Evaluation of Tree Health in Vermont Sugarbushes 1977 – 1985

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ABSTRACT

Fifty-four sugarbushes that had been part of a 1977 survey were re-evaluated in 1985. The average percent of dominant-codominant sugar maples that were healthy did not change, over the eight-year period, in either sugarbushes that had been generally healthy or generally unhealthy in 1977. There was a significant decline in the percent of maples healthy in stands which had been rated good or excellent in 1977 and defoliated at least once, by forest tent caterpillar, since then. The condition of the maples improved in 14, declined in 8, and did not change in 23 of the non-defoliated sugarbushes examined. Trees were more likely to be declining on sites that were less than optimum for sugar maple and on sites which had been disturbed. These conditions could make trees more vulnerable to stress from adverse weather conditions, air pollution, or insect defoliation. Monitoring should be continued to detect long-term changes in tree health and to determine whether the impact of disturbance is temporary. Recommendations are to reduce the effects of disturbance, while encouraging fast growth and wide crowns, by light, frequent, and careful thinnings, and to tap conservatively when trees are on less than optimum sites or recently disturbed.

INTRODUCTION

In 1977 an evaluation of maple decline in sugarbushes of Vermont was conducted by the Vermont Department of Forests, Parks, and Recreation, and the U.S.D.A. Forest Service. In 1985, 54 sugarbushes which had been part of the 1977 sample were re-evaluated. This was in response to a request by the Vermont Maple Industry Council, reflecting a concern about tree health among maple sugarmakers throughout the state. It was also in response to a need to develop better recommendations for managing sugarbushes to maintain tree health, and a need for better facts about the Vermont situation for policymakers and the popular press. The objectives of the survey were to determine whether the extent of maple decline in sugarbushes had changed since 1977, to determine what stand and site factors were related to tree health, and to evaluate the impact of a recent outbreak of forest tent caterpillar on affected sugarbushes.

Much of the popular concern about maple decline has been linked to concurrent concern about the potential impact of air pollutants on tree health, and about regional declines of spruce and fir. Although it can indicate whether there is a widespread decline of maples in the state, and can identify where declining stands are located, this survey cannot determine the impact of current levels of pollution on the stands examined. Determining the role of pollutants in forest decline is the objective of the Forest Response Program of the National Acid Deposition Assessment Program (Shriner, 1986).

PAST HISTORY OF SUGAR MAPLE DECLINE IN VERMONT

In the northeast, periods of sugar maple decline have been reported throughout the century (Westing, 1966). Particularly severe declines in the mid-thirties and mid-sixties were associated with prolonged dry periods. In Vermont, a 1963 survey of 11 well-managed and 16 poorly managed sugarbushes, showed that 7% of the maples in the former, and 10% of the maples in the latter, had symptoms of decline (Fisher, 1965). In 1954-55, maple decline was given widespread publicity, and called a "new serious threat" to the state's maple industry. This coincided with 200,000 acres of defoliation by forest tent caterpillar, peaking in 1953 and 1954. Hornbeck (in press) relates periods of decline in the increment growth of sugar maple in Vermont to documented defoliation or periods of below-average precipitation.

The 1977 sugarbush survey was done in response to concern among the state's maple producers about apparent severe maple decline and mortality in some sugarbushes at that time. Of the 91 sugarbushes surveyed, 88% were given an overall rating of good or excellent, and 12% were given a rating of fair or poor (Millers et al., unpublished). Unhealthy stands were less well-stocked than healthy stands. On the average, stands were at the minimum stocking levels for sap production. Decline was associated, in some stands, with grazing intensity and shallow soils. One-third of the trees that were currently being tapped were overtapped, but current tapping severity was not significantly related to sugarbush health. Injury from sugar maple borer occurred on 30% of the dominant-codominant sugar maples in the unhealthy sugarbushes, and on 21% of the trees in healthy bushes. The more open conditions were thought to favor borer attack.

WHY SUGARBUSHES ARE VULNERABLE TO STRESS

Sugar maple is a nutrient-demanding species generally found on more fertile sites (Mader et al., 1969). The roots require a narrow range of moisture conditions, moist but well-drained (Westing, 1966). It does best on cooler slopes. Because most of the feeder roots are very close to the surface, they are sensitive to dry periods. Sensitivity to drought increases with age.

Historically, most declining sugar maple have been in severely disturbed or unnatural sites, indicating that this species is particularly sensitive to abuse (Westing, 1966). Because trees in an ideal sugarbush have large crowns, exposed to sunlight, developing a sugarbush requires frequent, light thinnings begun when the stand is young. These stands should be understocked for timber production (Lancaster et al., 1974). These low stocking levels may increase the risk of maple decline. In addition to subjecting trees to frequent disturbance, possible reasons are that open stands favor the buildup of insect defoliators (U.S.F.S., 1964), are more exposed to pollutants because of increased air circulation around the trees (Carrier, 1986), and are more vulnerable to drought stress because of higher soil temperatures and more evaporatransportation from exposed crowns (Banfield, 1967). evapotranspiration

STRESSES THAT HAVE AFFECTED MAPLE IN RECENT YEARS

In recent years, sugar maple stands have been exposed to a variety of stresses, in addition to the continuous deposition of air pollutants. Between 1977 and 1982, nearly 498,000 acres were defoliated at least once by the forest tent caterpillar, representing over one-fourth of the northern hardwood forest type in the state (Teillon et al., 1986). Thousands of additional acres were defoliated at that time by simultaneous outbreaks of maple leaf cutter and saddled prominent. A frost in June 1980 damaged the foliage on over 124,000 acres at higher elevations. There was little snow in the winters of 1979-80 and 1980-81. In December 1980 and January 1981, these open conditions compounded the impact of severe cold. A long thaw in February of 1981, followed by cold temperatures, and dry periods in the spring and summer of 1982 may also have been complicating factors.

OTHER SUGAR MAPLE DECLINES OCCURRING IN THE REGION

In Quebec, sugarmakers first expressed concern about decline developing in sugarbushes in 1978 (Gagnon et al., in press). In a 1983 survey, 83% of the stands were considered healthy (Laflamme et al., 1984). Of all of the sugar maples examined, 44% had no dieback, 34% had <5% dieback, 13% had 6-25%, 3% had 26-50%, 2% had >50%, and nearly 3% were dead. The regeneration in affected stands was healthy. Decline progressed, particularly in severely affected stands, so that by 1985, only 60% of the maple type was rated healthy or slightly affected (Carrier, 1986).

Symptoms of decline are small, pale leaves, dieback, slow taphole closure, reduced radial increment, bark peeling off the large limbs and mainstem, premature autumn color and adventitious shoots. "Warning symptoms" have also been noted, which indicate a tree that will decline (Carrier, 1986). These include unnaturally vertical foliage, very dark, green leaves, leaf mottling, and small waxy foliage at the top of the crown.

