Vermont North American Maple Project Manual - 2006

Introduction and Background

NAMP Objectives

The Vermont objectives of the project are to:

1. Determine the rate of change in sugar maple tree-condition ratings from 1988 through 2006

2. Determine if the rate of change in sugar maple tree-condition ratings is different among sugarbush and non-sugarbushes.

3. Determine the possible causes of sugar maple decline and the geographical relationship between causes and extent of decline.

General Approach

The NAMP project began in the summer of 1987 with the development and testing of field methods. In 1988, 165 plots were established across eastern North America, from Ontario and Wisconsin in the west and to Maine and Nova Scotia in the east. The North American Sugar Maple Decline Project: Organization and Methods (1991) provides background on the start of the project. The original field methods used for plot establishment are in the Cooperative Field Manual dated February 10, 1988 as revised July 7, 1988; subsequent clarifications and changes were made during the Project Review at Montreal in 1989. A few minor clarifications were added in 1990 and 1991. In 2003, Vermont became the only remaining state or province continuing this survey, so additional modifications were made to improve consistency with other forest health surveys. The following manual incorporates the methods used in 2003 -2006.

Experimental Design

In Vermont, 26 plot clusters were established in 1988, and an additional 14 were added from 1989-1993, for a total of 40 plots. Since then, 2 plots were eliminated because the number of sugar maple trees was reduced to less than 10. In 2006, 38 plots will be examined for crown dieback and crown transparency and other measurements of health.

Each plot cluster has five plots in similar stand conditions. One-half of the plot clusters represents maple stands managed as sugarbushes and one half in non-sugarbushes, where human disturbance is minimal. The plot clusters were distributed to represent a range of exposure to pollution and a range of initial stand decline conditions (although extremely declining stands were avoided to allow for trend determination).

FIELD METHODS

PLOT ESTABLISHMENT

Stand Selection

Approximately one-half of the samples in a province or state is located in each of two management categories -- sugarbush or non-sugarbush -- and where possible, stands are paired for the two management options. The initial plan was to establish eight sets of clusters in two pollution zones, and to select for specific stand decline conditions. However, it was abandoned later when it was determined that the regional pollution maps might not reflect actual pollution, because of local pollution effects, and adequate declining sugar maple stands could not be located in all the areas. Instead, sites were selected in 1988 to represent a gradient of pollution between the extremes within a state or province. In addition, efforts were made to select sample stands to represent a range of original stand decline-conditions.

Originally, the plot-clusters were established for a two year project, which then was extended to 5 years. The current project is expected to be ongoing. Many cooperating landowners have therefore conducted some silvicultural treatements to satisfy their forest management needs. The present NAMP policy is to permit logging, although the recommendation is to continue without it as long as possible. When logging occurs, a 132-ft buffer around the plots is recommended, if possible. If not possible, documentation of basal area before and after treatment is conducted for each of the 5 plots.

Stands

The featured stand (term describes the main component of the dominant trees, excluding the remnants of a previous stand) is a hardwood stand in which more than 50 percent of upper story trees are sugar maples 50 to 150 years old. The two major types of stands, based on management history, are sugarbush and non-sugarbush. Portions of stands with dissimilar tree damage conditions were considered as separate stands. Care was taken to avoid unusual stands and sites not typical of the area, such as artificially established stands outside the natural range, and severely logged or grazed stands.

The following definitions and codes were used to describe the two stand management categories:

Sugarbush - A hardwood stand where more than half the upper canopy trees are sugar maples, 10 cm diameter at breast height (d.b.h.) and larger. These stands had evidence of sugaring in the last 5 years and at least a quarter of the trees had to have tapholes. Other disturbances associated with sugarbushes, such as logging or grazing, were accepted. (Code 1)

Non-sugarbushes - A hardwood stand with sugar maple, 10 cm d.b.h. and larger comprising more than half of the upper canopy. The stand could not have evidence of disturbance in the previous 5 years before establishment, such as sugaring or logging and it had to be at least 2 ha in area, preferably larger. (Code 2)

Range of initial damage

Each province or state coordinator was advised to choose stands with a wide range of stand-decline conditions, but to avoid stands where the majority of trees were declining (the trend might be difficult to measure).

Pollution gradient

The regionally selected stands represent a gradient from approximately 12 kg/ha/yr of sulfate wet-deposition to more than 34 kg/ha/yr (Sisterson et al.). Nitrate wet-deposition ranged from approximately 8 kg/ha/yr to approximately 22 kg/ha/yr (Fig. 1).

CLUSTER AND PLOTS

Cluster

In each stand a cluster of five plots is established to describe average site, stand and tree conditions. The sample is the average of the five plots. Extreme variability in stand conditions between plots was avoided.

Plot

Each plot is a 20-m x 20-m square, or 400 m^2 (66 ft x 66 ft, or 1/10th acre); the corners are at 45° from the cardinal compass directions and 14.2 m (47 ft) from the center stake. The outside boundaries of the plots are a minimum of 20 m (66 ft) from the edge of the nearest plot or from the edge of the stand. The preferred distribution of plots in a cluster consists of one plot in the center and four around it; one in each cardinal compass direction. Other designs are used where stand shape does not permit the preferred arrangement. Similar 20-m (66 ft) buffer is required between plots and on the outside when an alternative plot arrangement is used.

