THE NORTHEASTERN

ICE STORM 1998

A Forest Damage Assessment for New York, Vermont, New Hampshire, and Maine

The Northeastern Ice Storm 1998: A Forest Damage Assessment

Prepared by
Margaret Miller-Weeks
USDA Forest Service, Northeastern Area State and Private Forestry
and
Chris Eagar
USDA Forest Service, Northeastern Research Station

in cooperation with
Christina M. Petersen
North East State Foresters Association (NEFA)

Contributors:
Robert Smith, *USDA Forest Service, Northeastern Research Station*
Chuck Barnett, *USDA Forest Service Northeastern Research Station, Forest Health Monitoring Program*
Pierre DesRochers, *Natural Resources Canada, Canadian Forest Service*
Lewis Staats, *Sugar Maple Field Station, Cornell University*
Ron Kelley, *Vermont Department of Forests, Parks, and Recreation*
David Alerich and Jason Morrison
USDA Forest Service, Northeastern Research Station, Forest Inventory and Analysis
William Frament, Tom Luther, and Robert Cooke
USDA Forest Service, Northeastern Area State and Private Forestry

Special thanks to state members of the Ice Storm Assessment Team for cooperating in the planning, implementing, and reporting of the damage assessment:

Henry Trial and Dave Struble
Maine Forest Service

Jennifer Bofinger and Kyle Lombard
New Hampshire Division of Forests and Lands

Brent Teillon, Ron Kelley, Barbara Burns, Sandy Wilmot, and Jay Lackey
Vermont Department of Forests, Parks and Recreation

Mike Birmingham and Jenna Spear O'Mara
New York Department of Environmental Conservation

Editor: Helen Thompson, *USDA Forest Service*
Design: Baker Salmon Design, *Peterborough, NH*
Data Entry: Karen Davies and Sherry Legare, *USDA Forest Service*

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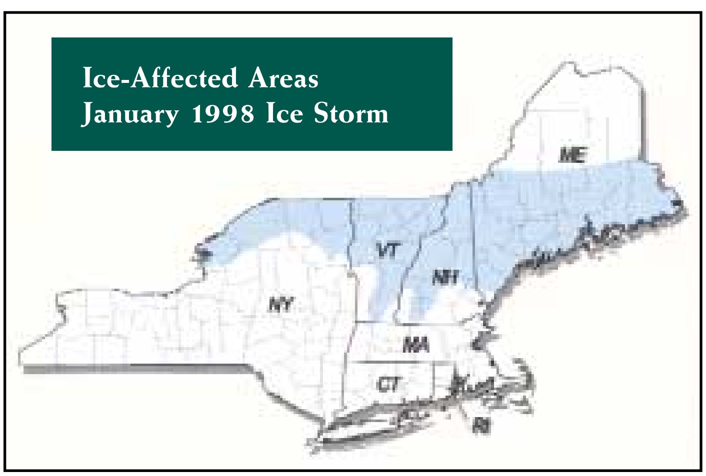
Highlights

■ **The ice storm of January 1998** affected 17 million acres of forestland in northern New York, Vermont, New Hampshire, and Maine, including parts of the Green Mountain National Forest and the White Mountain National Forest. Portions of eastern Canada were also impacted. The weight of accumulated ice caused trees to snap off or bend over to the ground. Large branches broke within crowns and debris littered the landscape.

New York	**4.6 million acres**
Vermont	**951,000 acres**
New Hampshire	**1,055,000 acres**
Maine	**11 million acres**

■ **Aerial surveys** conducted following the ice storm provided information on the location, pattern, and level of the damage, which was used to create state and regional maps. The maps helped in planning ground surveys to assess the severity of the damage and to characterize the type of damage to rural forests. The damage assessment was conducted by state and Federal forestry agencies during the spring and summer of 1998. Regional survey temporary plots, along with Forest Inventory and Analysis, Forest Health Monitoring, North American Maple Project, and Vermont Hardwood Health Survey permanent plots, were included in the assessment. All plots were located within the "footprint" of the storm, as defined by the aerial surveys.



■ **The impact to forests** varied greatly, both within forest stands and throughout the four-state affected area. Topography, forest composition, and meteorological conditions influenced the amount of damage. Locally, different degrees of damage occurred in a mosaic pattern, with patches of intense damage imbedded within larger less damaged areas. Individual landowners with a high-quality timber stand or high-yielding sugarbush that suffered an average crown loss of 50 percent or more incurred significant losses.

■ **Damaged beech, maple, and birch**, which are major components of northern hardwood stands, were frequently encountered within the ice storm impacted areas. American beech was the most uniformly impacted tree, most likely due to the incidence of beech bark disease, which weakens the wood structure. Hardwoods with fairly soft, brittle wood, including aspen, ash, basswood, and black cherry, also received higher than average damage. Softwoods had considerably less damage than hardwoods.

■ **The influence of ice damage** on mortality and growth may be important. Between one-fifth and one-fourth of the over 22,000 trees sampled have

Percent of trees sampled with diameter ≥ 5″ in each crown loss category

Crown loss	New York	Vermont	New Hampshire	Maine	Region
No damage (0%)	44.7	59.5	49.5	54.2	51.0
Light/moderate (1–49%)	28.4	24.5	27.2	28.8	27.7
Heavy (50–79%)	11.4	7.6	9.3	8.4	9.5
Severe (80–100%)	15.5	8.4	13.5	8.6	11.8

been seriously damaged or killed. Another one-third received light/moderate damage. The average crown loss due to branch breakage was 22 percent across the four-state affected area, ranging from no damage to 100 percent crown loss.

■ **Larger trees** were more likely to incur some ice storm damage. About 60 percent of the trees with a diameter greater than 10 inches were damaged by the ice storm. Understory saplings received considerably less damage than overstory trees.

■ **About 30 percent** of surveyed plots were in the high or moderate fire hazard categories. Fire hazard increased with amount of crown damage. Impacts from debris on forest access continue to be a concern.

■ **Data taken in plots** maintained by the North American Maple Project indicate that damage was more severe in nonsugarbush sugar maple stands than sugarbushes. Lower elevation sugarbushes with larger but fewer sugar maple stems were more resistent to the storm.

■ **Damage to sugarbushes** was especially severe in northern New York. On average, about 26 percent of sugar maple within the damaged sugarbushes that were sampled in the state were severely damaged and most likely will not survive.

■ **Aerial photography and satellite imagery** provided images of the storm that are now available for use. Images from color infrared digital cameras are being evaluated for detection and mapping of ice storms and other natural disasters.

■ **The 1998 field assessment** was not designed to determine the loss of timber volume or impacts on wood quality. Ongoing Forest Inventory and Analysis and Forest Health Monitoring surveys can provide information on the future status and condition of forest resources within the ice storm affected area.

■ **Monitoring projects** are underway to determine effects of damage on wood quality, wildlife habitats, plant communities, forest insects, aquatic habitats, sugarbushes, urban trees, and more.

Introduction

The ice storm of January 1998 affected 17 million acres of forestland in northern New York, Vermont, New Hampshire, and Maine, including parts of the Green Mountain National Forest and the White Mountain National Forest. Portions of eastern Canada were also impacted, especially Quebec. The weight of accumulated ice caused trees to snap off or bend over to the ground. Large branches broke within crowns and debris littered the landscape. Meteorologists have called the ice storm a 100-year event, and many compare it to the hurricane of 1938 with respect to damage to the region's forests.

The meteorological characteristics of the storm, topography of the landscape, and localized forest composition and structure caused damage that was highly variable within forests. An Ice Storm Assessment Team was formed in early February 1998 to assess the severity of damage. State forestry agencies in New York, Vermont, New Hampshire, and Maine; the USDA Forest Service's Northeastern Area for State and Private Forestry and Northeastern Research Station; and the Canadian Forest Service cooperated to collect information. A Federal Emergency Appropriation was signed in May 1998 to fund damage assessment and recovery from the ice storm.

The studies presented in this report characterize the type of damage observed in rural forests within the storm footprint, defined by the aerial surveys. Several data sets are examined, including a regional damage survey and information from Forest Inventory and Analysis permanent plots in New York, Vermont, New Hampshire, and Maine. Results are also presented from visits to permanent plots that are part of forest monitoring projects established over the last 15 years, including Forest Health Monitoring, the North American Maple Project, and the Vermont Hardwood Health Survey. Compared to the regional and FIA surveys the number of trees that were observed in these monitoring networks was small, due to the limited number of plots within the ice storm impacted area.


USDA Forest Service

Severe crown damage in hardwood trees in New Hampshire

This assessment was not designed to provide an estimate of the loss of timber volume or reduction of wood quality.

An update on remote sensing activities related to the ice storm is included in the report. Numerous research projects that have been initiated or proposed in each of the affected states are summarized. Information offered in the appendices includes USDA Forest Service Ice Storm Fact Sheets covering recommendations for managing ice damaged forests and a list of contacts and web sites for additional information.

