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INTRODUCTION

In 1985 and 1986, a survey was initiated by the Vermont Department of Forests, Parks, and Recreation to determine the health status of Vermont's hardwood forests (Kelley and Eav 1987). This established a data base for future monitoring of tree condition and the effects of various stresses on hardwoods in the state. This survey was repeated in 1990 and 1991 and again in 1995 and 1996 to obtain the current health status of Vermont's hardwoods. All surveys were a cooperative effort with the U.S. Forest Service.

The specific objectives of each survey were to:

- determine number and volume of dead and declining hardwood trees per acre.
- determine the area of hardwood decline and mortality by mortality class.
- provide data on tree mortality, crown condition, site and stand factors to be used to determine stand trends over time.

The first survey followed a period between 1977 and 1982 when over one-fourth of Vermont's northern hardwoods (about 498,000 acres) were defoliated at least once by the forest tent caterpillar. This resulted in 33,000 acres of tree crown dieback and tree mortality. Thousands of additional acres were defoliated by outbreaks of gypsy moth, maple leaf cutter, and saddled prominent, as well as by late spring frosts in 1980 and 1986. Additional stress factors included below average precipitation and a cold, open winter in 1980-81. This occurred at a time when there was much public concern about the impacts of air pollutants on tree health.

The first repeat of this survey in 1990-91 showed improvements in tree condition (Kelley, Smith and Cox, 1992). Some of the ground evaluation procedures were refined for this survey to correspond with national monitoring standards that had been developed since 1986.

SURVEY METHODS

Photo Interpretation

Color infrared aerial photos, representing approximately 1% of Vermont's forested area, were used to get a broad view of tree dieback and death and to serve as a basis for selection of ground plots. Mortality area was determined by counting dead and dying trees on photos covering 612,000 acres. These sample points were re-photographed in 1990 and 1995 to measure the change in number of dead and declining trees. At each photo point a 360 acre block was divided into 2.5 acre grid cells which were classified into one of the following mortality classes:

Photo Mortality Classes

- **Class 1** - no dead trees within the grid cell.
- **Class 2** - a single dead tree within the grid cell.
- **Class 3** - two to four dead trees within a grid cell.
- **Class 4** - five or more dead trees, but less than 10% dead trees within the grid cell.
- **Class 5** - from ten to thirty percent dead trees within the grid cell.
- **Class 6** - more than 30% dead.

(In 1985 mortality classes consisted of light - less than 10% of the hardwood canopy trees were dead (classes 1 to 4, above), moderate - 10-30% canopy dead (class 5 above), and heavy - more than 30% dead (Class 6))

Ground Survey

Ground survey methods were used to take a closer look at the extent of dieback and mortality. Based on interpretation of 1985 photos, two cells with heavy mortality, 22 cells with moderate mortality, and 51 cells with light mortality were intensively examined. Site and tree data were collected within each cell in 1986, 1991 and 1996.

Tree data were collected for all trees one inch in diameter or greater. This totaled over 2,000 trees in dominant or codominant (upper canopy) crown positions. Sugar maple, red maple and yellow birch were the species most frequently evaluated in 1986 and 1991, but beech replaced yellow birch as the third most abundant species by 1996.

Data included ratings for crown condition, including crown dieback. Dieback was based on visual estimates of the portion of tree crowns represented by twigs and branches that had recently died from the tips back.

Crown Dieback Ratings

In 1986, these crown dieback ratings were used:

- Healthy
- 1: No observable crown dieback
- 2: 1-10% dieback
- Moderate Dieback
- 3: 11-25% dieback
- 4: 26-50% dieback
- Heavy Dieback
- 5: 51-75% dieback
- 6: Over 75% dieback

In 1991, crown dieback measurements were changed to 5% categories (0, 5, 10, 15, etc.) to compare to national forest health monitoring standards. These categories were combined during analysis of 1991 and 1996 data to make direct comparisons to 1986. Quality control assurance was obtained by re-measuring seven percent of the ground points by different observers to assess measurement repeatability. Ninety five percent of crown dieback re-measurements fell within $\pm 10\%$ of the original 1996 field ratings.

RESULTS AND DISCUSSION

Area of Mortality

The statewide area of moderate or heavy tree mortality based on interpretation of aerial photographs decreased from over 13,000 acres in 1985 to 4,000 acres in 1990 and 1,000 acres in 1995 (Table 1).

Table 1. Area of Hardwood Mortality in Vermont in 1985, 1990 and 1995 Estimated by Photo Interpretation. (Thousands of Acres)

| Mortality Class* | 1985 | | 1990 | | 1995 | |
|--------------------|-------|------------|-------|------------|-------|------------|
| | Mean | Std. Error | Mean | Std. Error | Mean | Std. Error |
| Light - Class 1 | | | 1493 | 90 | 2431 | 115 |
| Light - Class 2 | | | 665 | 40 | 547 | 33 |
| Light - Class 3 | | | 464 | 37 | 215 | 23 |
| Light - Class 4 | | | 67 | 14 | 16 | 4 |
| Total Light | 2,519 | 138 | 2,689 | 143 | 3,209 | 147 |
| Moderate - Class 5 | 13 | 4 | 4 | 2 | 1 | 1 |
| Heavy - Class 6 | 0.5 | 0.5 | 0 | 0 | 0 | |

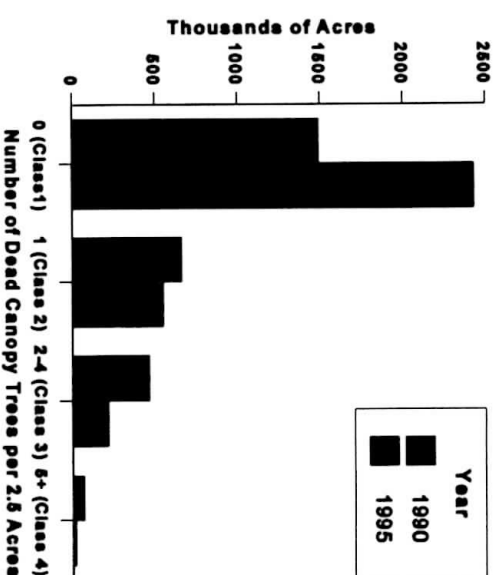


Figure 1. Statewide area of hardwoods estimated for the light mortality classes in 1990 and 1995 based on counts of dead canopy trees (described under Survey Methods/Photo Mortality Classes) visible on aerial photographs.

Tree Condition

All Species

This survey used a conservative definition of "healthy", meaning up to 10% crown dieback. Trees with over 10% dieback were labeled as declining. Based on this definition, most trees in the dominant and codominant crown positions were healthy in 1986, but 19 percent were rated as declining.

The percent of healthy trees increased from 77.8% in 1986 to 85.6% in 1991 and to 89.2% in 1996 (Figure 2).