Identification and marking

The center of each plot is marked with a plastic (PVC) pipe, 2 cm in dia. and 1 m long (1 in by 3 ft) driven into the ground at least half way (rocks were used to surround the stakes when they could not be driven into the ground). The stake is marked showing the cluster and plot number. The corners of the plot are marked with flagged stakes. A map is prepared showing the location of the plot and instructions for later relocation. The plot identification code number includes in a left-to-right sequence:

1. Management type: 1. Sugarbush, or 2. non-sugarbush

2. State or province letters: ME, MA, MI, MN, NB, NS, NH, NY, OH, PA, ON, QU, VT, WI

3. Cluster number: 3 digits including zeros to the left, as needed

4. Plot number: (1, north; 2, east; 3, south; 4, west; 5, center). When plots are arranged in different pattern, the first plot is coded 5, and the following plots are 6,7,8, and 9.

For example, the plot identification code 1 VT005 4, is a sugarbush in Vermont, cluster 5, west plot.

SITE DESCRIPTION

A suite of general site information indicators are recorded for the plots. However, since site descriptions are not critical data, more precise measurements are taken only if analyses suggest significant relationships. Plot establishment data are recorded on the Stand and Plot Data Form (Fig. 2).

Site description includes location and physiographic conditions usually obtained from published materials. The descriptions include a general regional description covering approximately 10 km^2 (4 sq mi) around the cluster and a local description at each plot.

Location

Plot-cluster location was initially recorded to within 100 m (330 ft) using the Universal Transverse Mercator System (UTM). Political geographic descriptions, such as county and township, are added as needed for local identification. In 2004, some plot-clusters had Geographic Position System coordinates recorded in NAD83, and recorded as latitude and longitude in decimal degrees. Remaining plot-clusters will be recorded in 2006.

Regional physiography

Information regarding regional physiography was obtained from published records and maps and consists of four types:

a. Terrain, coded into three kinds--1, flat; 2, hilly; and 3, mountainous.

b. General watersheds--such as major rivers, lakes, or oceans--to which local waters flow were included.

c. Weather data--The nearest weather station was used, with at least 30 year data on temperature (°C): maximum; minimum; mean annual; and precipitation (mm): annual; summer average (May-August).

d. Soil series--Local soils scientists or recently published soil surveys were consulted to obtain the soil series.

Local physiography

The terminology used by the North American Sugar Maple Decline Project is the same as that used by the other NAPAP Forest Response Program projects (Zedaker and Nicholas 1990). Nine categories are used (Figure 5):

a. Landform (Fig. 3a); coded into 8 descriptions:
1- ridgetop (primary ridge of a mountain system)
2- spur ridge (secondary or lateral ridge from primary ridge)
3- noseslope (diverging drainage at end of ridge)
4- headslope (convergent drainage above cove)
5- sideslope (parallel drainage along side of ridge)
6- cove (deep, narrow depression in the slope or bowl with one end open)
7- draw (depression open on both ends but bounded by steep sideslopes or noseslopes.
8- flat (the entire area typically is flat)

b. Slope position (Fig. 3b); coded into 7 types of slopes, as follows:
1- summit (highest point of landform)
2- shoulder (transitional zone between summit and backslope; the slope is always convex and has the greatest erosion loss on a mountain)
3- backslope (midportion of landmass, convex or concave)
4- footslope (between backslope and terrace, convex, has the greatest colluvial deposition on a mountain)
5- terrace (flat, but clearly above the floodplain)
6- floodplain (flat area flooded during high water periods)
7- flat (similar to terrace and floodplain, but not adjacent to hills or bodies of water)

c. Microrelief (Fig. 3c) is separated in three projections: 1, planar; 2, concave; and 3, convex.

d. Percent slope, is determined with a clinometer to the nearest one percent.

e. Elevation is shown to the nearest 10 m (33 ft), and determined from a topographic map.

f. Exposure designates the direction that the slope faces, to the nearest compass degree; 0 is used to show a flat area; 360 indicates north.

g. Soil coarseness is determined for soil immediately below the humus layer, as follows: A pinch of soil is rubbed in the palm of the hand or between fingers to estimate particle size. The average size of the particles is then classified:

Soil Code	Texture	Particle size limits: Lower	Upper
		-----in millimeters------	
1	Silt or clay	0.001	0.07
	Sand :		
2	Fine	0.07	0.42
3	Medium	0.42	2.0
4	Coarse	2.0	4.8
	Gravel:		
5	Fine	4.8	19.5
6	Coarse	19.5	76.2
7	Rocks	76.5	305

h. Rockiness. Three degrees of rockiness are coded:
1 - not more than 1 protruding large rock (cannot be moved easily by one person; usually more than 2 ft, or 61 cm, diameter) per plot; no bedrock exposed
2 - two to ten large rocks; bedrock not showing
3 - ten or more large rocks per plot or bedrock showing

i. Drainage is described in two classes: 1, well drained (no signs of prolonged flooding) or; 2, wet (signs of perched water such as presence of wetland indicator plants)

STAND DESCRIPTION

Stand descriptions indicate the general character of the sample areas and are not critical measurements; more precise measurements are taken when data analyses suggest significant relationships. The data are recorded on the Stand and Plot Description Form (Fig. 2). Six methods are shown.

Disturbance

At the time of establishment, disturbance is coded as 1,absent; 2, present (if present, disturbance is identified):

a. Logging, based on one of the four criteria:
1 - reasonably sure the stand was never logged in the last 50 years
2 - old, but no firm stumps present
3 - recent, but older than five years (firm stumps present)
4 - recent, logging in the last 5 years (stumps and logging residue present)

b. Forest type change assessment: 1, probably has not changed since European settlement, and; 2, changed from one forest type to another

c. Grazing assessed in 4 classes:
1 - no signs of grazing
2 - old damage, but no recent signs of grazing
3 - current, light; no tree damage apparent
4 - current, heavy; soil compaction obvious, tree damage present and very little reproduction present.

d. Tapping is rated in four classes:
1 - currently active
2 - at least once in last 5 years, but not in current year
3 - old, none in the last 5 years
4 - none ever

e. Tapping method (obtained from landowner) is coded as:
1 - bucket
2 - gravity tubing
3 - vacuum tubing
4 - no chemicals used
5 - type of chemicals used in tap
6 - combination; codes in notes

For other methods, descriptions should be included in the notes.