Meterological Details of the Ice Storm

The National Weather Service in Gray, Maine, reported that intermittent freezing rain developed over northern New York and New England on January 5, 1998. The freezing rain and drizzle became steadier on January 7 and continued through January 9. The overall weather pattern of the ice storm was caused by a low pressure system that developed in the Gulf of Mexico. The low pressure had moved northward to the Great Lakes area and then into Quebec by the morning of January 10. During this period, several weak areas of low pressure moved along the quasi-stationary front as southerly winds at mid-levels in the atmosphere brought warm moist air from the southeastern United States into the Northeast and Canada. The combination of these weak low pressure areas, abundant moisture in the atmosphere, and cold temperatures near the ground caused significant rainfall and severe icing in parts of northern New York, New England, and Quebec. Ice accretions between ⅛ and ¼ inch were reported, with as much as ½ inch to 3 inches in several isolated areas. Heavy sleet also fell in many areas, with up to 10 inches of sleet reported in central Maine. More than 2 feet of snow accumulated in northern Maine.

Intermittent freezing rain, freezing drizzle, rain, drizzle, and snow persisted during the 5-day period before skies cleared. On January 11 a drier cold front moved in. Another low moved through the area on January 12 followed by strong and gusty west to northwest winds. Maximum wind gusts were generally between 30 and 40 mph, but higher gusts were reported. These winds caused additional damage to the trees that were still laden with ice. Warmer temperatures and low pressure followed the cold front, bringing more precipitation in the form of snow to coastal and interior areas. Weather remained generally unsettled until January 23 when sleet developed, then changed to freezing rain. The mixture of precipitation continued into January 24, causing significant icing along coastal areas in New Hampshire and Maine.

Damage Assessment Surveys

Aerial surveys were conducted over forests in New York, Vermont, New Hampshire, and Maine immediately after the ice storm. Maps produced from the aerial surveys (pages 6 and 7) provided general information on the location, pattern, and estimated level of the damage. The damage maps were used to select areas to use for ground damage assessment surveys. Information was collected from forest plots, using standard measurements. Damage assessment began in the spring of 1998 and continued throughout the summer. Several components were incorporated, including:

- A regional damage survey
- Forest Inventory and Analysis sites
- Forest Health Monitoring sites
- North American Maple Project sites and additional sugarbush surveys
- Vermont Hardwood Health Survey sites.

Regional Damage Survey and Forest Inventory and Analysis Sites

The objective of the regional survey was to characterize the degree of damage to the forest resource by species and size class within the four-state affected area. The damage areas were classified as light/moderate, heavy, and severe, estimated by the amount of tree breakage observed from the air. Seventeen damage areas were sampled on the ground in New York, 23 in Vermont, 25 in New Hampshire, and 46 in Maine. Areas were selected to represent a range of topographic and forest type conditions. In Maine, study sites were specifically selected in proportion to damage class severity.

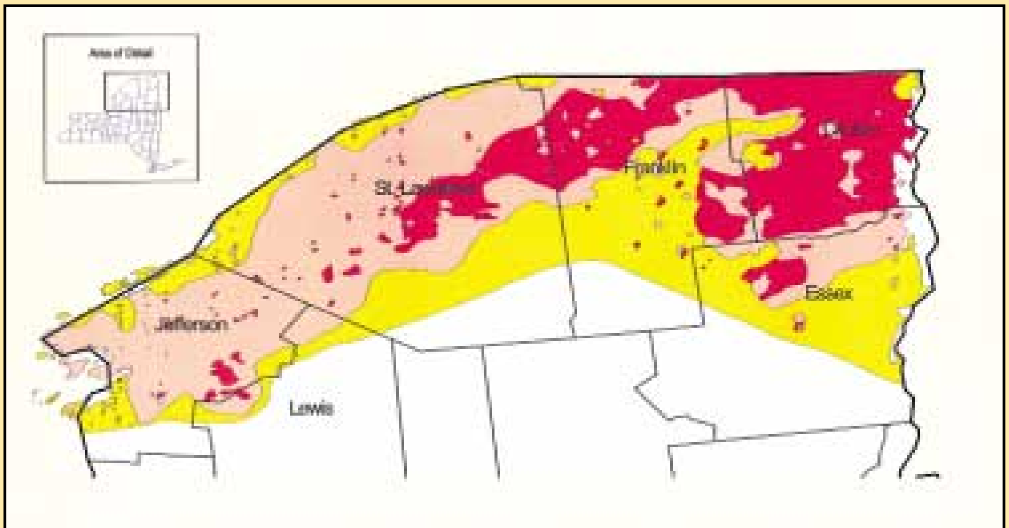
Depending on the size of the area, between 10 and 15 fixed radius plots, 1⁄24 acre each, were sampled in a transect across each selected damage area. Due to the amount of debris on the ground, areas with reasonable road or trail access were used to facilitate the work of state and USDA Forest Service ground crews. The plots were located randomly at least 100 to 200 feet off the access road or trail, but were not established as permanent sample sites. The plot size was the same as used in Forest Health Monitoring (FHM) and recently adopted by Forest Inventory and Analysis (FIA).

FIA has an extensive network of permanent plots throughout the United States. The data from these sites provide periodic information about the forest resource in individual states. The most recent FIA surveys were completed in New York in 1993, in Maine in 1995, and in New Hampshire and Vermont in 1997. Future inventories will be conducted on an annual basis. To obtain additional information on the impact from the ice storm, FIA plots that were within the ice storm damage areas were revisited. Throughout the area affected by the ice storm, 787 FIA plots were revisited, including 461 in New York, 118 in Vermont, 78 in New Hampshire, and 130 in Maine. This resurvey was carried out by the USDA Forest Service Northeastern Research Station FIA group and the Maine Forest Service. The plots in New Hampshire and Vermont were clusters of four 1⁄24-acre fixed radius plots. In New York, and Maine the 1⁄5-acre FIA plots were visited. The full plots were measured in New York, and the inner 1⁄10-acre portion of the 1⁄5-acre plots were measured in Maine.

All trees greater than 5 inches in diameter within the plots were tallied. To assess damage to the smaller sapling size trees, a 6.8-foot radius microplot was nested within the larger plot. The center of the microplot was offset 12 feet east of plot center.

Information related to site, tree damage, and fire hazard was collected within each of the plots, including:

- **sample site** — location, elevation, aspect, and forest type
- **fire hazard** — estimated within a 60-foot radius of plot center, including fuel load (high, medium, low, or none) and fuel type (based on percent of hardwood and softwood slash)
- **tree species**
- **diameter breast height (d.b.h.)**
- **crown position** — open grown, dominant, codominant, intermediate, or overtopped
- **bent or leaning** (greater than 45 degrees, greater than 45 degrees with crown touching ground, or uprooted)
- **percent crown damage** — amount of crown broken or removed due to ice damage, in 10 percent classes, from zero with no ice breakage to 100 percent where the entire crown was gone (branches that were broken but still attached were included; older, previously broken branches or dieback were not)
- **bole condition** — bole broken below the crown or severely split below the crown
- **general tree condition** — previous damage agent (for example, beech bark disease)
- **tree height** — estimate of total height.



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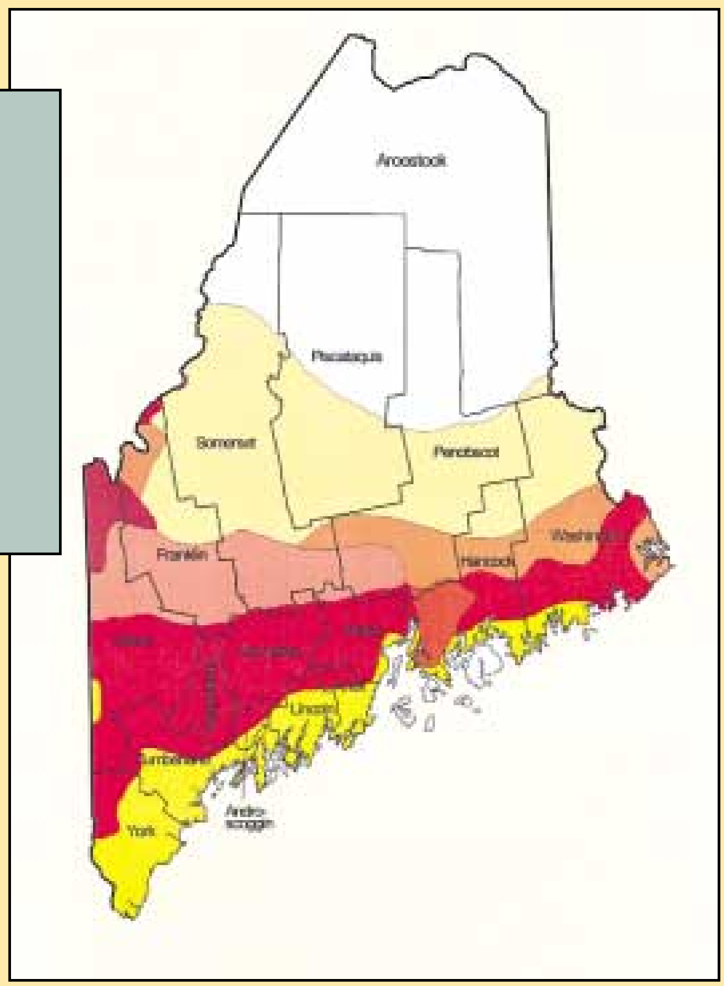
Ice-Damaged Areas in New York