Disturbance accounted for 40% of the decline in a 1983 survey of affected maple stands (Roy et al., 1985). Sugar maple was less resistant to decline on wet or dry sites than on mesic sites. Sites that were less than optimum for sugar maple were likely to have more trees of other species, and therefore, heavier cutting necessary to develop a sugarbush. Disturbance had the greatest impact on the health of sugar maple that was growing off-site.

Sites where decline was most likely to occur were those with the lowest levels of soil nutrients. Affected soils are rather acid, with low levels of calcium and magnesium, low base saturation, and high levels of iron and aluminum (Roy et al., 1985). The authors conclude that concentrations are abnormal for the soil type. On some forest sites, soil pH, calcium, magnesium and potassium have declined, and percent organic matter has increased since 1968 (LRTAP, 1986).

<u>In Ontario</u>, a survey of sugarmakers showed that 70% of the producers have observed decline symptoms in the past 10 years; three-quarters first observed the symptoms after 1980 (LRTAP, 1986). A 1984 survey in the generally affected area showed that 58% of the trees were healthy, 20% had moderate decline and 22% had severe decline, (McLaughlin et al., 1985). In the generally less affected area, 68% of the trees were healthy. The level of decline has remained stable between 1984 and 1986.

Seventy-nine percent of the sugar maple stands where producers reported decline had been thinned. Decline was not associated with stocking or basal area, but the larger trees were more likely to be declining. There was no consistent pattern relative to topography, aspect, or site. Decline was most common on older trees and trees which had been tapped or otherwise wounded. Site nutrient deficiencies were not related to decline, while root rot, tree age, and stand management practices all contributed to decline levels.

METHOD

SUGARBUSH SELECTION

Twenty-five sugarbushes given an overall rating of good or excellent in 1977 and twenty rated fair or poor were selected from sugarbushes with complete 1977 data and no history of recent defoliation. Random selections were made by geographic district. The generally unhealthy sugarbushes were sampled more intensively than those that had been healthy because they may have been more vulnerable to decline if subject to additional stress, and also had more room for improvement. A simple random sample would have selected too few of these bushes to determine whether or not their condition was changing. An additional nine sugarbushes, those that were part of the 1977 survey and were known to have been defoliated by forest tent caterpillar at least once since then, were also selected for sampling.

SAMPLE PLOT LAYOUT

So that results would be comparable, the 1985 survey method was similar to that used in 1977. Plots were established in the same general location as they had been in the previous survey, with the help of the landowner or a member of the 1977 field crew. Trees were marked so that plots could be relocated and resampled in the future.

Data was taken between mid-July and the end of August. A cluster of five 1/5th acre circular plots was sampled in each sugarbush. Plot five was in the middle of the sample area, and plots one to four were five chains to the north, east, south and west, respectively. In more narrow sugarbushes, the five plots were in a line at five chain intervals.

BUSH DATA

For each sugarbush, the landowner was consulted to determine the last year of paraformaldehyde use and grazing in the sugarbush, if any. Landowner information and department records were used to record the same information for defoliation. The landowner was also asked whether the objective of cutting was to thin and improve the sugarbush, whether cutting was mostly for improvement but included salvaging some dead or dying trees, or whether over half the cutting was for salvage. For each sugarbush, elevation was recorded from topographic maps.

After all the plots were sampled, each sugarbush was given an overall rating of excellent (overall stand healthy), good (some dieback, but not alarming), fair (obvious dieback present, a potential problem) or poor (serious dieback and death of trees). Ratings were based on trees observed in the plots and in travel through the stand.

PLOT DATA

In each plot, the following data was taken: degrees slope, aspect in degrees azimuth, three categories of crown closure (open, partially closed, closed), and four categories of grazing intensity (none, light, moderate, heavy). The presence or absence of rock outcrops and of soil disturbance by roads or recent logging activity within the plot was also noted.

Ground cover information was taken from five milacre sub-plots per plot; one at plot center, the others 20' away in the cardinal directions. Plots were rated as: advanced sugar maple (3' high-2" DBH) present; only sugar maple <3' high present; softwood present, but no sugar maple; Rubus sp. present, but no sugar maple or softwood; woody plants other than sugar maple, softwood or Rubus; fern but no woody plants; grass but no fern or woody plants; or other.

At each plot, an increment core was taken from the sapwood of the first dominant or codominant sugar maple. The width of the last five and the last ten rings was measured.

TREE DATA

Tree data collected for all stems greater than 5" DBH were: species, DBH to the nearest 0.1", crown class (dominant-codominant; intermediate, suppressed) and crown condition.

Crown condition was based on the live crown and rated as:

Healthy: foliage green <10% dead crown branches, leaf size normal

Fair: foliage off-color, 10-50% dead crown branches, abnormal leaf size

Dead: no foliage alive

Stumps present in the plot were recorded as trees if they were greater than 5" in diameter and still had bark on. Species was recorded for these stumps.

Crown dieback was also rated as 0%, 0-25%, 25-50%, 50-75%, 75-100%, or dead so data could be made comparable to other surveys. Dead trees were rated as one of four categories of time since death; fine twigs and buds present, bark tight; buds and some fine twigs gone, bark loosening; most fine twigs gone, bark loose and sloughing; all fine twigs gone, much or all bark sloughed.

SUGAR MAPLE DATA

For all sugar maples, the following injury agents or symptoms were recorded as absent, present but not causing decline or death, present and suspected cause of decline or death: logging injuries, sugar maple borer, cankers, bird or animal damage, stem rot, grazing injury and root collar rot. Leaf scorch and leaf damage other than scorch or defoliation was recorded as present or absent. Defoliation was recorded as absent, <10%, 10-50% or >50%, and defoliators were recorded as maple leaf cutter, leaf roller, forest tent caterpillar, pear thrips, or other. If a tree was recently dead, had the littleleaf symptom, or had severe dieback associated with basal injuries, a wedge at least 2" deep was chopped from the root collar to look for the streaking characteristic of sapstreak. Where streaking was present, samples were frozen and taken to the University of Vermont forest pathology lab for culturing. The bark was removed from the root collar of dead trees, and the presence of rhizomorphs, mycelial ferns and/or mushrooms of Armillaria mellea was noted.

Trees were recorded as being untapped, tapped, but not in 1985, or tapped in 1985. They were also rated for tapping severity; under, at or above the rates recommended by Lancaster et al. (1974). These recommendations are for 1 to 4 tapholes at tree diameter ranges of 10-14", 15-19", 20-24", and 25" and over, respectively. In addition, taphole closure was judged as being good or poor.

Where tubing was present in the plot, it was examined for the presence or absence of rodent damage.

SOILS DATA

Soil samples were taken from two plots in each sugarbush. These were to be from plots 2 and 4, unless they were not typical of the bush. Samples were taken from the upper 2", under the identifiable litter. Ten trowelfuls per plot were mixed, and kept refrigerated until analysis at the University of Vermont within seven days.