After plot establishment, presence of recent disturbance caused damage (since the last plot visit) is recorded annually, on a tree by tree basis, on the Field Form in the appropriate field. A supplementary Plot-Cluster Disturbance Form is completed when recent disturbance occurs over one or more of the plots (Figure 8). We are still trying to get historic natural disturbance records for all the plot-clusters. If there is no disturbance record for the last 20 years, a negative report is submitted.

When logging disturbance occurs in a non-sugarbush, the disturbance is indicated on the Field Form and on the Disturbance History form. In addition, data may be provided to show how much basal area remains. The sample is a minimum of 9 points.

Vegetation

This is not a critical measurement;. The three methods used to measure stand vegetation are:

a. Crown closure:
1 - full, less than 10 percent sunlight penetration
2 - moderate, 10 to 50 percent of ground receives sunlight
3 - open, more than 50 percent of ground receives sunlight

b. Crown structure
1 - single-story
2 - two-story
3 - multistory (stems smaller than 3 cm in dia. are not considered)

c. Site quality. In the opinion of the observer, past growth of sugar maple on the plot (before decline, if present) apparently was:
1 - average; similar to maples nearby (about 10 km2 area)
2 - less than maples nearby
3 - better than the maples nearby

The notes are used to show why the stand quality is below average, if known.

Stand age

Stand age was determined from five increment cores, one per plot, taken at the time of plot establishment. The stand age is assumed to be the age of the oldest of the five trees sampled. A codominant sugar maple was selected from the buffer zone adjacent to each plot. Unusual trees, such as severely damaged or wolf trees, were avoided. Trees with seams or cankers in the lower bole were avoided also because of the likelihood of rot. If a sample tree was hollow, another tree was chosen. The cores are taken at breast height.. When a core breaks, pieces are placed in sequence into the storage container. The storage container is a firm cardboard tube or straw. The ends of the tube are crimped and stapled. The plot identification number and the date of collection are recorded on the tube. Long cores require several straws; each part is labeled clearly. The cores are kept dry without chemical additives.

Laboratory core analysis follows standard operating procedures (Zedaker and Nicholas 1990). The tree age is determined at the USDA Forest Service, Northeastern Forest Experiment Station, Tree Ring Laboratory, Durham, New Hampshire.

REGENERATION

In 1998 through 2002, regeneration was recorded on each plot-cluster as a measure of the 1998 ice storm impact, but this was discontinued in 2003. The procedure was as follows. Regeneration was collected on each of the 5 plots within the plot-cluster. It was counted on a circular milacre plot (3.7 foot radius) located at 6.6 m (20 feet) from the plot center, in the East direction (90 degrees) If E was unavailable, a second choice was made going clockwise (S, W, N). The milacre plot was permanently marked at the center with a ½ inch pvc pipe.

Regeneration was counted on the milacre plot in 3 categories: Sugar maple, Other hardwoods, and Conifers. Other hardwoods included all commercial tree species. Each category contained 2 divisions: Seedlings < 1 m in height, and Seedlings & Saplings > 1 m in height, but < 10 cm dbh. Further, the Seedling < 1 m was divided into 2 classes: < 30 cm in height, and from 30 cm to 1 m in height.

All seedlings/saplings with greater than 2 leaves (cotyledons) were counted for each category and recorded in the appropriate box. If stump sprouts or coppices generated multiple shoots, each shoot was considered a separate seedling. Only those seedlings whose stem was within the milacre plot were counted. A maximum of 50 seedlings are recorded.
The data sheet included:

RECORD NUMBER IN EACH CATEGORY

CLASS 1: <=30 cm
CLASS 2: BETWEEN 30 cm & 1 m

	SEEDLINGS< 1 m		SEEDLINGS > 1 m
	CLASS 1	CLASS 2	SAPLINGS < 10 cm dbh
SUGAR MAPLE			
OTHER HARDWOODS			
CONIFERS			

Lecanium Scale Population Survey

Starting in 2005, visual estimates are made of scale populations on understory and lower branches of sugar maple using the abundance rating system listed below. Ten branches per subplot are examined and rated, using the branch portion with the most scales. Ratings are made to estimate the surface area covered with scales on 12 inches of growth (starting at internode marking previous year's growth). The minimum and maximum rating are recorded for each the 5 subplots. When scales are not present or visible, other evidence of scales is recorded: honeydew, sooty mold, crawlers on leaves.

Lecanium scale abundance rating system

0 = None
1 = Trace : spotty single scales
2 = Light : less than 30% of twig surface area with scales
3 = Moderate : 30-60% of twig surface area with scales
4 = Heavy : more than 60% of twig surface area with scales
5 = Other evidence of scale presence: honey dew, sooty mold, crawlers
6 = No understory sugar maple to rate

TREE MEASUREMENTS

The following section describes methods used to inventory individual tree condition. All the data were recorded at the time of plot establishment (Fig. 4). Thereafter, the primary emphasis is to record crown condition, with periodic accounting of ingrowth and DBH changes. Evidence of new bole or trunk damage and tree crown position changes are recorded annually.

Tree Selection and Identification

All the trees 10 cm (4 in) and larger were marked with aluminum tags and nails at d.b.h.; identified to species, or as close as possible; and inventoried for condition and damage. Major emphasis was placed on proper identification of sugar maple. Difficulties were encountered separating black maple from sugar maple so a few black maples may be included among the sugar maples.