Mapped area: 4.6 million acres

LEGEND

Ice Damage

- Heavy
- Moderate
- Light



USDA Forest Service

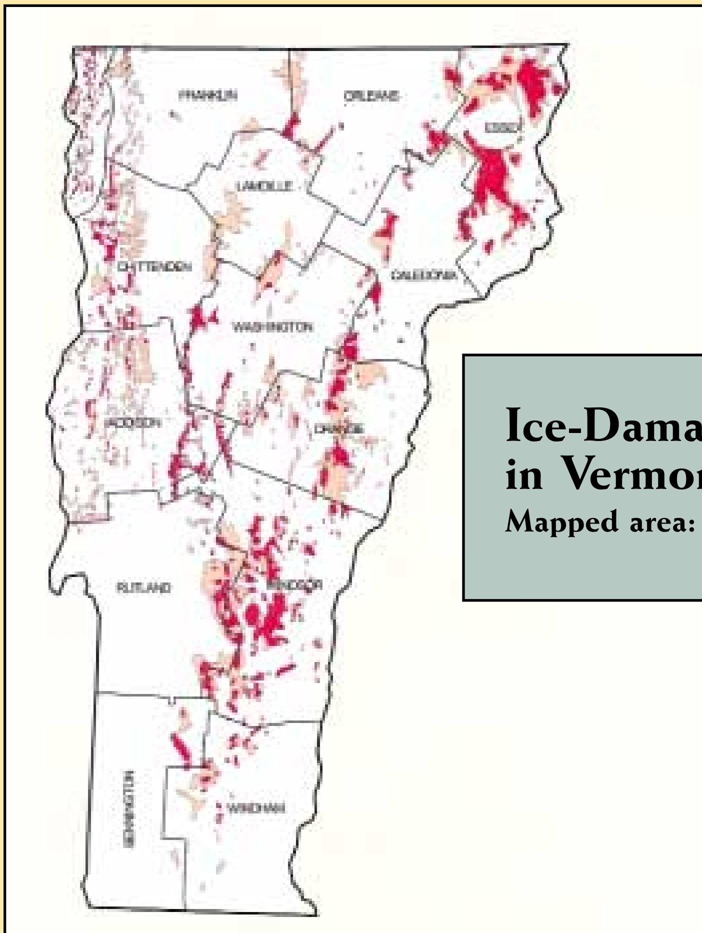
Ice-Damaged Areas in Maine

Mapped area: 11 million acres

LEGEND

Ice Damage

- Heavy
- Moderate/heavy
- Moderate
- Light/moderate
- Light
- Trace/light
- None/trace



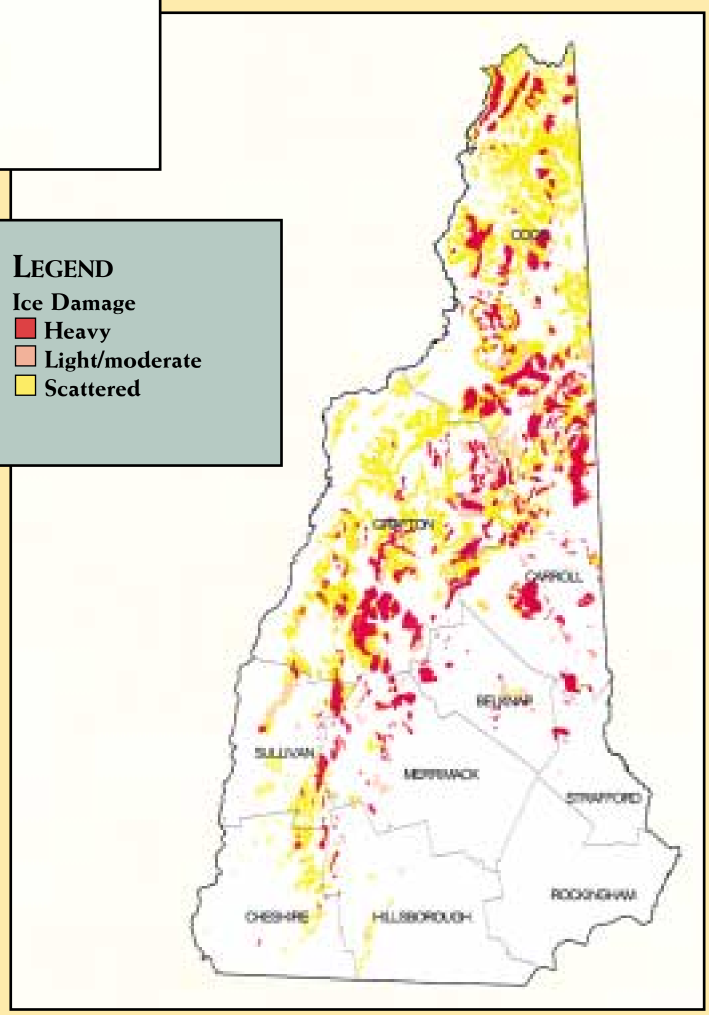
USDA Forest Service

Ice-Damaged Areas in Vermont

Mapped area: 951,000 acres

LEGEND

Ice Damage
- Heavy
- Light/Moderate



USDA Forest Service

Ice-Damaged Areas in New Hampshire

Mapped area: 1,055,000 acres

LEGEND

Ice Damage
- Heavy
- Light/moderate
- Scattered

Standard FIA and FHM data codes were used to record the information. All regional survey and FIA data were analyzed at the USDA Forest Service in Durham, NH. Initially, the regional survey and FIA remeasurement data sets for each state were analyzed individually for crown loss by species and tree size class. This preliminary analysis revealed only minor differences between the regional survey and FIA data sets with respect to the amount of damage and crown damage by species or tree size class. For the final analysis the two data sets were merged and treated as one set of samples for each state and for the entire four-state region. In some cases only the regional survey data were used because the sampling design allowed determination of average conditions within a particular stand.

Characteristics of Damage

The interactions of precipitation, temperature, wind, topography, forest stand structure, and individual tree architecture combined to produce a complex mosaic of crown damage and tree injury caused by ice accumulation during storm. There was an extremely high level of variability in the impact to forests, both within forest stands and throughout the region. At the landscape scale, there were differences in the distribution of ice storm damage to forests that were influenced by the interplay of meteorological conditions and topography across the four states.

The ice storm impacted forests in the northern six counties of New York in an area that stretches from the northern Adirondack Mountains to the St. Lawrence River. Ice accumulation on trees in New York occurred below an elevation of 1,800 feet. In Vermont the ice storm impacted forests in the Champlain Valley at elevations below 1,000 feet and throughout the Green Mountains in an elevation band between 1,800 and 3,200 feet. Ice accumulation in New Hampshire was restricted to an elevation band between 1,000 and 2,600 feet, with the damage occurring in the White Mountains and to the southwest toward the Mt. Sunapee area. There was a zonal pattern to the ice storm in Maine, with a band of ice accumulation extending across the southern third of the state. The elevation distribution of ice storm damage to trees in Maine was between 100 and 1,200 feet, with the upper elevation extending to 2,400 feet in the western part of the state.

Crown Damage

A general measure of the damage caused by the ice storm was determined by calculating the average crown loss across the four-state affected region and within each of the states. This average was based on the 10 percent crown loss classes that were assigned in the field for each tree. The average crown loss for all trees from all four states was 22 percent. New York had the highest average crown loss at 27 percent, followed by New Hampshire with 24 percent, Maine with 19 percent, and Vermont with 17 percent.

Overall averages are useful for broad comparisons, but they do not provide an adequate depiction of the damage because of the high variability of impacts caused by the ice storm. The sampling of damage areas identified by aerial surveys provided information on the range of crown loss within specific forest stands. The average crown loss for the damage areas sampled ranged from near zero to 64 percent. New Hampshire had the damage area with the highest average crown loss (64 percent), followed by New York (56 percent), Vermont (53 percent), and Maine (46 percent). In New York and New Hampshire, 60 percent of sampled areas had greater than 25 percent average crown loss,

NY Department of Environmental Conservation

Damage on hillside in northern New York

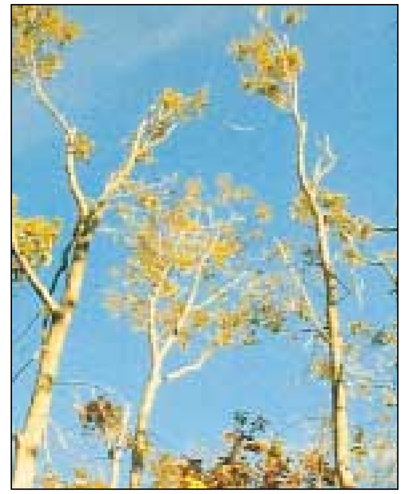
Table 1. Damage categories based on percent crown loss and expected tree impact

Damage category	Crown loss (%)	Impact on tree survival
No damage	0	None
Light/moderate	1–49	Survival good
Heavy	50–79	Survival likely, growth affected
Severe	80–100	Survival unlikely

whereas in Vermont and Maine only 30 percent of the sampled areas had greater than 25 percent average crown loss.