Soils from plot 2 of most bushes, and 2 and 4 combined from two bushes, were analyzed. Soils were analyzed for pH in water (2:1) and pH in salt (.01 M $CaCl^2$(2:1)). Percent organic matter as calculated from weight loss on ignitition. Bulk density was calculated as the dry weight of 5 ml. of moist soil. A 5:1 extraction with 1.25 N NH_4OAc determined pounds per acre of available calcium, magnesium, potassium, aluminium, manganese, iron, zinc, and phosphorus. E4/E6, a measure of organic matter and its state of decomposition, was calculated as the ratio of the absorbance of the NH4OAc extracts measured at 465 nm and 665 nm.

Millequivalents per 100 g of soil of calcium, magnesium, potassium, aluminum, manganese, and iron was determined by a .1 M $BACl_2$ extract. Cation exchange capacity was calculated as the sum of the millequivalents/100 g of calcium, magnesium, potassium, and aluminum. Percent base saturation was the percent of the exchange capacity occupied by calcium, magnesium, and potassium.

Milligrams per kilogram (ppm) of lead, cadmium, copper, nickel, and chromium were also determined for each sample.

Each sugarbush was visited by a soil scientist from the USDA Soil Conservation Service. The soil types and slopes in the mapping unit were noted. At points 2 and 4 of each sugarbush soils were described for series name, classification and drainage. Depths to bedrock, seasonal high water table (mottles), and to firm substratum (dense till) were also measured.

DATA ANALYSIS

All 1977 and 1985 data were summarized by sugarbush. All analyses were done with sugarbush averages except for relating stem rot, scorch, overtapping, sugar maple borer, and grazing injury to tree health.

Percent healthy was calculated as a percent of all live and dead dominant-codominant sugar maples. For 1985, all sugar maple stumps were counted as dead trees if the landowner had said that over half the cutting was done for salvage. Half were counted as dead trees if some but less than half were cut for salvage, while none were counted if the reason for cutting was improvement. Sugar maple borer and grazing injury in the 1985 were also calculated as a percent of all dominant-codominant sugar maples affected. Poor taphole closure, cankers, bird or animal injury, defoliation over 10%, root collar rot, logging injury, current tapping, crown class, and 1977 values for sugar maple borer, overtapping, stem rot, scorch and grazing injury were calculated as a percent of all sugar maples affected. 1985 values for stem rot, scorch, and overtapping were calculated by percent of live dominant-codominant sugar maples affected. Mean stand diameter and percent sugar maple were based on all trees.

For each sugarbush, soil water capacity was calculated as the average value for the predominant soil series. Geographic location was determined as west or east of the Green Mountain ridge, delineated by the Long Trail. Based on mean stand diameter, trees per acre, and basal area, each sugarbush was rated as stocked above or below the B-line (Lancaster et al., 1974).

Percent of dominant-codominant sugar maples in the 0-10% and 10-25% dieback groups was calculated from other data. A state average of percent of trees in all dieback groups was calculated as a weighted sum; 88% of the value for 1977 good-excellent sugarbushes and 12% of the value of fair-poor sugarbushes.

RESULTS

The results that follow consider only the condition of the dominant-codominant sugar maples, except where indicated. They receive adequate sunlight and their health is not significantly affected by competition with neighboring trees. Complete data summaries are in the appendix.

CHANGES IN SUGARBUSH HEALTH: 1977-1985

The average condition of the non-defoliated sugarbushes surveyed did not change between 1977 and 1985, based on the percent of trees that were rated healthy (Figure 1). This was true whether the sugarbushes were rated as being generally healthy or unhealthy in 1977. The average condition of the sugar maples in defoliated bushes that had been in good or excellent condition did significantly decline.

The average condition of trees in individual sugarbushes did change over the eight-year period (Figure 2). There were more sugarbushes where the percent of trees that were healthy significantly improved than where the percent healthy declined, especially among those which had been rated fair-poor in the 1977 survey.

The presence of several specific injuries was compared to crown condition on a tree-by-tree basis (Figure 3). No single agent was identified that consistently explained crown condition. Healthy trees were less likely to have stem rot or scorch than unhealthy trees. Both of these symptoms were probably taken into account by observers in rating crown health and are a symptom, not a cause, of poor condition. Trees which were currently healthy were also more likely to be overtapped. Sugarmakers are likely to tap trees which appear healthy more intensively. Other results suggest that the effects of overtapping do not show up immediately in the crown.

FACTORS ASSOCIATED WITH SUGARBUSH HEALTH

A review of data summaries and observers comments for individual sugarbushes suggests that the most important influences on tree condition vary from stand to stand. However, there were significant differences in stand and site factors between sugarbushes that were currently healthy and those that were currently unhealthy. Another set of factors were different between stands which improved between 1977 and 1985, and those that declined.

Non-defoliated sugarbushes were separated into those that were generally healthy and those that were unhealthy based on the percent of trees with healthy crowns. The 27 sugarbushes with at least 80% of the trees rated healthy were in the healthy group; 18 with less than 80% healthy trees were in the unhealthy group. These groups are not identical to the 27 bushes observers rated good or excellent in 1985 and the 18 rated fair or poor. However, the 80% cutoff was used because it was a more objective way to arrive at the same size groups.

Healthy sugarbushes had faster growing trees which had faster taphole closure (Table 1). Plots in these bushes were less likely to be disturbed by recent logging activity or woods roads.

Healthy sugarbushes were also more likely to be on sites which are good for growing sugar maples. Although the higher percent sugar maple in these stands could be due to management practices, other variables indicate the influence of a "sugar maple site." These include the deeper soils, and soils which are less acidic, have less organic matter, higher percent base saturation and less aluminum and iron. While most sugarbushes had a southern aspect, healthy sugarbushes were more likely to be on southeast facing slopes, while unhealthy sugarbushes tended to be facing southwest. East facing slopes are less exposed to the prevailing atmospheric conditions, and, receiving less direct sunlight, they are more mesic and likely to retain snow later in the spring.

Trees other than sugar maple were more likely to be healthy in healthy sugarbushes indicating that factors influencing the health of the sugar maples influenced trees of other species also. Leaf size and color were factors in rating tree health. Therefore, current defoliation was was higher in sugarbushes with less than 80% healthy trees. Healthy sugarbushes had trees with more grazing injuries, and they had more soil chromium.

FACTORS ASSOCIATED WITH CHANGE IN SUGARBUSH HEALTH

Of the sugarbushes that are currently healthy, nearly half had significantly improved from 1977 (Figure 4). One of the unhealthy sugarbushes had more healthy trees in 1985 than 1977, while nearly half had declined. The factors that are significantly different between the fourteen sugarbushes that improved and the eight that declined are listed in Table 2.

Sugarbushes that improved had trees with faster taphole closure and soils with higher percent base saturation, less aluminum and iron, and more chromium and nickel. They also were less likely to be west of the Green Mountain ridge.