Common names used were from Little (1953). Each species, or species group is assigned a code number. Unused code numbers are added to accommodate other species not listed below. The new code number is marked with an asterisk on the data sheet, and the species name recorded in the notes when used the first time on a plot.

The ingrowth was measured in 1993, 1997 and 2002.

Angiosperms				Gymnosperms	
10	Maple	30	Birch	91	E. White pine
11	sugar	31	yellow	92	Other pine
12	black	32	paper	93	Hemlock
13	red	41	Ash	94	Balsam fir
14	silver	42	Hickory	95	Spruce
15	striped	43	Poplar, Aspen	96	white
20	Oak	44	Basswood	97	red, black
21	white	45	Ironwood, Hophornbeam	98	Tamarack
22	bur			99	Other conifers
23	northern red	46	Cherry		
24	black	47	Elm		
		48	Beech		
		49	Other hardwoods		

Diameter

Tree diameter was measured at d.b.h., 1.37 m or 4.5 ft above ground, in 1988, 1992, 1997 and 2002. The diameter measurement is taken every 5 years. The diameter measurement was not a critical measurement at the time of establishment because tree growth was not expected to be significant during the first 3 years. The measurements are recorded to the nearest 1 cm.

Crown Position (All species - changes only)

Crown position ratings were recorded for all the species in 1988, and changes are recorded annually. Crown position rating of each tree was done by two observers. The lower rating was given when the two raters failed to reach an agreement. When crown positions had changed during the previous 5 years because of a disturbance the rating was given according to the best estimate of what the crown position was at the time of disturbance (tree and crown size were weighed more heavily than the light factor). Changes observed after the original plot establishment are entered as corrections of the previous entry. The following codes and definitions were used (USDA 1984):

1 -dominant (trees with crown extending above the general canopy and receiving full light from above and partly from the sides; larger than the average trees in the stand; crowns well developed, but somewhat crowded on the sides)

2 -codominant (trees with crowns forming the general level of the canopy and receiving full light from above, but relatively little from the sides; usually with medium size crown, more or less crowded on the sides)

3 -intermediate (trees shorter than in the preceding classes, but with crowns just below or extending into the canopy of dominant and codominant trees; receiving little

direct light from above and none from the sides; usually with small crowns considerably crowded from the sides)

4 -suppressed (trees with crowns entirely below the main canopy and receiving no direct light from above or sides)

Vigor Rating (All species)

General crown vigor was recorded for all species in 1988, and changes are recorded annually. The vigor rating is done in broad classes similar to those used in other forest decline projects. Although these were not initially considered critical measurements, in 1994, the definitions were clarified, and vigor became part of the training and certification. The acceptable error is plus-or-minus one vigor class. **Vigor ratings must be done before crown rating. The percentages of damage used for defining vigor rating classes are independent estimates, not related to the sums of crown rating percentages**. The codes are used as follows:

1 -healthy; tree appears to be in reasonably good health; no major branch mortality; crown is reasonably normal within the stand situation; less than 10 percent branch or twig mortality, defoliation or discoloration present.

2 -light decline; branch mortality, twig dieback, or foliage discoloration present in 10 to 25 percent of the crown; broken branches or crown area missing based on presence of old snags is less than 26 percent.

3 -moderate decline; branch mortality, twig dieback, or foliage discoloration in 26 to 50 percent of the crown; broken branches, or crown area missing based on presence of old snags is 50 percent or less.

4 -severe decline; branch mortality, twig dieback, or foliage discoloration present in more than 50 percent of the crown, but foliage is still present to indicate the tree is alive; broken branches, or crown area missing based on presence of old snags is more than 50 percent; branch breakage and crown missing is recorded in the 5-percent classes in the notes.

5 -dead, natural; tree is dead, either standing or down; phloem under bark has brown streaks; few epicormic shoots may be present on the bole; no further entries needed.

6 -dead, **human caused**; tree removed; tree has been sawed or girdled by humans.

Tapping Record (Sugar maple only)

From 1988 through 2004, taphole closure was recorded. The number of tapholes was recorded annually for all the sugar maples. One entry was made for the total number of open tapholes. A taphole is considered open when the point end of a pencil pushed into the hole hits cambium. When not certain the hole was not counted. Unusual observations, such as predominance of multiple taps on one side of a tree, are recorded in the notes. This measure was discontinued in 2005 because many sugarbushes had begun using smaller diameter taps, and it was difficult to determine taphole closure.

In 2005, the new tapping data consisted of: tapped or not tapped; and the size of the tap being used on each of the 5 plots (7/16" (standard), 19/64" (health spout), or smaller (micro)).

Bole Quality (All hardwoods)

No Bole Quality will be taken in 2006. Severe bole damage that might affect tree vigor was recorded for all species in 1988. Annually, **new damage** thought to have occurred since previous year, is recorded. The Field Form permits entry of a maximum of three types of damage. If more damage is noted, the numbers may be entered in the notes.

Location of bole defects

1 - lower half (above the stump, 30 cm above ground, but in the lower half of the bole)
2 - upper half (upper half of the bole, but below crown or branch forks)
3 - whole bole (defects in both halves or continuous)
4 - stump/roots (defects visible on the buttress roots or stump within 30 cm from the ground)
5 - whole tree (includes bole, stump, and roots)

Type of injury,damage, and defects on the bole

As many as three major defects or type of damage on the bole were recorded in 1988. Thereafter, any **new** growth-impairing injury is added annually. These defects are registered as:

21- sweep or crook (at some point within a 3-m length, curve of bole sufficiently severe that the curved section is completely outside the cylinder, above and below).
22- swelling (the swollen area exceeds one quarter of the bole diameter; slowly healing branch stubs with large swellings are included)
23- dead branches or stubs (dead branches larger than 10 cm on the bole or any dead stubs of that size creating open wounds; bole above the base of the crown, or any major branch fork, not included)
31- large open wounds (area of exposed wood larger than 4 cm^2; includes cankers that have exposed wood)
32- small open wound (area of exposed wood 4 cm^2 or less; holes created by tapping not included)
33- dead bark, dry & tight (old bruise or other damage extending more than 10 cm, covered by dead bark; includes cankers)
34- sloughing bark (bark is splintering and separating from the wood)
35- closed wound (large wounds healed and completely closed as indicated by overgrown live bark; may include large overgrown branch stubs)
36- seams or cracks (elongated narrow wounds, at least 1

m, not more than 2 cm wide; open or closed, including scars)
37- other (damage described in the notes)

Causal agents for trunk or bole defects

The probable agents responsible for trunk or bole defects are entered only when the observer is reasonably sure of the cause of damage. If more detailed identification is possible, such as wood-boring insect, it is recorded in the notes. Observations such as "windthrow", "hail damage", "frost damage" also are recorded in the notes. Probable agent groups and their designated codes are:

0 - causal agent not identified; or no damage present.
1 - insect - In the notes record what signs were present.
2 - fungus - Describe fruiting bodies or other signs.
3 - weather - Blowdown, leafscorch, hail, water level change, frost, etc.
4 - animal - Rubbing, gnawing, girdling, birdpecking, root damage from grazing, etc.
5 - human - Logging, blazing, girdling, etc.(Do not include tapping).
6 - fire - Fire scars near base, burnt wood.
7 - silvicultural - Damage probably caused by shading, competition, rotten branch stubs.
8 - tapping - Wound or decay that appears to have started at the taphole.
9 - overmaturity (only the largest trees affected; hollow bole; tree appears to be over 150 years old)

Notes

The notes section of the data sheets was used to record any unusual damage not covered in the Methods Manual, such as causes of defoliation, occurrence of heavy seed crops, presence of tattered or wrinkled leaves. Causal organisms also were recorded in the Notes when the observers could identify them.

CROWN DAMAGE ASSESSMENT

Crown measurements in 1988 included estimates of dieback, crown transparency, discoloration, dwarfed foliage, and presence of epicormic shoots. These were selected for the purpose of measuring annual changes and not to evaluate tree vigor or condition. Therefore, the emphasis in method selection was placed on repeatability of measurements between individual raters and timing of the measurements. Initially, crown condition ratings were made for sugar maples only. However, the following year (1989) the cooperators agreed to expand crown condition estimates to include all hardwood species. In the original plan, all the crown-condition rating elements were considered as critical measurements. However, because of difficulties of repeating measurements, the rating of dwarfed foliage and epicormic shoot measurements was dropped. When the situation suggests that these may provide additional information on tree health, estimates may be added in the notes.

Uncertainty about definitions for discoloration resulted in removal of this measurement from the critical measurement list, but the measurement continued to be collected.

Estimates of branch dieback and foliage transparency of sugar maples are retained as critical measurements. Originally these were collected based using a 12-class rating system. In 2003, this was changed to 21-class rating system that rates crown health in 5 percent categories, which is more compatible with other Vermont forest health surveys (Table 1). Data quality guidelines are followed for the critical measurements in order to determine measurement errors between individual raters. The acceptable variation between observers is 2 percentage classes higher or lower than the average, for dominant-codominant and intermediate trees; and a 4-percentage-class difference for suppressed trees. Two certified raters are required to make the estimate. When the two estimates disagree, the percentage class nearest the average of the two is recorded.

The timing of measurements extends from late June to the end of August. The purpose is not to initiate crown rating until leaves are mature and to complete the rating before the appearance of fall colors.

Description of Crown

A tree crown may be described in many ways. In this project, the crown is the silhouette, or single plane, outlined by the periphery of branch tips. The bottom of the crown is the lowest foliated area (excluding epicormics); it does not include the large branch stems that support the crown. For percentage estimates, large open areas within the crown are excluded; for example, openings created by the breakage of large branches. Likewise, areas on the periphery of the crown where the remnants of dead branches still remain, so called "snag" branches without small twigs, are excluded. The assumption is that the size of the crown remains relatively similar over time, but dieback, crown transparency, and discoloration are likely to change annually. A training aid and a calibration technique, the Crown Grid, are used for beginners to measure total crown and proportions of crown affected by dieback and other stress-induced symptoms.

Foliage Crown grid

The Crown Grid (Fig 7a) was developed from similar grids used to estimate areas on maps. The crown grid area does not represent a quantitative measure of the crown, rather it is used to determine the proportions of damage. The central square has 100 dots, and each peripheral square has 25 dots.

Instructions for use of the Crown grid:

1. Hold the transparency approximately 30 cm (1 ft) from the eyes.

2. Center the crown outline on the grid so that the entire middle square is within the crown perimeter, but none of the crown is outside the margins of the grid. This is done by moving the grid closer or farther from the eye. After the crown is centered, do not change the distance while the crown and damage are being outlined.

3. Draw the outline of the entire tree crown by connecting the tips of major branches and branch clusters, that is, draw a curve of the lines from branch tip to branch tip to avoid creating large open spaces between branches on the periphery of the crown. When outer portions of branches are dead, draw a line between terminals of dead twigs in order to obtain the crown outline. A very large hole in the crown, such as that caused by broken branches, should be excluded.

4. Trace the outline of the damaged portion of the crown within the outline produced in step 3.

5. Determine the number of dots or squares encompassed by the whole crown and the damaged portion separately.

6. Divide the smaller number (damaged area) by the larger number (entire crown) and multiply by 100 to get the percentage of crown damaged. Record the damage in one of the 21 damage classes (Table 1).

