Recovery of Hemlock in Vermont from Defoliation by the Spring Hemlock Looper, Lambdina athasaria (Walker)

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Abstract

Following an outbreak of spring hemlock looper in 1991, ten hemlocks in each of fifteen study plots were monitored annually through 1999. Although some mortality occurred within two years after defoliation, and additional mortality occurred in plots which were subsequently disturbed by logging, most defoliated trees recovered. Twenty-four percent of the trees with 90% defoliation and 43% with 100% defoliation were dead by 1999. Trunk and root collar wounds were more common on dead or unhealthy trees. Overall, tree crown condition improved. In the spring of 1993, only 14% of trees in heavily defoliated plots were in good condition. Six years later, 73% were rated as good. Trees with dead tops usually recovered, maintaining wildlife cover and other values, but the defect may affect timber quality. Three categories of risk are suggested by this study: <50% defoliation (mortality not expected), 50-80% (light risk of mortality), and 90-100% (moderate risk of mortality). Stand assessment two years after defoliation by spring hemlock looper provides an accurate picture of expected mortality, as long as no additional disturbance occurs.

Introduction

In 1991, populations of spring hemlock looper, *Lambdina athasaria* (Walker), increased suddenly in scattered New England locations. Hemlocks were defoliated on about 18,000 acres in five states (Hofacker et al., 1992).

The impact of spring hemlock looper defoliation on hemlocks was not known. Hemlock is vulnerable to exposure (Hepting, 1971) and to defoliation. In Connecticut, 45% of the trees with 90% defoliation by gypsy moth, and 94% with 100% defoliation, subsequently died (Stephens, 1988).

Management recommendations were developed based on the impact of gypsy moth defoliation on hemlock, and early observations of the current fall hemlock looper, *Lambdina fiscellaria* (Guenée), and spring hemlock looper outbreaks (Burns and DeGeus, 1992). Trees were considered likely to die if they had lost all of their older needles and had over 80% defoliation of current-year needles. Trees with no older needles and 50-75% defoliation of current-year needles were also considered at risk.

Plots were established in Maine, New Hampshire, Massachusetts, and Vermont to monitor the impact of spring and fall hemlock looper over a two-year period. In Maine, high levels of hemlock mortality from fall hemlock looper were associated with shallow, ledgy soils (Trial and Devine, 1994).

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By the end of the regional study, four percent of the trees which had been defoliated by spring hemlock looper were dead (Trial and Devine, 1995). Among surviving, but unhealthy, trees, many were showing signs of recovery. In Vermont, the percent of hemlocks with bare tops decreased from 42% in 1992 to 26% in 1993. Because the fate of defoliated trees was still uncertain, the Vermont plots were monitored annually through spring 1999.

Methods

Monitoring plots were established for this study in fifteen hemlock stands: seven had been heavily defoliated by the spring hemlock looper in 1991, six had been moderately defoliated, and two had received only light or no defoliation. In each stand, ten hemlocks were selected along a transect at thirty foot intervals. All plot trees were evaluated annually, in the spring, between 1992 and 1999.

In 1992 only, each tree was given two defoliation ratings to the nearest 5% class: defoliation of the current year's needles and of previous years' needles. In all years, each tree was rated for transparency using National Forest Health Monitoring standards (Gillespie et al. 1993). Trees were also evaluated as alive or dead and by whether or not a bare top was visible. Bare tops included a range of severities, from trees with little more than a dead leader, to trees with death to the mainstem extending down twenty feet or more from the top. Crown condition, the observers' estimate of the chance that the tree would recover, was rated as good, fair, poor, or very poor. Any wounds present on the trunk or root collar, including damage by hemlock borer, were noted. In 1992 and 1999, diameter at breast height was measured to the nearest 0.1 inch.

Results

In spring 1992, defoliation averaged 77% in heavily defoliated plots, 61% in moderately defoliated plots, and 21% in lightly defoliated plots. Transparency averaged 72%, 47%, and 33%, respectively.

In 1993, 1-1/2 years after defoliation, only 14% of the trees were rated as being in good condition in the heavily defoliated plots and 17% of the trees were rated as good in the moderately defoliated plots (Figure 1).