Other differences between bushes which improved and those that declined may be related to the significant difference in the amount of disturbance. Bushes which declined had fewer maples and trees per acre, and were less likely to be stocked over the B-line, indicating the result of cutting activity. They had more trees with stem rot and more with logging injuries in 1977, but had similar levels of these injuries as the improved bushes in 1985. They also had fewer cankered trees in 1985. These differences indicate that some of the rough and rotten trees were removed by cutting. Bushes that declined had more trees with leaf scorch, indicating water stress that may be associated with disturbance and opening the stand.

Bushes that declined had more overtapped trees in 1977. They also had faster taphole closure and more trees with healthy crowns at that time. This indicates that the effect of overtapping had not shown up in the growth or crowns of trees by 1977, but had eight years later.

A review of the data summaries and observers' comments for the eight sugarbushes that declined shows that nearly all were affected simultaneously by several poor sugarbush practices. These included current and/or past overtapping, current and/or past grazing, widespread disturbance, and leaving spouts in trees through the growing season.

FACTORS NOT RELATED TO SUGARBUSH HEALTH

A large number of factors were not significantly different between healthy and unhealthy sugarbushes or between sugarbushes that improved and those which declined. A variety of stem injuries were not consistently related to overall sugarbush health. Current tapping practices and grazing history were also unrelated. The differences in elevation, slope, drainage, and ground cover suggest site-related differences but were not significant. Basal area, tree diameter, percent of trees dominant-codominant, and crown closure were unrelated to sugarbush health. Soil nutrient analyses were similar between the groups, except as related to acidity. In general, variables related to stand and tree condition in 1977 were unrelated to 1985 condition. Non-significant, but higher basal area and tree diameter in bushes which declined suggest that large old trees may have been removed when these sugarbushes were disturbed.

CHANGES IN NON-DEFOLIATED SUGARBUSHES: 1977-1985

Stand composition data from both groups of non-defoliated sugarbushes, those that were good-excellent and those that were fair-poor in 1977, indicate that these are agrading stands. The stocking in terms of trees per acre and basal area increased between 1977 and 1985. More of the sugar maples were dominant-codominant in 1985. Mean annual increment and mean stand diameter also increased for the healthier sugarbushes. Since growth continues to increase, these stands may still not be fully stocked. Overstocking would have led to stagnation. The increase in relative stocking of sugar maple was significant only for those sugarbushes which had been fair or poor in 1977.

In general, there were fewer trees with specific injury agents in 1985 than in 1977. Overtapping decreased in the sugarbushes that had been fair-poor, suggesting, again, that sugarmakers are limiting tapping on unhealthy trees. There was a reduction in leaf scorch between 1977 and 1985. This may be due to an unusually dry period in the early growing season in both 1976 and 1977, while the same period was unusually wet in 1984 and 1985. Decreases in root collar rot, logging injury, and sugar maple borer indicate that defective trees are being removed, trees are outgrowing existing injuries, and/or conditions favoring these injuries have changed.

CHANGES IN DEFOLIATED SUGARBUSHES: 1977-1985

Many changes in non-defoliated sugarbushes also apply to those that were defoliated. Basal area, mean stand diameter, and percent dominant-codominant all increased, while the levels of scorch, root collar rot, logging injury and sugar maple borer declined. In spite of increased basal area, there was no increase in trees per acre. Also, the level of stem rot declined. These indicate that defoliation removed suppressed small or rotten trees disproportionately.

DIFFERENCES BETWEEN DEFOLIATED AND NON-DEFOLIATED SUGARBUSHES

Stand variables were compared between the 25 sugarbushes which were rated good-excellent in 1977 and not subsequently defoliated and the seven which were rated good-excellent and then defoliated. There were no significant differences between the two groups before defoliation in 1977, although the bushes which were to be defoliated had generally smaller trees, with more stems per acre.

In 1985, after defoliation, fewer of the sugar maples were healthy in the defoliated than in the non-defoliated sugarbushes. They also had less basal area. The number of trees per acre dropped, a significant difference from the increase in trees per acre in non-defoliated bushes.

DIFFERENCES BETWEEN DISTURBED AND UNDISTURBED SUGARBUSHES

Because the amount of disturbance was strongly related to sugarbush health, sugarbushes which had disturbed plots were compared to those with none. In addition to having fewer healthy trees and being more likely to have declined between the two study years, the disturbed sugarbushes were on deeper soils, had less sugar maple in the ground cover, and more conifer regeneration and fern. There were fewer trees with stem rot in 1985 but not 1977, and more with logging injuries in 1977 but not 1985. The relative stocking of sugar maple was less in both 1977 and 1985 in the disturbed sugarbushes than those that were undisturbed. The basal area in sugar maple and the mean stand diameter was smaller in 1985, but not 1977.

These data suggest that cutting is being done to develop sugarbushes where the relative stocking of sugar maple is low, and to remove rough and rotten trees, many of which would have been larger sugar maples. The deeper soils suggest that cutting is being avoided on wet or shallow sites.

DIFFERENCES BETWEEN SUGARBUSHES ON TUBING AND THOSE ON BUCKETS

Sugarbushes which were generally healthy in 1977 were compared based on tapping method. Only these sugarbushes were considered, because fewer compounding factors would be influencing tree condition. Seven of them had at least half the plots on buckets, while fourteen had at least half the plots on tubing, with or without vacuum.

No differences in tapping severity, tree health, or affect of tapping severity on tree health were significant. The data suggest a tendency toward heavier tapping in tubing bushes, fewer healthy trees, and a greater influence of heavy tapping on tree health. Again, sugarmakers seem to be tapping trees with full, healthy crowns more intensively.

DISCUSSION

CHANGES IN SUGARBUSH HEALTH 1977-1985

The results of this survey show that, on the average, sugar maples in Vermont's sugarbushes were as healthy in 1985 as in 1977. While the condition of trees in about half the sugarbushes did not change, some sugarbushes were healthier than they had been and others were much worse. Many sugarbushes which were healthier had been in fair or poor condition in 1977, and had more room for improvement over the eight-year period.

The results of ths survey discount the occurrence of a widespread, recent, and rapid decline of sugarbush maples. However, eight years are short in the life of a sugarbush. Trends which showed up between 1977 and 1985 may or may not be consistent in another eight or sixteen years. Additionally, the 1977 survey was done in response to concern about widespread decline at that time. As a baseline, it may not represent the normal health of the state's maples.

Crews did not separately record symptoms such as chlorosis and small or thin foliage. A tree with abnormal foliage, however, would not have been rated "healthy" even if dieback was present. Since the codes, instructions, and many of the observers were the same in 1985 as 1977, the data should be comparable. Some of the "warning symptoms," noted in Quebec on trees that will subsequently decline, would not have been taken into account.