This procedure is intended to help the beginner gain confidence, to calibrate estimates, and to learn the area-estimation method. It is recommended that during the training phase, the observer first make an estimate of the percentages, and compare this with the value obtained from the Crown Grid.

Twenty-one-class Damage Rating System

In 1988, the regional cooperators agreed to a 12-class system which was used from 1988-2002. In 2003, Vermont implemented a 21-class damage rating system that was more consistent with other forest health surveys, and provided finer resolution data (Table 1). The class codes are recorded on the tree measurement data forms, and represent a 5 point range in damage. Acceptable data quality includes 2-class above or below the class code. Two observers are required for crown rating. When there are difference between the 2 observers, observation points are first compared to account for rating differences. If no agreement can be reached, the 2 ratings are averaged.

Branch Dieback (All hardwoods)

Branch dieback is used as a measure of an unhealthy condition and is defined as branch mortality that begins at the terminal portion of a limb and progresses downward. Branch dieback is assumed to be the result of stress on the tree. Short-term stresses such as excessive seed production, weather extremes, or insect defoliation may cause temporary dieback, but when the stress is removed the trees may recover. Prolonged stresses may result in increase of dieback, and eventual decline and death of the tree.

This measurement is an estimate of the proportion of the crown silhouette involved in dieback. Two certified raters are required to make the estimate from opposite sides of the tree. Branches with prematurely dead terminals are considered to have dieback down to the next lower fork of equal size branch. Assume that large dead branches within the upper crown area died from the terminal down unless signs of girdling or breakage are present indicating that they died at the base first. To be considered for dieback, a branch must be 1 inch or less in diameter, at the point of attachment of the branch to another branch or bole. Snag branches -- large branches without small twigs under 2.5 cm (1 in) diameter, and usually with the bark absent or with dead bark peeling away -- are assumed to have died much earlier. They are not considered as part of the crown and are not included in the dieback percentage. Likewise, branch mortality at the base of the crown, assumed to be the result of shading, is not included in the measurement. The proportion of crown with crown dieback is rated using the 21-percentage-class system (Table 1). The presence of one

Table 1.—New Twenty-one-class Rating System used since 2003. Percentage classes and acceptable range of observer variability for estimates of branch dieback, foliage transparency, and discoloration.

Class code	Class range	Acceptable observer variability
0	0	0-10
5	1-5	0-15
10	6-10	0-20
15	11-15	1-25
20	16-20	6-30
25	21-25	11-35
30	26-30	16-40
35	31-35	21-45
40	36-40	26-50
45	41-45	31-55
50	46-50	36-60
55	51-55	41-65
60	56-60	46-70
65	61-65	51-75
70	66-70	56-80
75	71-75	61-85
80	76-80	66-90

85	81-85	71-95
90	86-90	76-100
95	91-95	81-100
99	96-100	86-100

dead branch tip, at least 10 cm (4 in) long, in the upper portion of the tree crown, is rated as the lowest class with dieback in the 5-percent class. When dead twigs are scattered throughout the crown, an estimate is made of the approximate proportion of foliage lost from the dead twigs, which is then recorded as the dieback percentage.

In addition to normal dieback, extensive branch mortality, including snag branches, that might be affecting tree growth will be recorded in the notes The extent of the crown lost will be recorded in the same 5-percent classes.

Foliage Transparency (All hardwoods)

Foliage transparency is determined by estimating the amount of skylight visible through the foliated portions of branches and averaged for the crown as a whole. It includes normal tree characteristics of foliage density as well as reduced foliage density resulting from insect damage, disease, or environmental stresses. Areas included in dieback are not rated for foliage transparency. It is assumed that an increase of foliage transparency over time indicates reduced tree vigor that eventually may lead to branch dieback. Recovery is expected from short periods of defoliation events. Two certified raters are required to make the transparency estimates from opposite sides of the tree. The 21-class rating system will be used to estimate foliage transparency (Table 1). Foliage transparency is a critical measurement that requires extensive training to achieve standardization among observers and consistency among years.

Foliage transparency grid

The Foliage Transparency Grid (Fig. 5b) is a visual presentation of varying proportions of black and white squares. The black areas represent the foliated portion of the crown, while the white areas represent the skylight visible through the crown. The percentage class is shown beneath the square. The Foliage Transparency Grid is used as a training aid. Comparisons are made between the grid and foliated portions of the branches on the periphery of the crown as well as in the midcrown areas.

Foliage transparency standards

The Foliage Transparency Standards (Fig. 6) are used to standardize foliage transparency estimates among observers and to provide a reference guide for subsequent years. These are photographs of actual sugar maple crowns showing the amount of skylight visible through the crown. The "0" class, not shown, indicates a very dense crown where practically no skylight is visible through the crown (a rare condition). Pocket size laminated cards of the standard is issued to every certified rater.

Foliage Discoloration (All hardwoods)

The estimate of foliage discoloration is based on the foliated portion of the crown and does not include areas where branches are dead or absent. Foliage is considered discolored when the overall appearance of a leaf is more red or brown than green. Fifty percent or more of the leaf has to be discolored for the leaf to be rated as discolored. Then, the area of the crown occurpied by leaves with that condition is rated with the 21-class scale. When the observer is not sure whether the foliage is green, it is rated green. Two certified raters are required to make the discoloration estimates from opposite sides of the tree.

Patterns and types of off-green coloration on diseased trees are reconized as an indicator of tree health problems. These indicators are not measured in this study, because of the difficulty of standardization between raters. However, the condition may be recorded in the notes. Marginal leaf scorch and similar partial discoloration will not be recorded unless more than half of all the leaves are affected. Premature fall coloration of leaves has been associated with the decline of sugar maple. Rapid changes over time and regional differences preclude use of early fall coloration as a critical measurement. After the 1988 field season, foliage discoloration was removed as a critical measurement, but its presence is still documented. Early leaf coloration and partial leaf discolorations may be recorded in the notes. When special conditions exist, a special rating scheme may be developed to measure the unique foliage damage condition. Data entries may be made in the blank columns provided for that purpose and a detailed description will be provided to the national coordinator and the data analyst.