The 10 percent increments of crown loss used in the field have been grouped into four biologically meaningful categories (Table 1). Trees in the first category did not have any ice storm damage. The light/moderate damage category contains trees that had very little visible ice storm damage through those that lost 49 percent of their crowns. Trees in this category are expected to live and resume normal growth. For trees with crown loss between 30 and 49 percent, there may be a period of reduced growth for a few years, but the prospect of survival and recovery is high. The occurrence of other major stressors such as drought or insect infestation may affect growth and survivability. The heavy damage category includes trees that lost between 50 and 79 percent of their crowns. Individuals in this category are susceptible to long-term adverse impacts. Most will survive, but recovery to normal growth may be significantly delayed. The high incidence of branch breakage associated with this category can provide increased opportunity for infection by organisms that cause discoloration or decay. The impact of this secondary injury will be more detrimental to wood quality if large branches were broken from the main stem. Individual trees in this category may also become poor competitors for growing space and, over time, could be overtopped by neighboring trees that incurred less damage. The severe damage category consists of trees that lost 80 percent or more of their crowns, including trees that lost their entire crown. It is highly unlikely that trees in this category will survive.

Of the 22,268 trees in this study with d.b.h. of 5 inches or larger, 51 percent did not have branches broken by the ice storm (Table 2). The portion of the undamaged trees was 45 percent in New York, 50 percent in New Hampshire, 54 percent in Maine, and 60 percent in Vermont. Across the region, 28 percent of the trees in the areas sampled for the assessment were in the light/moderate damage category and should fully recover from the ice storm. Almost 10 percent of the trees sampled were in the heavy damage category. About 12 percent were in the severe damage category and will most likely die due to ice storm damage.



USDA Forest Service

Sparse foliage within ice damaged crowns

In New York about 27 percent of the trees sampled were in the heavy or severe categories and are in jeopardy of significantly reduced growth, increased incidence of infection, loss of wood quality, or death. New Hampshire had about 23 percent of the sampled trees in the heavy or severe categories. In New York and New Hampshire, more trees were in the severe damage category, about 16 percent and 14 percent, respectively, than in the heavy damage category, 11 percent and 9 percent, respectively. Maine and Vermont had about 17 percent of the trees in the heavy or severe categories.

Although it might be expected that the larger surface area provided by the foliage of softwoods would allow higher ice loading than the leafless hardwoods, softwoods as a group had considerably less damage than hardwoods. Only 9 percent of the softwoods were in the heavy or severe damage categories, compared with 26 percent of the hardwoods (Figure 1). The low level of damage to

Table 2. Percent of trees sampled with d.b.h. ≥ 5″ in each crown loss category

Crown loss	NY	VT	NH	ME	Region
No damage	44.7	59.5	49.5	54.2	51.0
Light/moderate	28.4	24.5	27.2	28.8	27.7
Heavy	11.4	7.6	9.3	8.4	9.5
Severe	15.5	8.4	13.5	8.6	11.8

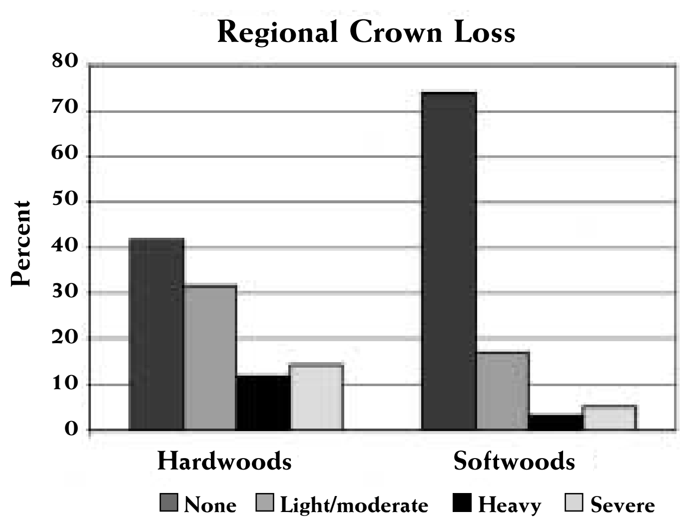


Figure 1. Percent of hardwoods and softwoods sampled in each of the four crown loss categories across the ice storm affected area

softwoods was consistent for all species that were sampled, including cedar, white and red pine, hemlock, spruce, fir, and larch.

Damage to Frequently Occurring Species

Figures 2a-d show the number of trees (sample size) and percent within species in the four crown loss categories for the most frequently sampled species in New York, Vermont, New Hampshire, and Maine. Beech, maple, and birch, which are major components of northern hardwood stands, were frequently encountered within the ice damaged areas. Red spruce, white spruce, and balsam fir were combined into a single group, since results were similar for each of these species. Species such as big tooth aspen, basswood, hophornbeam, and silver maple that were not encountered frequently enough to receive separate listing are included in the "other" species group.The species in this group varied among the states.

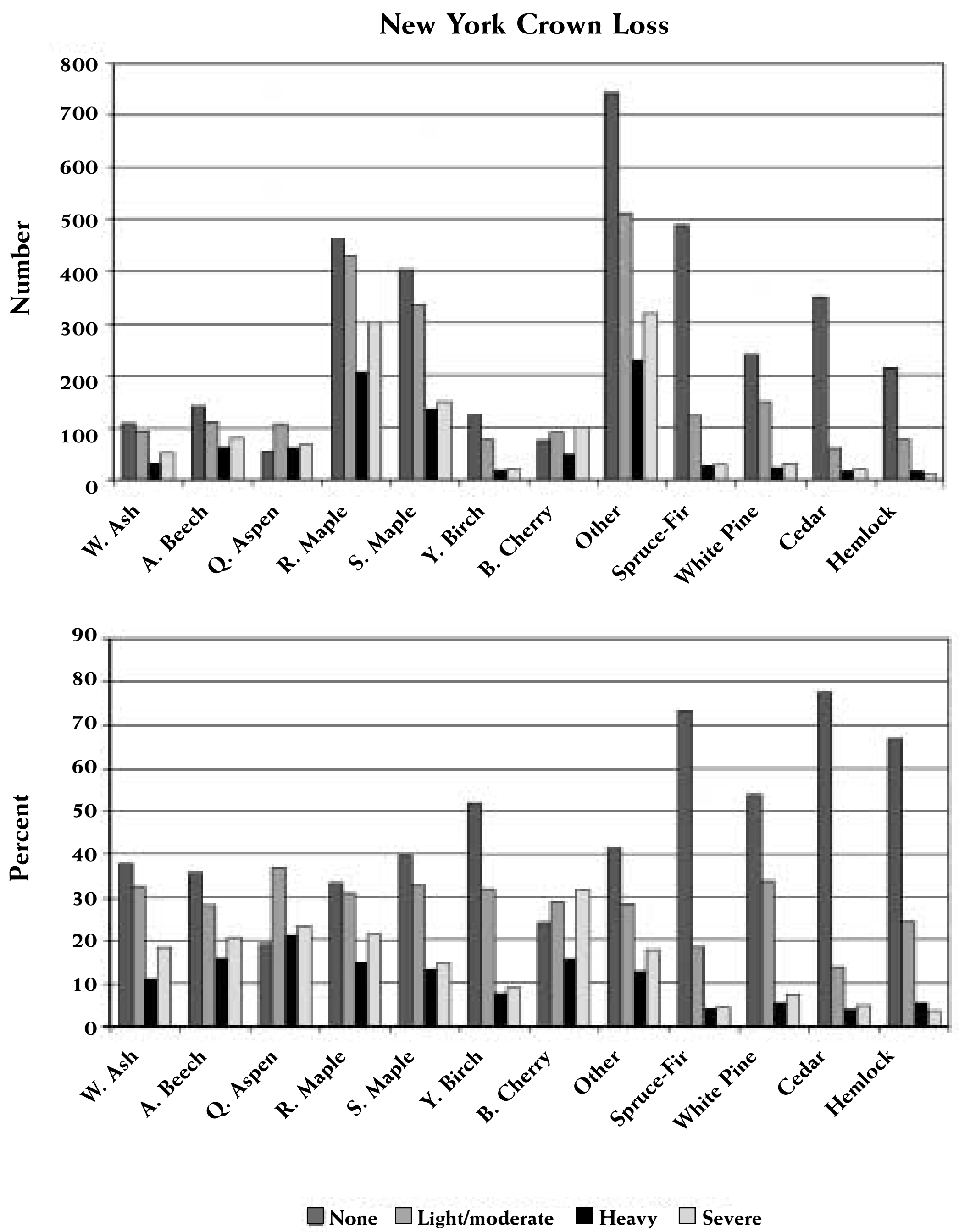


Figure 2a. Number and percent of trees within species in each of the four crown loss categories in New York

New York — Black cherry and quaking aspen were heavily damaged in New York, with about 45 percent of each species having either heavy or severe damage. Thirty percent of the black cherry and 23 percent of the quaking aspen had severe crown damage. About 36 percent of the red maple and American beech sampled received heavy or severe damage, with 21 percent of each species in the severe category. White ash had about 30 percent of the sampled trees in either the heavy or severe damage category. Several species in the "other" group had high levels of damage. American basswood had 58 percent of the trees sampled in either the heavy or severe damage categories, with 40 percent in the severe category. Big tooth aspen had damage similar to quaking aspen, with 43 percent of the trees with either heavy or severe damage. Northern red oak had 38 percent of the trees sampled in either the heavy or severe damage categories. Yellow birch in New York received less damage than in the other three states.