COMPARISON OF MAPLE HEALTH IN VERMONT TO OTHER PARTS OF THE REGION

The condition of the maples surveyed is similar to conditions reported from the 1983 Quebec survey. Statewide averages of 42% of trees with no dieback and 49% with <25% dieback compares with Quebec averages of 44% and 47% with these crown dieback ratings. Since maple decline increased in Quebec, however, in 1985 the average condition of maple stands would not have been the same. Vermont's averages are not directly comparable to data from Ontario where tree health was rated by a comprehensive decline index.

STAND AND SITE FACTORS RELATED TO MAPLE HEALTH

No one factor is responsible for the condition of the sugarbushes surveyed. A review of data summaries for individual sugarbushes shows that maple decline is occurring where trees are variously overtapped, grazed, very old, injured by logging, overcrowded, growing on infertile sites, attacked by natural pests or exposed to unfavorable atmospheric conditions. It is difficult for the effect of any single factor to be significant statewide when so many influences are involved.

Sugarbush health was significantly related to the amount of disturbance. Disturbance is also associated with many declining sugar maple stands in Quebec and Ontario, and is historically associated with decline throughout the maple-growing region. Much of the disturbance in Vermont is the result of sugarbush improvement: removing competing species or rough and rotten trees. While sugarbushes at the correct stocking were less healthy than overstocked stands, this may be only from the temporary effect of disturbance. Continued monitoring will be necessary to determine whether recommended stocking levels are ideal for the health of sugar maple through the life of the sugarbush.

Sugarbush health was also related to site quality for sugar maple. Although rightly considered a "maple state", not every acre of Vermont is suitable for growing sugar maple, nor is every maple growing on a site which permits it to be tapped annually and remain healthy. The situation in Vermont appears to be comparable to Quebec where off-site maple is more likely to be disturbed because competing species are removed to improve the stand as a sugarbush. Where disturbance occurs on a poor site unhealthy trees may result.

THE IMPACT OF FOREST TENT CATERPILLAR DEFOLIATION

Sugarbushes defoliated by forest tent caterpillar were only a small part of the sample. The significant decline in sugar maple health and stocking in the previously good-excellent sugarbushes does indicate that disturbance by insect defoliation can be the critical stress factor where trees are otherwise healthy. The small sample did not suggest stand conditions which would help identify a stand vulnerable to defoliation.

THE POSSIBLE ROLE OF AIR POLLUTION

This survey does not address the effect of pollutants on sugar maple. Local levels of air pollution are unknown for much of the state, and the effects of specific levels of pollution on tree health are not understood. Some of the data, however, may be interpreted to suggest a role of air pollution in maple decline.

Where maples are unhealthy, other species are unhealthy as well, indicating a uniform, non-specific stress. Disturbance, exposure, and poor site conditions should affect the unusually sensitive sugar maples more than species which are more tolerant of these stresses. However, these adverse conditions are not ideal for the vigor and growth of any tree species.

The tendency of declining sugarbushes to be west of the Green Mountain ridge and of unhealthy sugarbushes to be on west-facing slopes suggests that they may be exposed to higher pollutant levels. West-facing slopes are also generally drier sites, and therefore often less suitable for sugar maple. Overall, seven of the eight declining sugarbushes were severely disturbed. It is possible that sugarbushes in the Champlain Valley are more likely to be associated with farming operations and perhaps grazed or disturbed by more frequent thinning.

Unhealthy sugarbushes were more likely to be on acid soils than healthy ones. Forest soils are naturally acid, with some parent materials leading to soils which are more acidic than others. Because no soil samples are available from 1977 or before, it is unknown whether differences in soil acidity are from these natural factors or from acid deposition.

Declining sugarbushes tend to be less densely stocked. Crowns in open stands are more exposed to pollutants. They are also more subject to drought stress because of drier soils and faster evapotranspiration.

While waiting for more complete understanding of the link between air pollution and forest health, these results suggest caution before discounting the role of air pollution. However, other possible interpretations of this data must also be considered.

RECOMMENDATIONS FOR MAINTAINING SUGARBUSH HEALTH

Sugarbushes need to be disturbed. They need to be disturbed while young to develop full crowns, disturbed when mature to maintain growth, remove defective trees, and encourage regeneration, and disturbed during sap collecting operations. These results, however, suggest that disturbance should be kept to a minimum by limiting the number of woods roads, by avoiding tree injuries, and by frequent light thinnings to avoid the impact of a sudden heavy thinning. To minimize damage and remove the poorer condition trees, they should be marked with leaves on, and logged during the winter.

Trees should be tapped conservatively. The effects of overtapping do not show up immediately. Trees on less than optimum sites should be tapped at less than recommended rates. These trees are growing slowly, old tapholes are closed slowly, and there is little new wood for new tapholes. They cannot sustain the same level of tapping as trees on good sites.

Tapping should be reduced after stresses such as thinning, defoliation, or adverse weather. This is particularly true for older trees and trees on poor sites. Older trees are less resistant to drought and are usually growing slowly. Trees on shallow or wet sites have vulnerable roots, because they are close to the surface. Trees on dry or exposed sites are vulnerable because they need their full complement of roots to absorb all available water.

These data also indicate that sugarbushes are "growing up". As they mature, crowded trees with less full crowns will die as healthy, full-crowned trees express their dominance and more fully occupy the site. This natural mortality should be expected throughout the life of the sugarbush.

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APPENDIX

TABLE 1. Percent of dominant-codominant sugar maples that were healthy in 1977 and in 1985, by sugarbush sub-sample group and defoliation history, corrected for salvage.[1]

1977 Sugarbush Rating	Defoliated Since 1977	# of Sugarbushes	% of Dominant-Codominant Sugar Maples Healthy	
			1977	1985
Good-Excellent	No	25	84.8	84.0
Fair-Poor	No	20	69.4	77.7
Good-Excellent	Yes	7	88.0	73.6 [C]
Fair-Poor	Yes	2	35.4	79.7

C T-test difference significant at p=.10

1 Where reason for cutting was over half salvage, all sugar maple stumps were assumed to be dead codominants. Where reason for cutting was less than half salvage, half of the sugar maple stumps were assumed to be dead codominants. Where reason for cutting was improvement, stumps were not included.

TABLE 2. Percent of trees with and without injuries that were healthy in non-defoliated sugarbushes where the injury occurred.

Injury	# of Sugarbushes	% of Sugar Maples: With Injury that were Healthy	% of Sugar Maples: Without Injury that were Healthy
Stem rot[1]	44	74.8	86.8 A
Scorch[1]	14	58.0	78.8 B
Sugar maple borer[2]	42	79.2	82.6
Grazing injury[2]	18	82.1	68.5
Tapped above 1977 rates [1,3]	33	82.9	80.6 A
Tapped at or above 1977 rates [1,3]	40	83.2	63.2

A,B T-test difference significant at p=.01 and .05, respectively.