Defoliation (All hardwoods)

Early defoliation (pear thrips, forest tent caterpillar, gypsy moth, etc) could substantially modify the overall crown condition ratings made in late summer, and so the impact from these pests could be missed with a single mid- or late summer visit. The early entry is made when most of the defoliation by a given pest is expected to be complete. If it is determined during the spring visit that none of the trees is expected to have greater than 30 percent defoliation at the end of the feeding period, a 0 value is entered on the Tree Data Field Form under Early Defoliation Rating and a line is drawn vertically to the bottom of the page, indicating that an individual tree defoliation rating was not made. If one or more trees on a plot is likely to have moderate or greater defoliation, all trees on that plot are individually rated and recorded on the data sheet.

Defoliation is estimated in four classes:
0 - none to light defoliation.

1 - less than 30 percent of crown defoliated.
2 - 31 to 60 percent defoliation.
3 - more than 60 percent defoliation.

The causal agent, if identifiable, is recorded in the Notes section. No other tree condition ratings are made during the spring defoliation visit.

Occasionally, late season defoliation may occur (for example, saddled prominent). When the potential for this is detected during the scheduled crown rating visit, a return visit to more accurately rate the degree of defoliation is encouraged.

Seed Production (Sugar maple only)

Excessive seed production is believed to weaken a tree and result in increased dieback the following year. Therefore, it was agreed by cooperators in 1993 to have seed abundance recorded as follows:

1. None (no seed is visible with binoculars)

2. Light to moderate seed present, BUT NOT abundant enough to cause noticeable discoloration in the upper crown

3. Heavy (branches in the upper crown with reddish-brown cast in mid- to late summer as a result of color change of samara from green to reddish-brown)

DATA MANAGEMENT AND QUALITY ASSEMBLY

Data Collection and Transmission

Standard field forms are used to record data (Figs. 4, 6) in the field. Previous years data are carried forward for the first 5 items on the form. Indelible ball point pens are used to permit photo copying and prevent erasures. Changes are initialed and dated by the person making the change. When data must be transcribed because of damage to the original data sheets, another person checks the transcript, initials, and dates each page. The original data sheet is attached to the transcript. In the field, the recommended practice for the recorder is to repeat measurements audibly before data are recorded. Absence of an item is recorded as "0" to indicate that a measurement or an observation was made. Absence of an entry on the data sheet is considered as missing data unless specifically permitted. The crew leader is responsible for checking completeness of data sheets before leaving the plot. The names of the crew and the date of collection are recorded on each data sheet.

Data sheets from all clusters are stored in a single envelope with proper plot identifications. Two copies are made of each data sheet. One copy of the field sheets is kept in the office of the field crew, a second copy is sent to the data entry staff, and the original is mailed to the State Coordinator. Data are entered into Excel spreadsheets once in the District Office and a second entry in the Waterbury Office. These two files are used to verify the data entry. All forms and electronic data are due to the State Coordinator by OCTOBER 1, 2006.

Entry, Validation, and Storage

NAMP provides information for up to 26 variables on approximately 5,000 trees of which approximately 80 percent are sugar maples. Because of the size of the data set, it is important that the data be entered correctly and that an efficient method of validation be developed to ensure accuracy. The files are stored on hard drives as well as on CDs with the State Coordinator. Once a file has been entered, checked, and validated, the file is archived on a CD. Annually, one copy of all files, in the form of a CD, is submitted for storage in a fireproof vault and for public access to the Vermont Monitoring Cooperative.

QUALITY ASSURANCE

Quality assurance consists of an organized group of activities defining the way in which tasks are to be performed to ensure an expressed level of quality. These activities ensure that the operations and procedures requiring control are defined, documented, and implemented. This plan prescribes proper handling of critical equipment, specifications for critical measurements, training requirements to achieve necessary data standardization, and required field checks to document and assure data comparability.

Data Quality

Crown-condition measurements are critical for determining changes in the condition of sugar maple. The crown-condition ratings are subjective, quantitative, ocular estimates. The repeatability of measurements is assured through intensive training, standardized guides, and the use of two persons, minimum, to rate each tree. The first 2 years of cross-checking showed that approximately 95 and 90 percent of remeasurements were within one class for dieback and crown transparency, respectively. Discoloration and dwarfed foliage remeasurements also showed high measurement repeatability, but a majority of the measurements were in the very low percentage classes. Crews are trained and tested annually for satisfactory performance. Field situations may occur when a measurement cannot be taken. Documentation must be provided for any measurement not taken by leaving blank the space in the record. That portion is deleted in the analysis and does not appear as 0 or 1.

Standards and Critical Measurements

In 1988, the five crown-rating measurements were: branch dieback, foliage transparency, foliage discoloration, dwarfed foliage, and presence of epicormic shoots. Because of poor remeasurement precision for epicormic shoots and dwarfed foliage, these measurements were deleted from subsequent annual measurements. Foliage discoloration measurements were down-graded to non-critical measurements and their quality is not checked for compliance with minimum standards. In 1989, a new measurement was added to assess the degree of insect defoliation. It is not considered a critical measurement and is not checked for repeatability precision. Also in 1989, crown ratings of hardwoods other than sugar maple were added, but these are not checked for compliance with minimum standards. In 1993, vigor ratings were added to the critical measurements.

