in mind when taking tree data:

1. Write large and dark. Small or lightly written notes can be very difficult to discern, particularly on scanned images.
2. There will likely be trees that have died since the previous survey and are no longer standing, in which case the tree may be standing and dead, fallen, or gone. Update tree status according to tree status definitions and update tree diagram for fallen/gone trees by crossing off those trees.
3. If a tree was obviously missed during the previous survey (e.g., in the middle of the module), note this in Tree Notes. New trees will be given the next tree number available. In other words, if there were 20 trees measured during the last sampling event then the first new tree will receive the number 21.
4. There will also likely be trees that have grown to 10 centimeters (3.9 in) DBH since the previous survey that will need to be added to the datasheet. These new trees will be given the next tree number available and added to the tree diagram.
5. Make sure to note in tree notes which trees are tag trees and include the tag number if not already done during plot establishment (this helps to make sure the DBH of the tag tree in SOP 3 *Site Selection and Plot Establishment—Version 1.48* (CUPN 2023c) matches that of the same tree in this SOP).
6. If species ID was incorrect or missing during the previous survey, cross out the incorrect species code and write the correct code; if needed make note in tree notes about why it was corrected. Utilize information such as previous DBH, location on tree map, and any other available data from the previous survey to make certain that you are confident in your decision. Before making any species ID changes consult the botanist for confirmation as the botanist on the plot is the final authority.
7. Similarly, if tree DBH appears grossly different from the previous survey (such as increasing by 10 centimeters), consult the previous survey's field forms to ensure that you are measuring the correct tree. It is possible that the correct diameter was written on the field form during the previous survey and the erroneous DBH was a data entry error in the database.
8. Make sure that all trees with a current status of 1 or 2 are mapped. It will also be helpful to future teams to map trees on, but just outside the plot boundary. This can be done by marking these trees just outside the plot with an "x" and note indicating species and approximate DBH (see Figure 5 for an example).

9. If a tree note written on the datasheet during a previous survey is no longer relevant, cross it off in order to prevent confusion during the next revisit, as tree notes get carried over to subsequent visits.

Equipment List

- DBH Tape (in centimeters)
- Small binoculars
- Hand lens (optional)
- Tree identification references
- Plant press and newspapers (should not be carried in the field)
- Zip seal plastic bags in case you need to collect plant specimens
- Compass
- Hammer with prongs (for removing vines when needed)

Completing Field Data Forms

A detailed list of field descriptions for each field on the field data form associated with this SOP, (Figures 6 and 7) can be found in Table 5.

CUPN Vegetation Monitoring Protocol Data Resample Form

Based on Data_Form_20150415 revised 2021-04-21 BJM printed 9/5 14:15

SOP 6

Tree Measurements

KNOB016

Start Date: / /23
(mm/dd/yy)

Person who measured trees Reviewed by

Module	Tree #	Notes?	Species Code (correct if needed)	(last DBH)	DBH	(last status)	Data on living trees only					Dead standing trees		
							Tree Status	Crown Class	Tree Vigor	Dieback	Tree Condition/Damage Codes (for trees with more than one foliage condition character, indicate condition and % foliage affected by tree # in tree notes)	Foliage Condition (record up to 3)	Foliage %	Decay Class
1	1	☐	QUERVEL	(11)		1								
1	2	☐	CARYOVAT	(31)		1								
1	3	☒	CARYOVAT	(40)		1								
1	4	☒	CARYOVAT	(40)		1								
1	5	☐	ACERSACM	(14)		1								
2	6	☒	QUERVEL	(36)		1								
2	7	☐	ULMUALA	(11)		1								
2	8	☒	LIRITUL	(18)		1								
2	9	☒	QUERALB	(13)		1								
2	10	☐	MORURUB	(18)		1								
2	11	☒	PRUNSER	(20)		1								
2	18	☒	LIRITUL	(12)		1								
3	12	☒	LIRITUL	(40)		1								
3	13	☒	LIRITUL	(16)		1								
3	19	☐	MORURUB	(12)		1								
4	14	☒	CARYTOM	(15)		1								
4	15	☐	CARYTOM	(22)		1								
4	16	☒	CARYOVAT	(12)		1								
4	17	☐	JUNIVIR	(22)		1								
4	20	☐	ACERRUB	(16)		1								
	21	☐												
		☐												
		☐												
		☐												

(fill in new page numbers if
additional pages are added)
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Figure 6. Example CUPN Forest Vegetation pre-printed data form (plot revisit) for recording of tree data, page 1.