1 % of Live dominant-codominant sugar maples
2 % of All dominant-codominant sugar maples
3 1977 Rates (DBH: # of tapholes) 10-14":1, 15-19":2, 20-24":3, 25+":4

TABLE 3. Average value of variables for non-defoliated sugarbushes grouped.

	By Sugarbush Condition in 1985[1]		By Change in Condition Between 1977 and 1985[2]	
	Unhealthy (n=18)	Healthy (n=27)	Declined (n=8)	Improved (n=14)
A: 1985 Tree Condition Variable				
% Healthy[3]	64.7	92.2[A]	55.4	92.3[A]
Change in % healthy between 1977 and 1985[3]	-12.6	13.8[A]	-30.1	30.3[A]
% Non-sugar maples healthy[4]	72.6	88.8[A]	77.2	87.5
Mean annual increment 1980-1985	3.0	3.9[C]	3.2	3.7
% with Poor taphole closure[5]	31.9	15.5[A]	44.1	18.9[A]
% with Stem rot[6]	41.1	43.0	29.1	53.9
% with Scorch[6]	3.7	2.2	6.6	1.0[C]
% with Cankers[5]	10.7	12.2	5.3	17.9[C]
% with Bird or animal damage[5]	3.0	3.5	2.8	1.7
% with >10% Defoliation[5]	7.4	0.1[C]	7.9	0.3
% with Root collar rot[5]	5.6	7.0	10.3	3.1
% with Logging injury[5]	3.9	5.8	2.3	4.5
% with Sugar maple borer[3]	21.3	20.3	21.7	17.1
% with Grazing injury[3]	11.1	31.9[C]	12.6	18.9
B: Stand History Variables				
# of Plots disturbed	2.5	1.3[B]	2.9	1.0[B]
# of Plots untapped	0.3	0.5	0.6	0.4
# of Plots on buckets	1.4	2.0	1.4	2.1
# of Plots on tubing	3.3	2.6	3.0	2.5
# of Plots on tubing with vacuum	0.4	0.4	0.6	0.0
% Tapped in 1985[5]	47.2	50.7	44.0	49.1
% Tapped above 1977 rates[6,7]	15.2	10.3	16.4	12.3
% Tapped at or above 1977 rates[6,7]	70.6	65.8	63.2	65.1
% of Sugarbushes where paraformaldehyde has been used	33.3	37.0	25.0	35.7
% of Sugarbushes which has been grazed	61.1	74.1	62.5	57.1
Grazing severity[8]	0.5	1.0	0.5	0.4
% of Sugarbushes where trees were cut for salvage	11.1	14.8	12.5	21.4

A,B,C T-test difference significant at p=.01, .05, and .10 respectively
a,b,c X^2 test difference significant at p=.01, .05, and .10 respectively

1 In unhealthy sugarbushes, <80% of the dominant-codominant sugar maples were rated healthy in 1985. In healthy sugarbushes ≥ 80% were healthy
2 In sugarbushes that declined, the % of dominant-codominant sugar maples rated healthy was significantly (p=.10) less in 1985 than in 1977. In sugarbushes that improved, the % healthy was significantly greater.
3 % of all Dominant-codominant sugar maples.
4 % of all Dominant-codominant trees, other than sugar maples
5 % of all Sugar maples
6 % of all Live dominant-codominant sugar maples
7 1977 Rates (DBH: # of tapholes): 10-14":1, 15-19":2, 20-24":3, 25+":4
8 0=none, 1=light, 2=moderate, 3=heavy

TABLE 3. Average value of variables for non-defoliated sugarbushes grouped.

	By Sugarbush Condition in 1985[1]		By Change in Condition Between 1977 and 1985[2]	
	Unhealthy (n=18)	Healthy (n=27)	Declined (n=8)	Improved (n=14)
C: Site Variables				
Elevation (ft)	1222	1133	1188	1314
Slope (deg.)	7.0	8.9	5.5	8.9
Aspect (deg. departure from due south)	29.8	-30.6	29.9	4.0
# Plots with outcrops	1.6	1.3	1.7	0.9
Depth to bedrock (in)	31.5	31.3	38.0	29.5
Depth to mottles or dense till (in)	44.1	54.7	41.9	52.5
% of Bushes with depth to bedrock or mottles >24"	33.3	63.0[b]	50.0	64.3
Departure from well-drained	2.7	2.1	2.7	2.5
Average soil water capacity (in/in)	.16	.15	.16	.16
% of Sugarbushes: west of Green Mountains	50.0	29.6	62.5	7.1[a]
D: Stand Composition Variables				
Sugar maples/acre	78.9	99.6	71.2	115.3[B]
Trees/acre	116.3	124.1	100.2	143.1[C]
% of Trees: sugar maple	71.2	81.3[C]	71.1	83.4[C]
Basal area: sugar maple (ft^2/acre)	88.8	96.8	98.6	100.3
Basal area: all species (ft^2/acre)	107.2	108.4	114.9	110.9
Mean stand diameter (in)	12.2	12.1	12.1	11.4
% of Sugar maple: dominant-codominant	78.9	73.9	77.6	75.4
% of Sugar maple: stumps	1.9	3.0	1.2	1.4
% of Sugar maple: stocked over the B-line[4]	66.7	77.8	50.0	92.9[b]
Crown closure[5]	1.2	1.3	1.5	1.6
# of Ground cover plots with sugar maple	12.8	14.1	11.2	15.4
# of Ground cover plots with advanced sugar maple	3.3	3.1	5.0	4.3
# of Ground cover plots with conifer[6]	1.1	0.4	0.7	0.3
# of Ground cover plots with fern[7]	7.2	4.8	9.6	4.3

A,B,C T-test difference significant at p=.01, .05, and .10 respectively
a,b,c X^2 test difference significant at p=.01, .05, and .10 respectively

1 In unhealthy sugarbushes, <80% of the dominant-codominant sugar maples were rated healthy in 1985. In healthy sugarbushes ≥ 80% were healthy

2 In sugarbushes that declined, the % of dominant-codominant sugar maples rated healthy was significantly (p=.10) less in 1985 than in 1977. In sugarbushes that improved, the % healthy was significantly greater.

3 1=well drained, 3=somewhat excessively or moderately well drained

4 Lancaster et al. 1974

5 0=open, 1=partially closed, 2=closed

6 Sub-plots with conifer regeneration, but no sugar maple

7 Sub-plots with fern, but no woody plants

TABLE 3. Average value of variables for non-defoliated sugarbushes grouped.