Data quality requirements for the critical measurements were outlined at the beginning of the project. Acceptable variability between raters, for example, tolerance limits, was established at +/- 2 class for dominant, codominant, and intermediate crown-class sugar maples, and +/- 4 classes for suppressed trees. Exceeding these limits is considered an error in measurement. The average of two or more experienced raters is considered as the correct measurement. Plot measurements were acceptable with less than 10 percent error.

Data quality was achieved by implementing the following activities:

1.Each critical measurement is rated by two certified crown raters from opposite sides of a tree. When the two raters do not agree, the class corresponding to the average ratings of the two is recorded.

2.Each rater is required to attend an annual training session and pass a rating qualifications examination. Records are maintained from all training sessions, examinations, and certifications.

Analysis of the remeasurement data showed that in 1988 approximately 5 percent of branch dieback and 9 percent of foliage transparency remeasurements exceeded the allowable tolerance limits (Burkman et al. 1990; Cline et al. 1989). With improved training in 1989, less than 5 percent and approximately 8 percent of the remeasurements exceeded the tolerance limits (Burkman et al. 1990).

Training and Certification

Annual training is provided to the field crews involved with the crown rating. The crown raters are required to attend the training and to complete certification for performance. Certifications are received when a person demonstrates ability to rate dieback and foliage transparency within the specified tolerance limits more than 90 percent of the time.

Large group training requires preselection of practice and certification trees. Training is provided in groups of approximately five persons under the guidance of an experienced crown rater. Approximately 20 trees are evaluated to achieve proper standardization. Then 20 trees previously rated by at least two experienced crown raters, are rated by each trainee. Trees are rated from one side only, usually indicated by a tag, to assure that the persons are rating the same condition. Trainees are given the opportunity to rerate a tree when their assessment deviates more than two classes from those of experienced raters.

A similar approach is used for small groups, except that the experienced raters and the trainees evaluate the trees at the same time, then discuss the ratings. The trainees are asked to record their ratings. Deviations from the experienced raters are discussed and the trainees are permitted to change their values. Usually, acceptable standardization is achieved after the first six trees. The rating exercise is terminated after the trainees agree within the acceptable 2-class limits for five successive trees. The experienced crown raters usually are the national coordinators and the quality assurance officers.

DATA QUALITY CONTROL

Data Verification and Transmittal Procedures

To ensure valid data, internal checking procedures were implemented. Data verification ensures that the final data are of a known and documented data quality and that valid data codes are in the final data set. A schematic flow chart shows the internal checking procedures for data completeness and transmittal (Fig. 7). Revisiting the plot is required when missing data can be obtained.

FIELD CREWS ARE ASKED TO EXAMINE ALL DATA SHEETS FOR COMPLETENESS AND TO VALIDATE DATA CODES BEFORE DEPARTURE FROM THE FIELD.

The State Coordinator examines each data sheets for proper entries and relays any observations to the data entry staff. Errors are documented and the reviewer identified on the cover sheet. When data entries are completed by data entry personnel, the original data sheets are stored in a fireproof vault for safekeeping.

Audits

The purpose of the audit is to determine if the field and data entry procedures prescribed in the guidelines are being implemented correctly. In practice, each District field crew will be audited once in 3 years. During the audit, the field crews are solicited for opinions on improving the field work.

Remeasurements

No remeasurement plots will be conducted in 2006. The precision of critical crown-rating measurements is determined each year using QA/QC remeasurements. Precision is defined as the level of agreement among multiple measurements of the same sample or repeated measurements by the same individual. Accuracy cannot be determined for most of the field measurements because the "true value" is not known and cannot be determined. The remeasurement method is used to determine the precision of measurements. About 10 percent of the plot clusters are scheduled to be checked and within each cluster two plots are remeasured for critical measurements. Remeasurements done without reference to the previous measurements, are completed either by the same or different crews. Results from the remeasurements show that crew precision is greater with same-crew remeasurements than with different crews, but no significant differences were observed between crews of the same state or province and crews from different states or provinces (Burkman 1990; Burkman et al. 1990).

Crews with allowable errors in more than 5 percent of their sample are reported to the state. A problem resolution report is prepared. Lack of documentation of corrective action requires deletion of all the data collected by that crew.

ANALYSIS

The analysis and management of data for Vermont are currently conducted by the State Coordinator. Analyses of the data serve the following functions:

1. Provide results on the current condition of sugar maple trees across Vermont for annual reporting of statewide forest health;
2. Provide results on trends in sugar maple and other hardwood species tree health and potential causes for tree health problems;
3. Provide site specific results on tree health for use by landowners for sustainable forest management practices.

Tables are used to present summary information for each cluster, and for the entire state. Much of this information is in the form of averages: average number of trees per cluster, average number of tapholes per tree, average d.b.h., and averages of the critical variables (dieback, transparency, and vigor). The ranges for the variables are given in addition to their averages.

In addition to averages, the frequency of healthy and unhealthy trees by site, incidence of defoliation, and bole and stand damage summaries are calculated.

EQUIPMENT AND SUPPLIES

At the time of plot establishment, several land surveying and forestry tools were used. Binoculars, however, are the only specialized equipment used for crown-rating remeasurements. The crown-rating guide is carried by the crews for field reference. The following list includes most of the equipment and supplies used by the field crews in:

Plot establishment:

Compass
Increment borer, 3 to 5 mm dia.
Tree identification manual
Measuring tape (metric)
Clinometer
PVC pipe, 2 cm dia., 1 m long; 5 per plot, 25 per cluster
Numbered aluminum tree tags and aluminum nails
Cardboard tubes or paper straws for increment cores
Stand and Plot Description Form
Tree Data Field Form
Tree flagging
Indelible pen

Annual crown rating:

Binoculars
Foliage Transparency Standards
Tree Data Field Form
Indelible pen

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