By 1999, most trees had recovered. At that time 73% were rated as good in both heavily and moderately defoliated plots. Transparency had recovered to 24%, 32%, and 24%, respectively, in the heavily, moderately, and lightly defoliated plots.

Seven of the seventy trees in heavily defoliated plots and five of the sixty in moderately defoliated plots were dead by 1999. Trees that died over the course of the study averaged

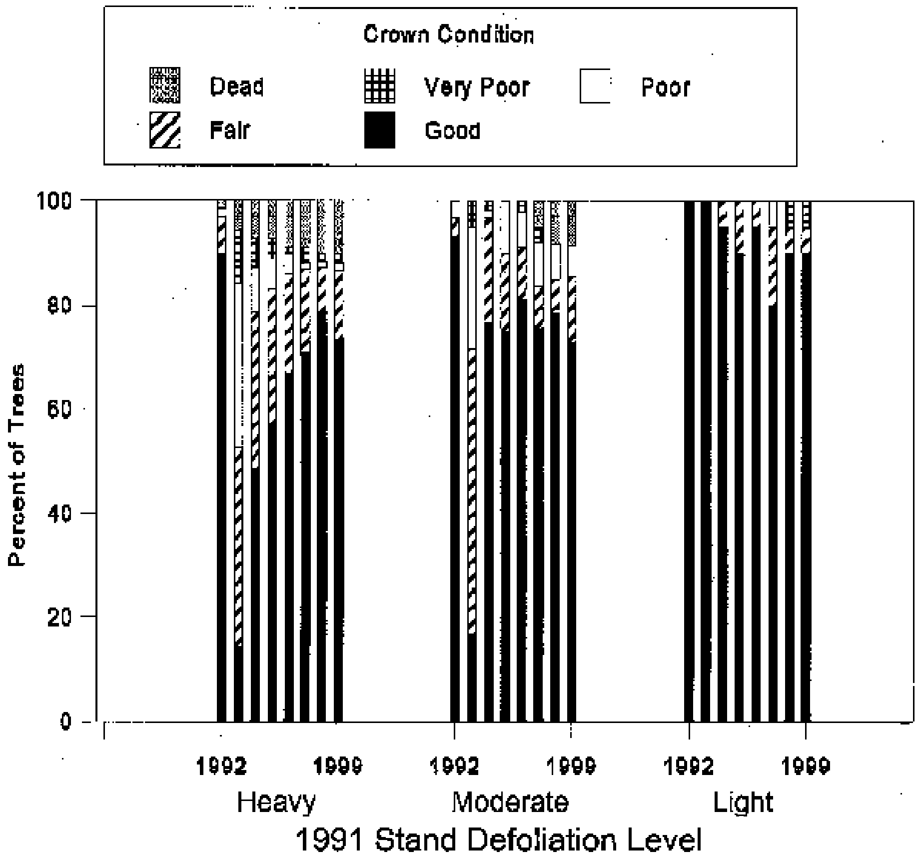

Figure 1.—Annual rating of hemlock condition as percent of trees in each of five crown condition classes, evaluated in spring 1992-1999. Results are grouped by the general severity of the 1991 defoliation by spring hemlock looper defoliation in the stand. Data are from ten trees in each of seven stands which had heavy defoliation, six which had moderate defoliation, and two which had no defoliation.

Table 1.—Percent of hemlocks which were dead eight years after defoliation by spring hemlock looper, by defoliation severity class. Data are from ten trees in each of fifteen plots.

	Severity of 1991 Defoliation[1]									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Average 1992 % Defoliation	<15	16-25	26-35	36-45	46-55	56-65	66-75	76-85	86-95	>95
Percent Dead[2]	0%	0%	0%	0%	8%	0%	7%	4%	24%	43%
Number of Trees in Class	9	8	9	12	13	17	29	25	21	7

[1]Tree defoliation class based on the average of two estimates of defoliation, defoliation of 1991 needles and defoliation of previous years' needles, as rated in spring 1992.

[2]Cumulative mortality through 1999.

86% defoliation in 1992. Trees which survived averaged 62%. Mortality occurred to 43% of the trees with 96-100% defoliation and 24% of the trees with 86-95% defoliation (Table 1).