	By Sugarbush Condition in 1985[1]		By Change in Condition Between 1977 and 1985[2]	
	Unhealthy (n=18)	Healthy (n=27)	Declined (n=8)	Improved (n=14)
E: Soil Analysis Variables				
pH in water	4.9	5.3$^{B}_{B}$	4.9	5.2
pH in salt	4.0	4.5	4.0	4.3
% Organic matter	20.3	15.8^{B}	20.7	16.7
Cation exchange capacity	9.9	11.4$_{B}$	9.3	10.6$_{A}$
% Base saturation[4]	61.2	78.8	49.5	81.4
E4/E6[5]	7.9	8.2	7.5	7.6
Calcium (meq/100g)	5.9	8.7	4.7	8.2
Magnesium (meq/100g)	0.9	1.0	0.8	0.8
Potassium (meq/100g)	0.4	0.3$_{A}$	0.3	0.3$_{A}$
Aluminum (meq/100g)	2.8	1.4	3.6	1.3
Manganese (meq/100g)	0.3	0.4	0.3	0.4
Iron (meg/100g)	0.8	0.1	0.7	0.1
Calcium (lbs/acres)	2272	2659	2775	2364
Magnesium (lbs/acre)	194	236	190	204
Potassium (lbs/acre)	223	208	224	204$_{C}$
Aluminium (lbs/acre)	375	284	526	293
Manganese (lbs/acre)	118	149	112	139$_{B}$
Iron (lbs/acre)	190	122	277	113
Zinc (lbs/acre)	9.4	8.3	8.8	8.7
Phosphorus (lbs/acre)	11.0	9.2	9.7	9.1
Lead (ppm)	42.7	39.5	43.7	39.4
Cadmium (ppm)	1.1	1.0	1.1	1.0
Copper (ppm)	18.7	18.0	20.6	18.8$_{C}$
Nickel (ppm)	19.2	23.5	17.2	25.4$_{B}$
Chromium (ppm)	26.0	32.3^{C}	23.7	34.4

A,B,C T-test difference significant at p=.01, .05, and .10 respectively
a,b,c X^2 test difference significant at p=.01, .05, and .10 respectively

1 In unhealthy sugarbushes, <80% of the dominant-codominant sugar maples were rated healthy in 1985. In healthy sugarbushes ≥ 80% were healthy

2 In sugarbushes that declined, the % of dominant-codominant sugar maples rated healthy was significantly (p=.10) less in 1985 than in 1977. In sugarbushes that improved, the % healthy was significantly greater

3 Equal to millequivalents/100g of soil of (Ca + Mg + K + Al)

4 % of Cation exchange capacity occupied by CA, Mg and K

5 Ratio of the absorbance of NH4OAc extracts measured at 465 nm and 665 nm. Indicates organic matter and its state of decomposition.

TABLE 3. Average value of variables for non-defoliated sugarbushes grouped.

	By Sugarbush Condition in 1985[1]		By Change in Condition Between 1977 and 1985[2]	
	Unhealthy (n=18)	Healthy (n=27)	Declined (n=8)	Improved (n=14)
F: 1977 Stand Variables				
% Healthy[3]	77.3	78.4	85.5	62.0[A]
Mean annual increment 1967-1977(mm)	2.9	3.1	3.1	3.0
% with Poor taphole closure[4]	28.8	23.4	44.1	18.9[A]
Sugar maples/acre	55.5	62.0	58.0	71.5
Trees/acre	85.3	88.9	80.7	103.9
% of Trees: sugar maple	68.8	73.7	73.5	73.1
Basal area: sugar maple (ft^2/acre)	57.1	52.8	75.5	54.6
Basal area: all species (ft^2/acre)	65.5	63.0	83.7	66.1
Mean stand diameter (in)	10.3	10.9	12.0	10.0
% of Sugar maple: dominant-codominant[4]	61.9	62.8	65.6	64.8
% Overtapped[4,5]	20.7	21.4	23.5	16.1
% with Stem rot[4]	36.5	31.5	43.0	28.0[C]
% with Scorch[4]	14.9	10.8	20.2	18.9
% with Root collar rot[4]	24.5	24.3	35.6	21.1
% with Logging injury[4]	20.0	11.2	24.5	10.4[C]
% with Sugar maple borer[4]	28.0	24.4	34.6	24.6
% with Grazing injury[4]	12.5	24.5	17.3	17.7

A,B,C T-test difference significant at p=.01, .05, and .10 respectively
a,b,c X^2 test difference significant at p=.01, .05, and .10 respectively

1 In unhealthy sugarbushes, <80% of the dominant-codominant sugar maples were rated healthy in 1985. In healthy sugarbushes $\geq$ 80% were healthy

2 In sugarbushes that declined, the % of dominant-codominant sugar maples rated healthy was significantly (p=.10) less in 1985 than in 1977. In sugarbushes that improved, the % healthy was significantly greater

3 % of all Dominant-codominant sugar maples

4 % of all Sugar maples

5 1977 Rates (DBH: # of tapholes): 10-14":1, 15-19":2, 20-24":3, 25+":4

TABLE 4. Average stand composition and tree condition variables, comparing 1977 and 1985 values, by sugarbush sub-group.

Stand Composition or Tree Condition Variable	Sugarbush Sub-Sample Group					
	Non-Defoliated					
	Good-Excellent n=25		Fair-Poor n=20		Defoliated n=9	
	1977	1985	1977	1985	1977	1985
% Healthy [2]	84.8	84.0	69.4	77.7	76.3	74.9
Mean annual increment(mm) [3]	2.9	3.7^{C}	3.1	3.4	3.4	3.3
% with Poor taphole closure [4]	20.3	17.3	32.1	28.1	28.4	22.3
Sugar maples/acre	60.6	90.9^{A}	57.9	91.8^{A}	66.6	66.0
Trees/acre	84.7	118.8^{A}	90.9	123.6^{A}	104.7	95.1
% of Trees: sugar maple	76.5	79.8	65.8	74.2^{C}	69.5	70.7
Basal area: sugar maple(ft^2/acre)	55.5	98.1^{A}	53.4	87.9^{A}	50.7	77.7^{A}
Basal area: all species (ft^2/acre)	65.8	112.5^{A}	61.7	102.2^{C}	58.9	93.7^{A}
% Dominant-codominant [4]	59.3	75.9^{A}	66.4	75.9^{B}	60.3	83.1^{A}
Mean stand diameter (in)	10.8	12.4^{B}	10.4	11.7	9.4	12.4^{B}
% with Stem rot [4]	31.7	37.2	35.7	46.7	45.0	21.0^{A}
% with Scorch [4]	11.9	2.3^{C}	13.1	3.0^{A}	12.8	4.4^{C}
% with Root collar rot [4]	18.9	4.5^{A}	31.1	9.0^{A}	30.7	4.7^{A}
% with Logging injury [4]	13.9	5.0	15.7	5.1^{B}	34.3	11.1^{A}
% with Sugar maple borer [4]	20.6	19.8	32.4	20.1^{B}	42.9	21.9^{B}
% with Grazing injury [4]	18.1	32.3	21.7	10.3	6.6	29.7
% Tapped above 1977 rates [4,5]	16.9	13.8	26.4	18.2^{B}	25.0	6.5

A,B,C T-test difference significant at p=.01, .05, and .10 respectively

1 Rated good or excellent in 1977, and not defoliated between 1977 and 1985; Rated fair or poor in 1977 and not defoliated; Defoliated at least once between 1977 and 1985

2 % of all Dominant-codominant sugar maples

3 For 1977, average of last 10 years; for 1985, average of last 5 years

4 % of all Sugar maples

5 1977 Rates (DBH: # of tapholes) 10-14":1, 15-19":2, 20-24":3, 25+":4

Table 5. Average values of 1977 and 1985 stand composition variables, and change in values between 1977 and 1985, for sugarbushes that were rated good-excellent in 1977; comparing 25 that were not defoliated between 1977 and 1985 to 7 that were defoliated at least once.