Vermont — Crown damage was fairly uniform for the major hardwood species in Vermont, with between 16 and 25 percent of sampled trees sustaining heavy or severe damage. American beech and yellow birch had slightly more damage than sugar maple and paper birch. American beech had more individuals in the severe category (13 percent) than in the heavy category (11 percent). Sugar maple was the most frequently encountered species in Vermont, making up 28 percent of the trees tallied. Damage to sugar maple was lighter in Vermont compared to the level of crown loss recorded for this species in the

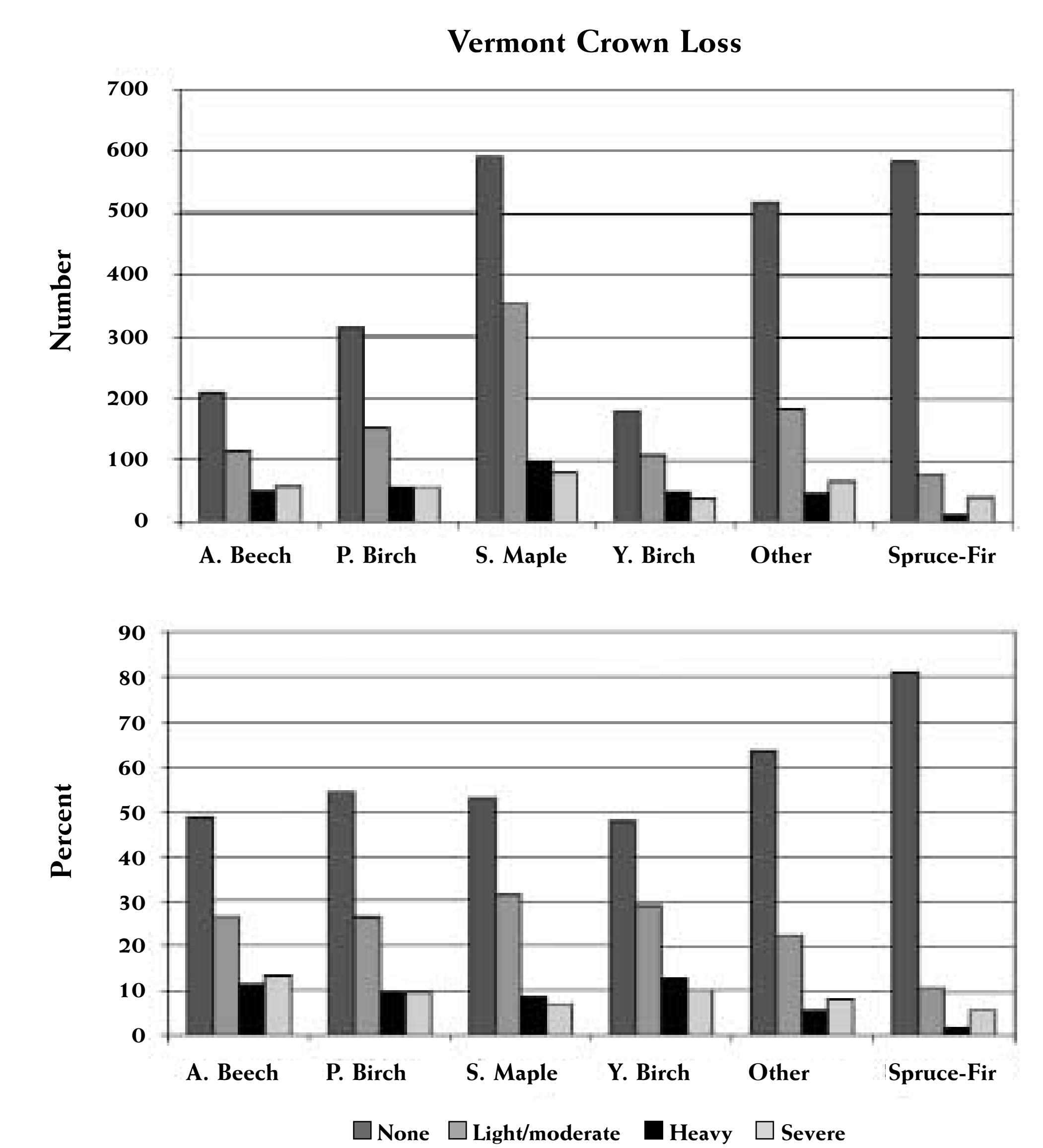


Figure 2b. Number and percent of trees within species in each of the four crown loss categories in Vermont

other three states. Eighty-four percent of the sugar maple sampled had no damage or were in the light/moderate category, and only 7 percent were in the severe category.

New Hampshire — American beech and sugar maple incurred the most crown damage in New Hampshire. American beech had 40 percent of the sampled trees in the heavy or severe damage categories, with 23 percent in the severe category. Thirty-four percent of the sugar maple sustained heavy or severe damage, with 18 percent in the severe category. Yellow birch sustained slightly more damage than the statewide average for all species, with 26 percent of the individuals sampled in the heavy or severe damage categories. There was an even split between the heavy and severe damage categories for yellow birch. Among the other species affected, quaking aspen and white ash experienced higher than average levels of damage, with 38 percent and 28 percent respectively in the heavy and severe damage categories.

Maine — Crown loss in the heavy or severe categories for the major hardwood species in Maine ranged from 14