Although the mortality rate was similar between heavily and moderately defoliated plots, the progression of mortality was quite different. In the heavily defoliated plots, all of the trees that died were already in very poor condition or dead by 1993. In the moderately defoliated plots, no trees died until 1997, and all trees that had been in very poor condition in 1993 had improved by 1995. However, two of the moderately defoliated plots were logged in 1996. Mortality subsequently occurred in these plots.

Based on the management recommendations made during the outbreak, twenty-one of the plot trees would have been predicted to be "likely to die", because they had complete defoliation of older needles and over 80% defoliation of current needles. Of these, eight had died by 1999, and thirteen were still alive. By contrast, four of the 129 trees which were not considered "likely to die" also died. All four

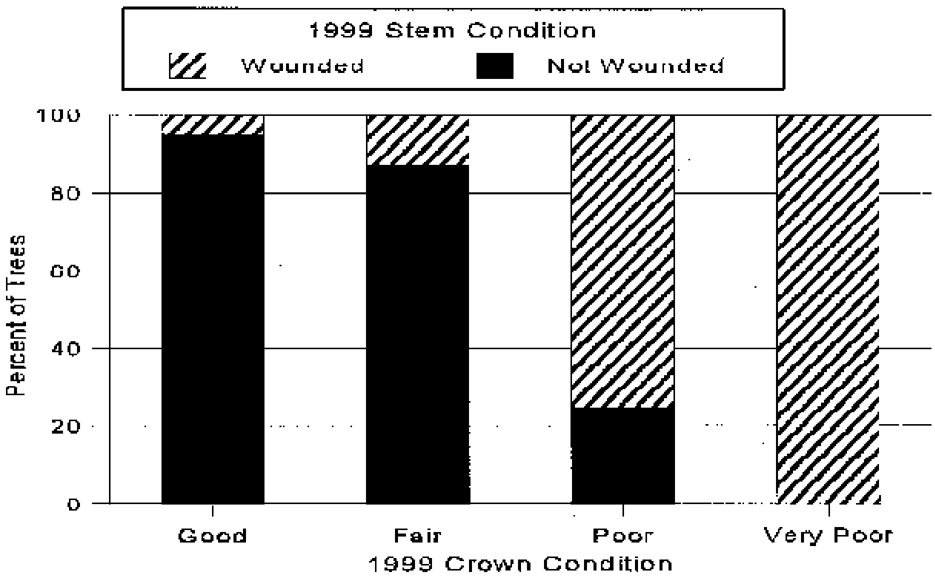

Figure 2.—Percent of hemlocks, in 1999, with and without wounds to the stem or root collar, by crown condition. Data are from fifteen spring hemlock looper impact monitoring plots, with 113 trees in good condition, 18 in fair condition, 5 in poor condition, and 2 in very poor condition.

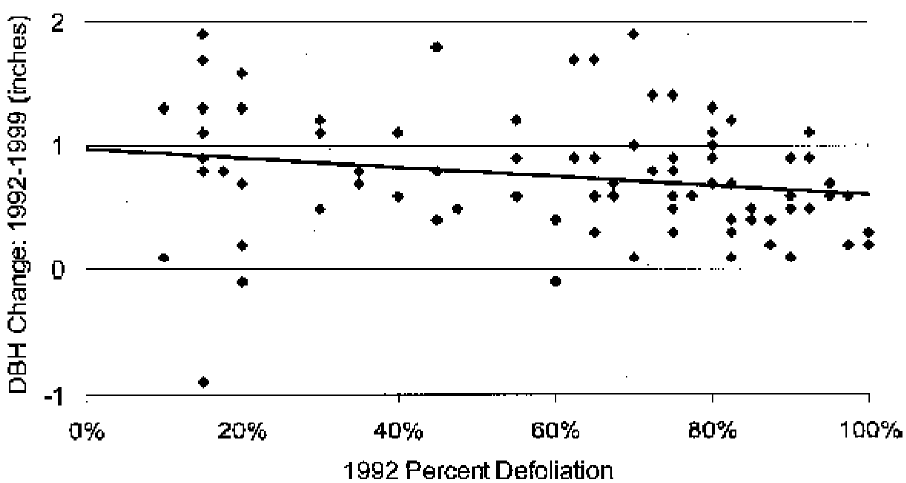

Figure 3.—Change in diameter at breast height between 1992 and 1999, by severity of hemlock looper defoliation in 1991, as measured in spring 1992. Data are from 138 surviving hemlocks in fifteen monitoring plots.

had large root or stem injuries sustained before or during the study.