Stand Variable	Average Values for 1977 Good-Excellent Sugarbushes					
	1977		1985		Change Between 1977-1985	
	Non-defoliated Bushes	Defoliated Bushes	Non-Defoliated Bushes	Defoliated Bushes	Non-Defoliated Bushes	Defoliated Bushes
% Healthy[1]	84.8	88.0	84.1	73.7[C]	- 0.7	-14.5
Mean annual increment (mm)[2]	2.9	3.7	3.7	3.5	0.7	- 0.2[B]
Sugar maples/acre	60.7	74.0	90.9	68.9	30.2	- 5.1[A]
Trees/acre	84.7	115.3	118.8	97.4	34.2	-17.9
% of Trees: sugar maple	76.5	72.4	79.8	72.3	3.3	- 0.1
Basal area: sugar maple (ft^2/acre)	55.5	54.4	98.1	77.3[C]	42.6	22.8
Basal area: all species (ft^2/acre)	65.8	60.6	112.5	90.7[C]	46.6	30.1
Mean stand diameter (in)	10.8	9.2	12.4	12.1	1.6	2.9
% Dominant-codominant[3]	59.3	60.1	75.9	84.3	16.6	24.1

A,B,C T-test difference significant at p=.01, 0.05 and .10, respectively.

1 % of all Dominant-codominant sugar maples
2 For 1977, average of last 10 years; for 1985, average of last 5 years
3 % of all Sugar maples

TABLE 6. Average values of tree condition and stand composition variables for non-defoliated sugarbushes, comparing 20 where no plots were disturbed by logging activities to 25 where one or more plots had been disturbed.[1]

Tree Condition or Stand Composition Variable	Average Values for Sugarbushes With No Disturbance	Disturbance
% Healthy[2]	87.2	74.4[B]
Change in % healthy between 1977 and 1985[2]	11.6	-3.4[B]
Mean annual increment 1980-1985 (in)	3.5	3.6
% with Stem rot[3]	63.8	24.9[A]
% with Scorch[3]	1.2	4.1
% with Logging injury[4]	5.0	5.1
Depth to bedrock (in)	23.6	37.6[A]
Depth to mottles (in)	47.6	52.7
Soil drainage[5]	5.7	5.3
Sugar maples/acre	97.8	86.1
Trees/acre	119.8	122.2
% of Trees: Sugar maple	84.3	71.7[A]
Basal area: Sugar maple (ft^2/acre)	102.0	86.8[C]
Basal area: All species (ft^2/acre)	113.2	103.7
Mean stand diameter (in)	13.0	11.4[C]
% Dominant-codominant[4]	74.7	76.9
% of Sugar maple: stumps[4]	1.9	3.1
% of Sugarbushes: stocked over the B-line	1.9	2.2
# of Ground cover plots with sugar maple	16.5	11.2[B]
# of Ground cover plots with advanced sugar maple	5.0	1.8[C]
# of Ground cover plots with conifer[6]	0.2	1.1[C]
# of Ground cover plots with fern[7]	3.3	7.8[B]
% Healthy 1977[2]	75.6	79.8
Sugar maples/acre 1977	60.6	58.5
Trees/acre 1977	83.4	90.7
% of Trees: Sugar maple 1977	77.5	67.1[C]
Basal area: Sugar maple 1977 (ft^2/acre)	56.9	52.7
Basal area: All species 1977 (ft^2/acre)	63.6	64.3
Mean stand diameter 1977 (in)	10.5	10.4
% of Dominant-codominant 1977[4]	62.8	62.2
% with Stem rot 1977[4]	33.0	33.9
% with Logging injury 1977[4]	9.5	18.9[B]

A,B,C T-test difference significant at p=.01, .05 and .10 respectively

1 Data from 1985 unless specified
2 % of all Dominant-codominant sugar maples
3 % of Live dominant-codominant sugar maples
4 % of All sugar maples
5 1=excessive 3=somewhat excessive 5=well 7=moderately well 9=somewhat poor 11=poor
6 Sub-plots with conifer regeneration, but no sugar maple
7 Sub-plots with fern, but no woody plants

TABLE 7. Average values of tapping severity and sugar maple health variables for non-defoliated sugarbushes rated good-excellent in 1977, comparing 7 with over half the plots on buckets to 14 with over half the plots on tubing.[1]

Health or Tapping Severity Variable [2,3]	Average Values of Sugarbushes With: >1/2 Buckets	>1/2 Tubing
% Tapped above 1977 rates	7.4	11.6
% Tapped at or above 1977 rates	79.9	71.5
% Healthy	87.9	81.4
% Tapped above 1977 rates that were healthy [4]	96.3	93.8
% Tapped at or above 1977 rates that were healthy [5]	89.8	85.8

1 No T-test differences are significant
2 All variables % of Dominant-codominant sugar maples
3 1977 Rates (DBH: # of tapholes) 10-14":1, 15-19":2, 20-24":3, 25+":4
4 For 5 sugarbushes on buckets and 9 on tubing with tapping above 1977 rates
5 For 7 sugarbushes on buckets and 13 on tubing with tapping at or above 1977 rates

TABLE 8. Percent of dominant-codominant sugar maples by % crown dieback, for sugarbush sub-sample groups and weighted state average.

Crown Dieback	Sugarbush Sub-Sample Group[1]			Weighted State Average for Non-Defoliated Bushes[2]
	Good-Excellent (n=25)	Fair-Poor (n=20)	Defoliated (n=9)	
0%	41.9	38.9	45.7	41.5
>0-10%[3]	42.2	38.9	29.4	41.8
10-25%[3]	7.2	7.0	8.9	7.2
25-50%	4.7	9.8	8.5	5.3
50-75%	1.7	3.0	4.5	1.9
75-<100%	0.6	1.1	1.5	0.7
100%	1.7	1.3	1.5	1.7

1 Rated good or excellent in 1977 and not defoliated between 1977 and 1985; Rated fair or poor in 1977 and not defoliated; Defoliated at least once between 1977 and 1985

2 State average for non-defoliated bushes calculated as: (0.88 X % for good-excellent bushes) + (0.12 X % for fair-poor bushes)

3 Calculated from field ratings