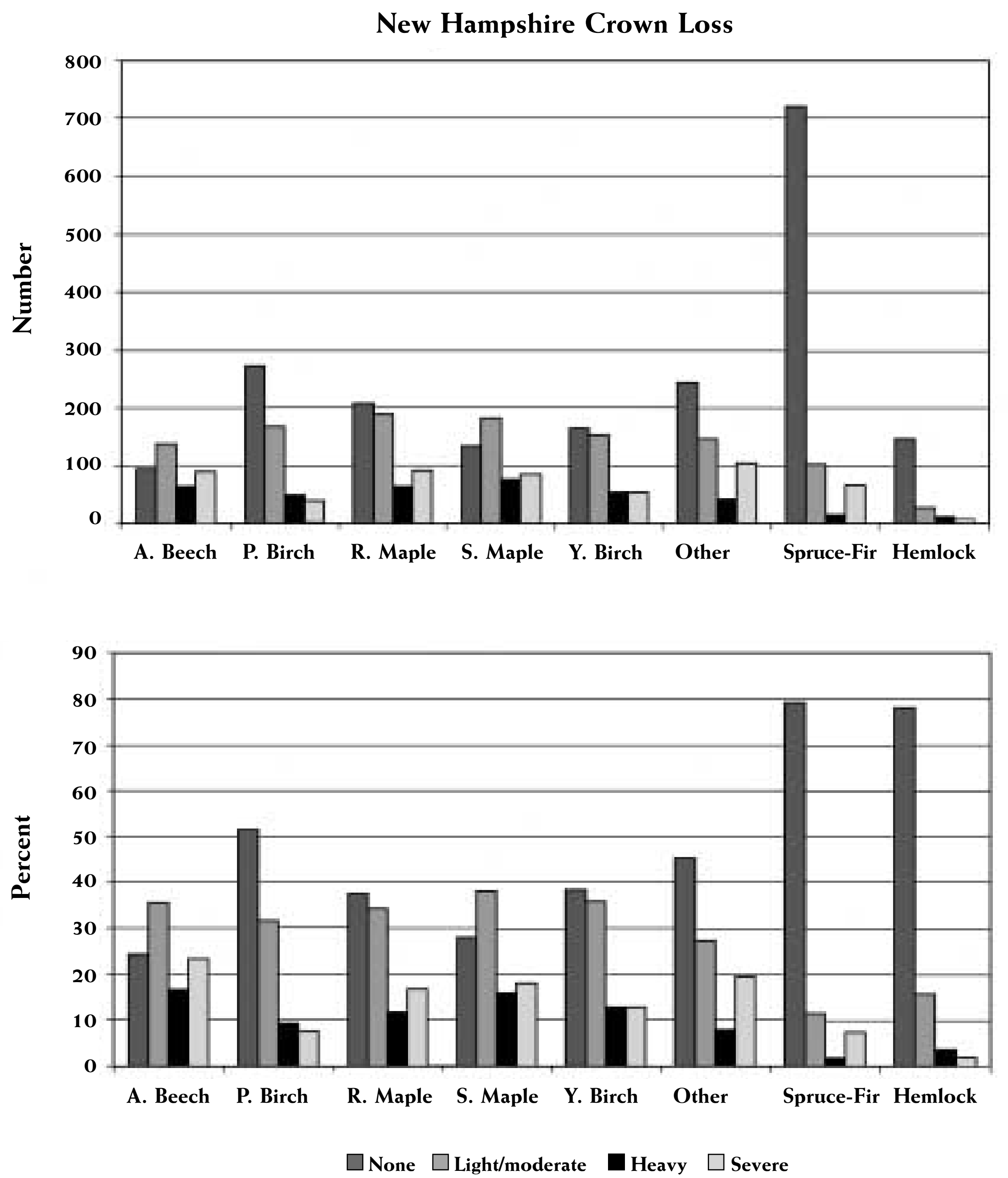


Figure 2c. Number and percent of trees within species in each of the four crown loss categories in New Hampshire

to 31 percent of the species sampled. American beech and yellow birch were the species most impacted in Maine, with about 30 percent of each species in the heavy or severe categories. Paper birch was the next most damaged species, with 25 percent of the sampled trees in the heavy and severe categories. Fifteen percent of the sampled trees were in the severe category. Paper birch had higher levels of damage in Maine than in New Hampshire and Vermont. Red maple and sugar maple had the same level of crown damage, with 23 percent of the trees sampled in the heavy or severe categories. Twelve percent of the red maple were in the severe category, as were 9 percent of the sugar maple. Two species, white ash and northern red oak, were less damaged in Maine (19 percent and 14 percent respectively in the heavy or severe categories) than in New York (30 percent and 38 percent, respectively).

Damage in Relation to Tree Size

The diameter distribution of the trees sampled for this assessment conformed to the distribution described for forests in the Northeast — mostly small diameter trees with a steep but even decline in the number of trees with larger

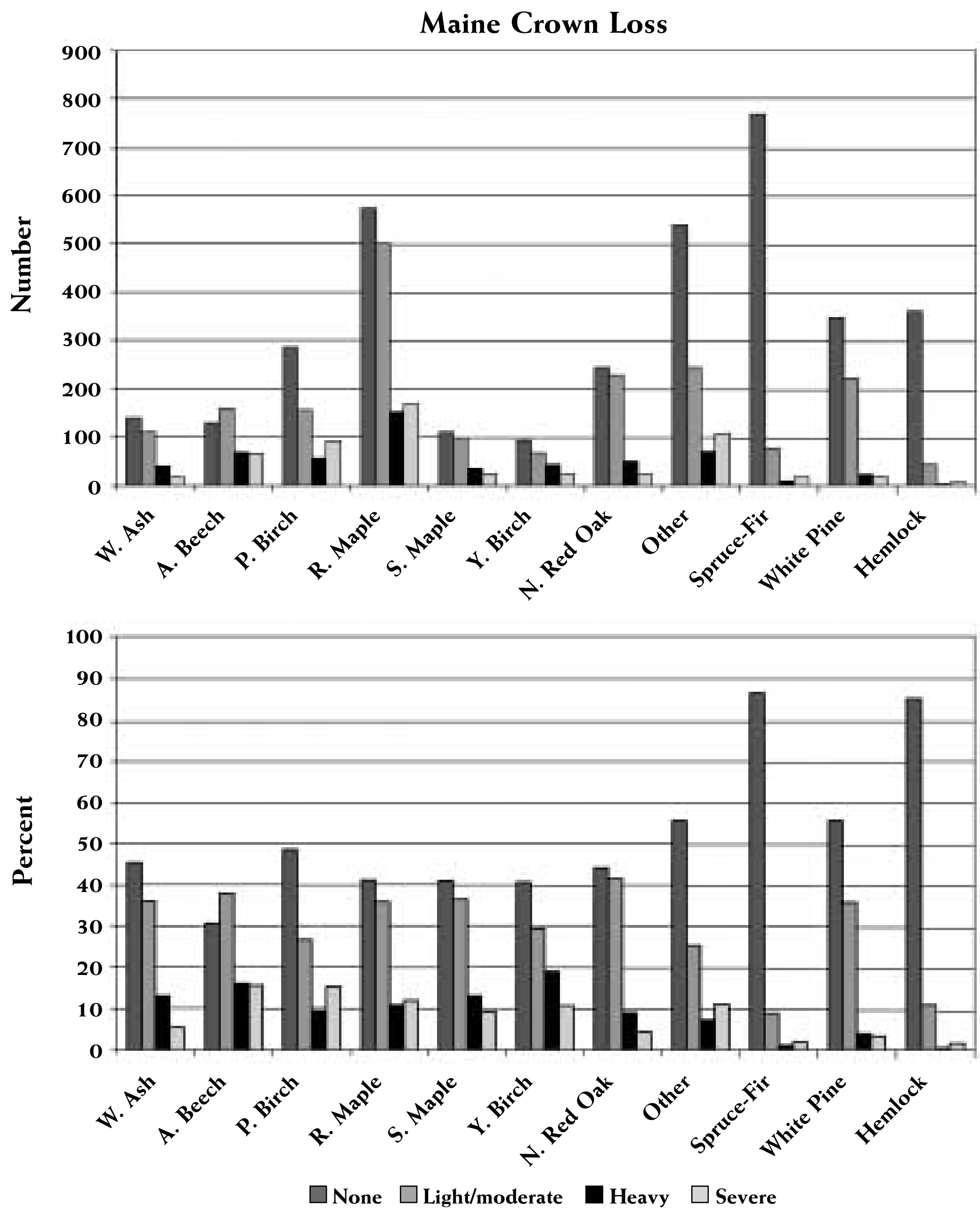


Figure 2d. Number and percent of trees within species in each of the four crown loss categories in Maine

diameters. Across the four-state affected region, larger trees were more likely to incur some ice storm damage than smaller trees, indicated by the decreasing percentage with no damage as d.b.h increased (Figure 3). There was an increase in the percentage of trees in the light/moderate category with increasing d.b.h., and there was a slight increase in the percentage of trees in the heavy and severe categories combined with increasing d.b.h., up to 14 inches d.b.h. For trees larger than 14 inches d.b.h., there was no relationship between increasing d.b.h. and damage; however, the number of trees sampled in the larger size classes is very small. Two factors could explain these trends: trees in the canopy accumulated more ice and had higher levels of crown damage than understory trees, or branches in larger trees were more easily broken by the buildup of ice. Since there was no relationship between crown position and crown damage, the latter factor seems most likely.

For the entire four-state affected region, 79 percent of the trees sampled had a d.b.h. less than 11 inches and 63 percent had a d.b.h. less than 9 inches. The smallest trees sampled, with a d.b.h. between 5 and 6.9 inches (6-inch d.b.h. class), had less crown damage than larger trees. As previously noted, 51 percent of all the trees sampled in this study did not have crown damage; however, this number drops to 39 percent for trees with d.b.h. larger than 10 inches (Table 3). If other types of damage such as severe bending or uprooting are factored in, then small trees had similar damage levels to larger trees. In Vermont and New Hampshire, trees with d.b.h. between 11 and 12.9 inches (12-inch d.b.h. class) had slightly more crown damage than either larger or smaller diameter trees. This relationship was not apparent in the data from Maine and New York.

Bent or Leaning Trees

There were several other types of visible tree damage associated with the ice storm. Some trees were bent over in a sweeping arch with their crowns touching the ground. Trees that were still leaning more than 45° several months after the ice storm are not likely to recover to a typical tree growth form, although they may survive for many years. The tension created from bending could result in serious cracks in the bole, which will disrupt translocation of water and nutrients, provide infection sites for a wide range of organisms, and degrade the quality of the wood.

Overall, about 5 percent of the trees sampled were leaning more than 45° or were uprooted by the weight of the ice that accumulated in the crown. Smaller diameter trees were much more likely to be leaning or uprooted than larger trees. There were over four times more leaning trees than uprooted trees. Of the trees that were leaning or uprooted, 61 percent were in the 6-inch d.b.h. class and 24 percent were in the 8-inch d.b.h. class. Vermont had the lowest percentage of leaning or uprooted trees (2.6 percent); the other three states had similar percentages ranging from 5 to 5.8 percent. Paper birch and red maple were the species most likely to be leaning, followed by yellow birch. Paper birch made up 33 percent of the leaning trees in Maine and 31 percent in Vermont. Less than 1 percent of the sampled trees showed severe cracking of the bole due to tension from being bent over.