The presence of stem or basal wounding was related to crown condition in all plots, including those with light defoliation. Only four of the ten trees which had wounds in 1999 were rated in good condition. Four of the five trees rated as poor or very poor had wounds (Figure 2). Exit holes from hemlock borer were not observed on plot trees.

The most severe symptom on surviving trees was a bare top. In 1992, 61% of the trees in heavily defoliated plots and 30% of the trees in moderately defoliated plots had bare tops. Trees with bare tops averaged 80% defoliation, compared to 52% defoliation of trees whose tops were still alive. Of the sixty trees which had bare tops in 1992, nine died over the next seven years. Among the 51 survivors, however, bare tops were no longer visible on 37 (73%) of them by 1999.

Between 1992 and 1999, heavily defoliated trees generally grew less in diameter than lightly defoliated trees (Figure 3), but the relationship was not significant. Diameter growth averaged 0.91" in lightly defoliated plots, 0.75" in moderately defoliated plots, and 0.73" in heavily defoliated plots.

Discussion

Most trees survived spring hemlock looper defoliation. Even trees with severe defoliation were more likely to survive than trees with a similar level of defoliation by gypsy moth. Spring hemlock looper may cause less mortality because its damage occurs late in the growing season, when most carbohydrate production has already taken place. Gypsy moth defoliation peaks in early summer.

Mortality generally occurred within two years of defoliation. Because mortality occurs rapidly, stand assessment two years after defoliation can provide an accurate picture of expected mortality, as long as no additional disturbance occurs. However, partial cutting to salvage dead and dying trees at this time may result in further mortality. Stress from defoliation, hemlock's vulnerability to post-logging decadence, and, possibly, shoestring root rot, may each contribute to these additional losses.

In most of the plots, any role of "secondary" organisms appears to be, in fact, secondary. If shoestring root rot had played an important role, mortality would be expected to build up over several years as the fungus increased within infection centers. This may yet happen in plots which were subsequently logged. Hemlock borer activity was not observed. However, in stands where this insect is active, higher rates of mortality would be expected.

Wounds affected recovery. Wounds existing prior to defoliation or wounds created afterwards were more common on unhealthy trees. Unwounded trees were more likely to survive. Since wounding and exposure often happen simultaneously, for instance during logging, the association between wounds and health may be caused by the wound itself or by the impact of exposure.

The importance of site factors were not specifically evaluated. Nonetheless, these results reinforce previous observations that hemlocks on shallow, drought-prone sites are at greater risk. The shallow roots on these sites would be more vulnerable to wounding and to disturbance, both of which were linked to mortality.

The risk rating system used in 1992 overestimated mortality, but the categories of risk were consistent with observations from this study. Over 60% of the trees considered "likely to die" survived. However, mortality among trees in this category was more common than mortality among other trees. All of the trees which died had at least 50% defoliation, and so were considered "at risk" according to the 1992 system. Three categories of risk are suggested by these results: <50% defoliation (mortality not expected), 50-80% (light risk of mortality), and 90-100% (moderate risk of mortality).

Many surviving trees had dead tops, although new leaders developed over time. Stands with dead tops had healthy, dense foliage eight years after defoliation occurred. In areas where hemlock retention is the goal, dead tops should have little impact on wildlife cover or other values. Where timber production is important, however, dead tops can lead to ring shake or decay, leading to loss of volume. Plans to salvage trees with dead tops should be tempered by concern for the additional impact of disturbance on residual trees.

Diameter growth of heavily defoliated trees was insignificantly slower than lightly defoliated trees. Even defoliated trees grew in diameter over the seven years of the study. However, there was considerable variability in growth, and many trees were growing slowly. More precise diameter measurements or analysis of wood increment growth may have revealed a more important relationship. As crowns continue to recover, the rate of diameter growth should be expected to recover as well.

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