CUPN Vegetation Monitoring Protocol Data Resample Form

Based on Data_Form_20150415 revised 2021-04-21 BJM printed 9/5 14:15

SOP 6**KNOB016**Start Date: / /23
(mm/dd/yy)Tree ID Notes for individual trees as necessary. Indicate tree #, if multiple foliage condition, record % foliage
Conf Tree Notes affected. Record ID confidence if not "certain," (Probable or Uncertain)

3		tag tree #757, lots of fallen leaves and nuts, forks with tree #4
4		lots of fallen leaves and nuts, forks with tree #3, some bark has peeled off since 2013
6		vine=Vitis sp.
8		vine=Vitis sp.
9		vine=Vitis sp.
11		vine=Vitis sp.
12		tag tree #70
13		branch off of tree #12
14		short but in a gap
16		short but in a gap
18		vine=SMILROT

(fill in new page numbers if
additional pages are added)
p. 6 () of 17 ()**Figure 7.** Example CUPN Forest Vegetation pre-printed data form (plot revisit) for recording of tree data, page 2.

Table 5. Field data form field name and field descriptions for this SOP.

Field Name	Field Description
Data Taker Initials/Person Who Measured Trees	Initials of individual collecting the data. In some cases one person will be calling out data, while another records. Data taker initials should be the one with greatest knowledge and experience in tree identification, condition codes. etc.
Reviewed by	Initials of individual who reviewed completed data sheet for SOP 6 elements. Ideally this should be someone other than individual who recorded data on this portion of datasheet.
Module	Module (1,2,3, or 4) where tree occurs. For revisit plots, a pre-populated tree list will be provided. Update/correct as necessary.
Tree #	Recorded sequentially beginning with 1 until completed. For revisit plots, a pre-populated tree list will be provided. Update/correct as necessary.
Species	Seven or in some cases eight letter species code, typically comprised of first four letters of genus and first three letters of species. Refer to park species list to determine which species require the eight letter tie breaker codes. In instances where a species does not occur on the species list (i.e., no known species code), write out the entire scientific name. Ask field botanist for assistance on spelling. For revisit plots, a pre-populated tree list will be provided. Update/correct as necessary.
DBH (diameter at breast height)	Record DBH of measured tree, rounding to nearest centimeter. Tree must measure 10.0cm before it should be recorded (i.e., don't round up to 10). For revisit plots, previous DBH will be provided as well.
Tree Status	Record tree status where 0=No status, previously tallied tree no longer in sample, 1=Live tree, 2=Standing tree, 3=Removed, 4=Fallen dead tree. For revisit plots, previous tree status will be provided as well.
Crown Class	For all live trees only – record crown class where 1=Open-grown, 2=Dominant, 3=Co-dominant, 4=Intermediate, and 5=Overtopped.
Tree Vigor	For all live trees only – record tree vigor where 1=Healthy, 2=Light decline, 3=Moderate decline, 4=Severe decline, and 5=Functionally dead.
Tree Dieback	For applicable live trees only – record tree dieback where 1=1-10%, 2=11-25%, 3=26-50%, 4=51-75%, and 5=76-100%.
Tree Condition/ Damage Codes	For applicable live trees only – record one or more of the 3 or 4-letter tree condition codes, as appropriate, from the provided list.
Foliage Condition	For applicable live trees only – record up to three foliage condition codes where C=chlorosis, N=necrosis, H=holes, S=small leaves, W=wilting, L=leaf loss, and O=other. Describe other in tree notes section.
Foliage %	For applicable live trees only – record foliage percentage affected by each of the previously listed foliage condition codes where 1=1-10%, 2=11-25%, 3=26-50%, 4=51-75%, and 5=76-100%.
Decay Class	For dead trees only – record snag decay class (1-5) based on provided table and associated descriptions.
Snag Height	For dead trees only –record estimated snag height to nearest meter.

Field Name	Field Description
Tree Notes	Record any noteworthy information, as well as use this area as overflow to record additional damage codes, vine species, etc. Tree notes from previous survey will be carried over for revisit plots-update/correct/cross out as needed.
Tree ID confidence	In cases where tree identification is not certain record tree number and ID confidence in Tree Notes where P=probable and U=uncertain.
Tree Diagram	Plot out all recorded trees with a status of 1 or 2 on the diagram, as well as smaller trees on edge of plot lines to aid in future plot layout. Update/correct if necessary on revisit plots and check “updated” box.

Literature Cited

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- United States Forest Service. 2005a. Forest Inventory and Analysis National Core Field Guide Phase 3 – Crowns: Measurements and Sampling. Version 3.0. United States Forest Service. 20 pp.

Revision Log

Revision History Log.