USDA Forest Service

Injury caused by branch breakage

Damage to Saplings

Understory saplings received considerably less crown damage than overstory trees. Table 4 provides a summary of damage to saplings. The average crown loss ranged from 5.1 percent in Vermont to 10.7 percent in New Hampshire. Between 70 and 84 percent of the saplings sampled had no crown damage. Although damage to saplings was low, when there was crown damage it tended to be severe instead of heavy. There were two to three times more trees with severe crown damage than heavy damage in three of the four states. Saplings were much more likely to be bent at greater than 45° than overstory trees, as was evident in 10 to 24 percent of the trees sampled.

Aspect and Elevation

There was a slight tendency for more damage on slopes that faced south or east. New Hampshire had a stronger aspect signal than the other states, but the tendencies for more damage on one aspect were not pronounced. Damage

Table 3. Comparison of damaged and undamaged trees by d.b.h. measurement

Damage type	Trees ≥ 5″ d.b.h.		Trees ≥ 10″ d.b.h.	
	Number	Percent	Number	Percent
No damage	11,364	51	2,548	39
Damage	10,904	49	3,966	61
Total	22,268	100	6,514	100

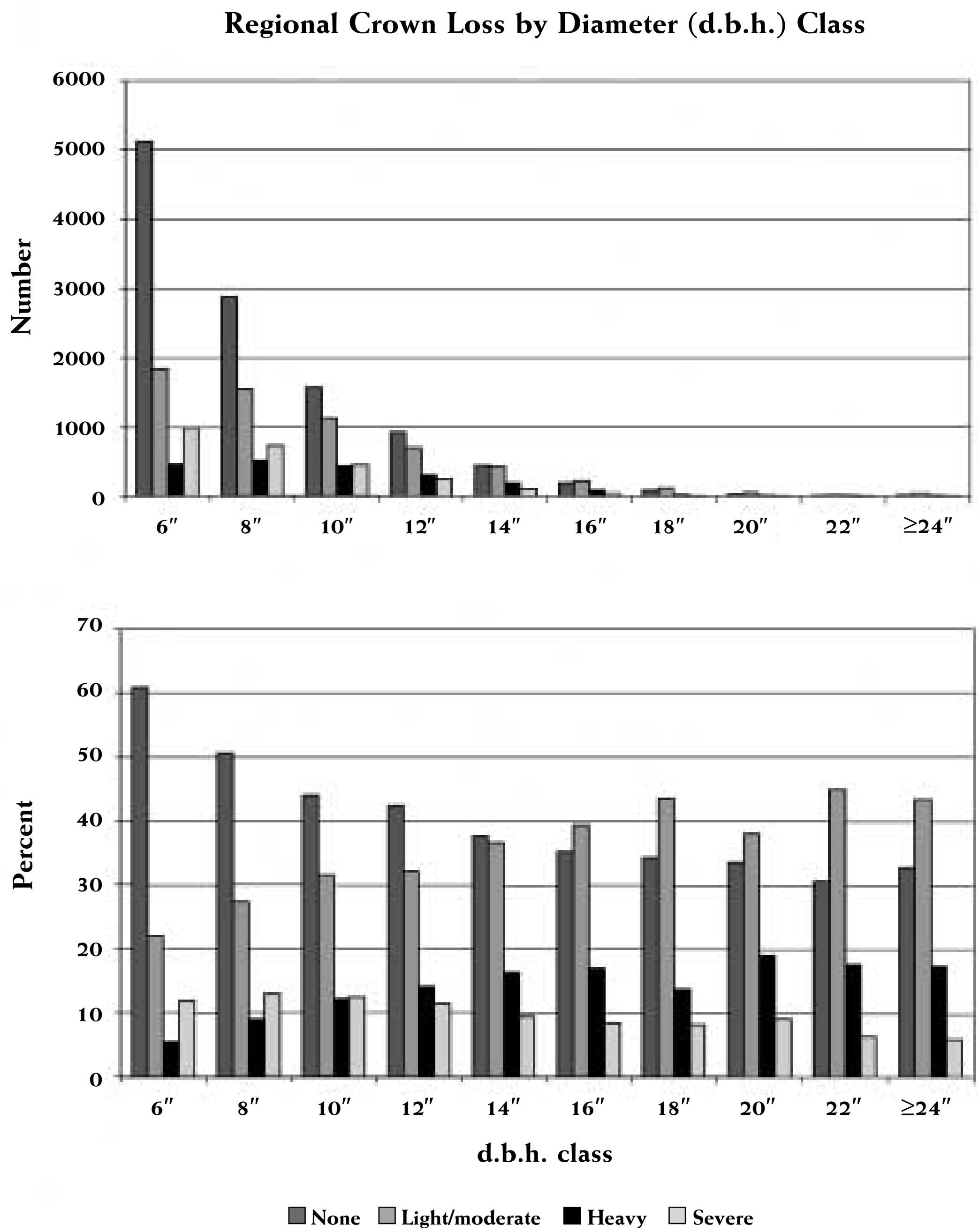


Figure 3. Number and percent of trees within each diameter class in each of the four crown loss categories

was slightly greater in certain portions of the elevation range of ice storm damage in New York, Vermont, and New Hampshire. Much of the area affected by the ice storm in Maine and New York had gently rolling terrain and lower elevations. In New Hampshire and Vermont the ice storm was widely distributed throughout the mountains. No elevation trend was detected in Maine. In New York there was a slightly higher percentage of trees affected between 300 and 900 feet than at other elevations. In the Green Mountains of Vermont there was more damage between 2,100 and 2,700 feet than at other elevations, and in New Hampshire the zone of higher damage was between 1,800 and 2,100 feet.

Fire Hazard

Fire concerns were raised over the amount of fuel and the blockage of fire access roads from fallen debris, including broken branches and whole trees. To address

Table 4. Summary of damage to saplings (<5″ d.b.h.) based on temporary plots established for the regional survey (percent)

State	Average crown loss	No damage	Heavy damage[1]	Severe damage[2]	Leaning >45°
NY	10.4	72.2	2.6	6.5	24.0
VT	5.1	82.6	3.3	1.1	10.0
NH	10.7	69.5	1.9	5.9	14.0
ME	6.7	83.5	2.6	4.2	20.0

[1]Heavy damage: 50–75% crown loss
[2]Severe damage: 80–100% crown loss

this concern, plots within the regional and FIA surveys were assessed for potential fire hazard. Fire hazard ratings were based on a system developed by the New Hampshire Division of Forests and Lands, but did not take into account access or proximity to human development. Fuel load and fuel type were estimated within 60 feet of plot center. Fuel load is determined by the size, amount, and distribution of slash. Fuel types are based on the amount of hardwood and softwood that make up the slash.

About 30 percent of the plots were in the high or moderate fire hazard category, with mostly hardwood slash present (Table 5). About 4 percent of the plots were rated with a high fire hazard. One-quarter of the plots had a moderate fire hazard, ranging from about 23 percent of the plots in Vermont to 27 percent in New York. Approximately half of the plots were rated in the low fire hazard category, ranging from 40 percent of the plots in New York to 59 percent in Maine. In Vermont and New Hampshire about half of the plots had a low fire hazard. No fire hazard was observed on about one-fifth of the plots regionwide. About 28 percent of the plots in New York and 10 percent in Maine had no fire hazard present. In Vermont and New Hampshire, 26 and 19 percent of the plots, respectively, had no fire hazard.

Fire hazard increased with the amount of crown damage recorded on the plots (Figure 4). Plots rated as high fire hazard with more than 50 percent hardwood slash had an average crown damage ranging from 45 percent in New Hampshire and Maine to 50 percent in Vermont and 54 percent in New York. Plots rated as low fire hazard with more than 50 percent hardwood slash ranged from about 19 percent average crown damage in Vermont and Maine to 23 percent in New Hampshire and 32 percent in New York.

Forest Health Monitoring Sites

The Forest Health Monitoring (FHM) plot network has been in place in New England since 1990. Information on tree growth, damage, and crown condition is collected on all trees at each location. One-quarter of the plots are visited each year, thus all plots are measured once every 4 years. FHM plots were used in the ice storm damage assessment to provide a comparison to pre-storm information. The number of trees that were observed was small, compared to the regional and FIA surveys, due to

Table 5. Percent of plots within each fire hazard category based on fuel load[1] and fuel type[2]

State	H1	H2	H3	M1	M2	M3	L1	L2	L3	None
NY	3.5	0.6	0.8	21.1	3.5	3.1	29.7	3.7	6.6	27.7
VT	3.1	0.0	0.0	17.9	4.4	0.8	33.1	6.4	7.9	26.4
NH	3.5	1.2	0.5	20.7	2.5	2.2	32.3	8.2	9.7	19.2
ME	3.0	0.6	0.6	15.5	7.5	3.8	37.2	12.7	9.1	10.1

[1]H (heavy): slash 3–6 inches in diameter, piled over 4 feet uniformly across the ground
M (moderate): less than 3-inch diameter slash, with about half of the slash within 2 feet of the ground
L (low): lesser amount of smaller size slash that is scattered

[2]1: more than 50 percent hardwood slash
2: equal mix of hardwood and softwood slash
3: more than 50 percent softwood slash

the limited number of FHM plots throughout the ice storm impacted area. All measurements were made according to FHM protocols. Chuck Barnett of the USDA Forest Service, Northeastern Research Station, provided the FHM data analysis.