Version #	Date	Revised by	Changes
1.1	01/15/12	B. Moore and R. White	Clarified that a full park species list would be provided to field crews indicating whether each woody species is classified as a tree. Previous text indicated only a "cheat sheet" of "woody plants for which life form is not obvious" would be provided. Removed Horizontal distance definition. Added text for VINE (tree damage) code "Vine should reach above dbh in order to be counted." Added text that it is not a requirement to provide a species ID for a snag where it is no longer discernable.
1.2	09/27/12	B. Moore and R. White	All edits within track changes are attributed to "Rickie White." Text changed for measuring DBH of Live windthrown tree: DBH should be measured "where tree breaks the plane" of 1.37 meters above the forest floor" as opposed to measuring from top of root collar along the bole, which was previous direction. Changed binoculars to an optional item in the equipment list.
1.3	03/29/2017	C. Bledsoe	"Time allotted: 50 minutes" changed to "Time estimate: 60 minutes" Added clarifications for revisits including: Importance of using previous team's map to utilize the previously assigned tree numbers and to make determinations as to whether trees on boundary should be included (if previous team included than it should be included in currently sampling as well even if you believe it is "mostly" out); Should begin with tree #1 and move through data collection in a coherent fashion; Good idea to map trees just outside boundary to aid future teams with plot set up; Added text to definition of Tree Status=0. Added more description to Necrosis in Foliage Conditions section. "Cleaned up" text under Decay Class and Snag Height sections. Clarifications to reporting tree pests and pathogens including who to contact and updates to species list to more accurately reflect CUPN region. Species list changes include removing the pest species (Asian Ambrosia Beetle, Elongate Hemlock Scale and Redhaired Pine Bark Beetle) and adding one species (Spotted Lantern Fly). Removed sentence from snag section regarding the recording of vines (vines have never been recorded for snags).

Version #	Date	Revised by	Changes
1.4	04/03/2018	C. Bledsoe and B. Moore	Added table of “required” and “if applicable” data elements to be recorded in field by Tree Status. “Substantially” reorganized sections of SOP. Changed foliage % code from 0-10% to 1-10% (note field forms always had 1-10% as the category and this was the category used in field). Clarified reference in table that vines are only recorded if in canopy (This change was first implemented during the plot establishment years, 2011-2015) but not sure exactly which year. Added text emphasizing need to measure DBH under any vines on the bole. Added hammer with prongs to equipment list (aid in moving vines for DBH measurements). Added “Notes on Plot Revisits” Section which contains several tips for revisit teams. Added clarifications for revisits including: Additional emphasis on need to record same trees as previous team; Consult botanist before changing species ID; Be sure to cross off previous tree notes on revisit form regarding vines if vine no longer present/visible in canopy; Added instructions to map all stems (trees) ≥ 10 cm DBH. This was done to aid revisit teams with matching up previous tree numbers. Removed all references to measuring DBH of trees that fork below breast height, at 1.0 meter above the fork. This was not practiced in field instead teams followed alternate (and conflicting) directions in SOP to generally measure as near DBH as possible and record location taken in tree notes. Clarified text on Tree Damage Code ‘EPIC’ limiting its use to trees where this condition is uncharacteristic. Added text to definition of ‘Open Grown Tree.’ Updated Tree Diagram Figure with better resolution image (digital vs. scanned).
1.41	3/23/2020	B. Moore	Moved Revision History to end of SOP and added much more detailed list of changes made to date. Minor editorial changes
1.42	8/16/2020	B. Moore	Address grammatical changes and clarifying comments made by IMD regional program manager. Removed meter stick and Biltmore Stick from equipment list as these are not acceptable methods for measuring tree DBH.
1.45	2/26/21	B. Moore	Changed procedure that a ‘missing tree’ that is likely fallen but not located should receive a status of 4 (fallen dead). Previously a missing tree was given a status of 0 (no status). Added text (from ERMN protocol) stressing importance of crew members being familiar with “healthy” specimens of species when assigning vigor and other condition codes. Removed reference to “Appendix E: Field Guide to CUPN Potential Forest Pests, Pathogens and Invasive Exotic Plant Species of Concern” as it was replaced by Invasive Species Early Detection Protocol. Removed the following Tree Condition Damage Codes: BROM, CROK, FORK, FRST, LEAN, OZON, ROTT, SPAR, because they were too subjective and/or damage could be categorized via another code (e.g., sparse foliage addressed by foliage condition codes). Added tree pest and pathogen table, including species impacted, as well as signs and symptoms.

Version #	Date	Revised by	Changes
1.48	8/3/2023	B. Moore and C. Bledsoe	Updated tree pest and pathogen list (table 6.2), including removal of Butternut Canker, Common Pine Shoot Beetle, Eastern Tent Caterpillar, Sirex Woodwasp and Sudden Oak Death; changed Gypsy Moth to Spongy Moth and Redbay Ambrosia Beetle to Laurel Wilt Disease; added oak wilt disease. Minor editing to tree status definitions to more closely align with field “cheat sheet” and added missing foliage definitions-also from cheat sheet. Formatted by editor to regional I&M publication standards.