In Vermont, the FHM plots scheduled for measurement in 1998 were visited. In New Hampshire, all existing FHM plot locations were visited. In Maine, plots in the footprint of the ice storm were measured in addition to the plots scheduled for measurement in 1998. New York was not scheduled to begin establishing FHM plots until 1999. However, the FHM plot locations are co-located with the Forest Inventory and Analysis (FIA) plots that were visited, and measurements were taken during the FIA visit to determine the impact of the ice storm on the future sample sites.

Results

Ice damage was noted on 31 percent of all the forested FHM plots measured in Vermont, New Hampshire, and Maine, mainly due to the scattered pattern of the ice damage. This includes 3 of 9 forested plots in Vermont, 8 of 34 forested plots in New Hampshire, and 17 of 48 forested plots in Maine.

The 1998 FHM measurements of about 1,000 trees on 53 of the plots were compared to the 1994 measurements. One measurement of crown condition — foliage transparency — is defined as the amount of light visible through the live crown. Ratings are made for each tree as a percentage of the live crown. Individual trees with higher transparency ratings have thinner crowns. For some species, the percentage of trees with high foliage transparency rose slightly between 1994 and 1998. The percentage of hardwood trees with more than 30 percent foliage transparency rose from 1.0 percent in 1994 to 2.3 percent in 1998. The percentage of birch trees with more than 30 percent foliage transparency rose from 2.3 percent in 1994 to 5.3 percent in 1998. Given that these trees were in areas impacted by the ice storm, they may have experienced a loss of buds or branches, which resulted in thinner crowns.

USDA Forest Service

Debris from broken tree tops in the White Mountain National Forest

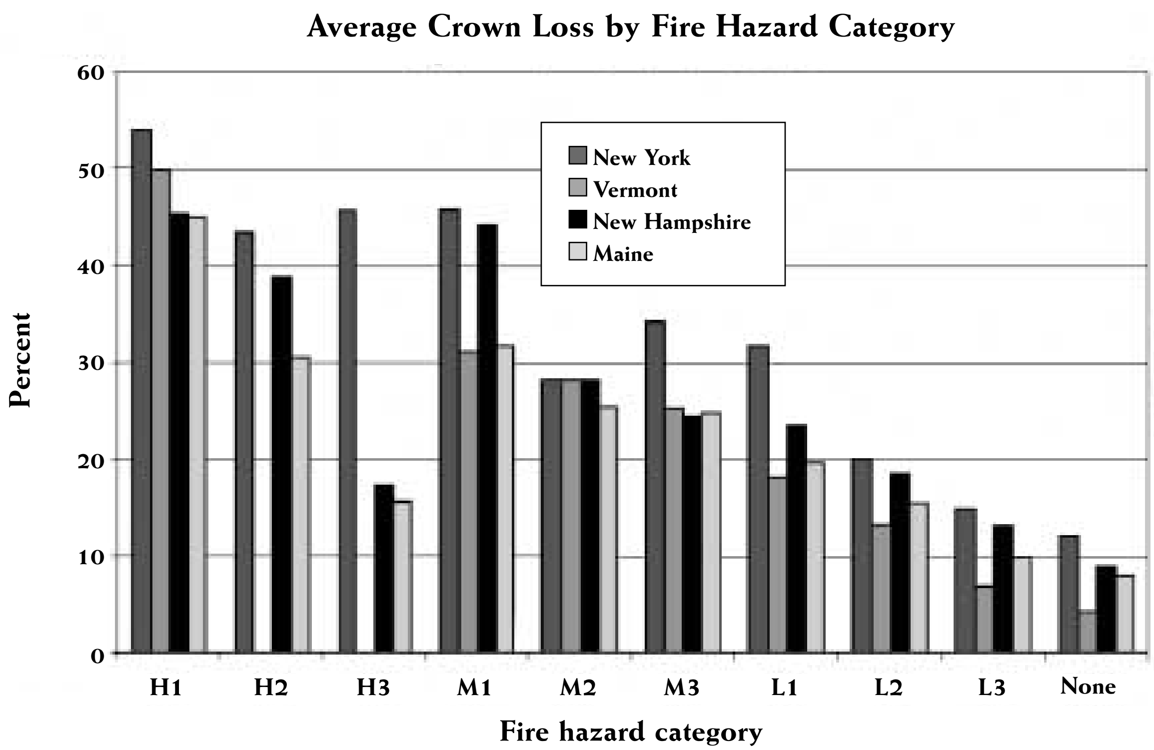


Figure 4. Average crown loss for each fire hazard category (see Table 5 for definitions)

Comparisons were also made using the annual measurements made on plots from 1995 to 1998. Because of the rotating, systematic sample, plots measured in these samples are largely different from one year to the next. Between 1,700 and 4,000 trees were measured each year on forested plots from 1995 to 1998. The percentage of beech trees with more than 30 percent foliage transparency increased slightly from less than 1 percent in 1995-1997 to 3.5 percent in 1998. Crown condition will continue to be monitored through the FHM Program.

North American Maple Project Sites

North American Maple Project (NAMP) sample sites were visited after the storm to determine damage to sugarbushes (trees managed for maple syrup production). NAMP is a United States and Canadian program implemented in 1988 to assess and monitor the health of sugar maple. Sample sites were measured in both sugarbushes and nonsugarbush maple stands. Data was collected by state and Federal forestry agencies and analyzed by Pierre DesRochers, Natural Resources Canada, Canadian Forest Service.

Forty-seven NAMP plot clusters are located in areas affected by the January 1998 ice storm. The plots are in Maine, New Hampshire, Vermont, New York, Nova Scotia, New Brunswick, Ontario, and Quebec. Among these, 38 clusters had visible tree damage. Two sugarbushes and two nonsugarbush maple stands located in an area that did not receive any freezing rain were used as controls. In the impacted stands and the control stands, damage was assessed for each tree in all five plots per cluster in April and early May 1998. About 1,800 trees were observed.

Each plot cluster was characterized by management category (sugarbush or nonsugarbush maple stand), elevation, basal area, stocking, species diversity, and amount of freezing rain received. Damage was recorded for each tree, including fallen, bole broken below the crown, crown damage, top broken, major branches broken at the bole, and wounds within or below the crown.

Crown damage was calculated as a percentage of crown loss by assessing the volume of broken branches hanging on the tree or fallen beneath the tree canopy. The damage classes were combined into light and moderate/severe categories for analysis (Table 6). Crown damage, presence of broken tops, and presence of major branches broken at the bole were the most sensitive indicators of damage caused by the ice storm.

Doug Rose

Ice accumulation in a Vermont sugarbush stand

Results

Tree damage was observed on NAMP plots in Vermont, Maine, and Quebec (Table 7). No visible signs of damage were recorded in NAMP clusters in New Brunswick, New Hampshire, New York, or Nova Scotia, since these plots were not located in ice storm impacted areas. Data from Ontario was not available.

The two greatest factors affecting tree damage on NAMP plots were the amount of freezing rain and the type of stand management (sugarbush or nonsugarbush maple stands). The most severe damage was noted in Quebec, which received the heaviest ice load. Also, for the same amount of freezing rain, sugarbushes suffered less damage than nonsugarbush maple stands.

Ice accumulation was grouped into three ice zones (0mm, 5-60mm, and greater than 60mm). Between each of the ice zones, the risk of moderate to severe damage increased more than a thousand times for crown damage, presence of broken tops, and presence of major branches broken at the bole. The risks of damage also increased over a thousand times in nonsugarbush stands compared with sugarbushes. In areas impacted by the ice storm, moderate to severe crown damage occurred on 22 percent of the trees in sugarbushes and 29 percent of the trees in nonsugarbush maple stands. Where the ice accumulation was greatest, the risks of moderate to severe crown damage were 4.5 times higher in red maple than in other species. The odds of finding broken tops were two times higher in

Table 6. Damage categories for the NAMP data analysis based on percent crown loss

Damage category	Crown loss (%)
No damage	0
Light damage	1–10
Moderate to severe damage	11–95

Table 7. Number of trees within sugarbush and nonsugarbush maple stands in each crown damage category in NAMP plot clusters damaged by the ice storm and in control clusters

Management	Damage category	Maine	Quebec	Vermont	Control	Total
Sugarbushes	No damage	457	350	52	170	1,039
	Light	90	60	20	0	160
	Moderate to severe	66	184	43	0	293
	Total	603	594	115	170	1,482
Nonsugarbush maple stands	No damage	560	392	71	157	1,080
	Light	77	67	143	0	287
	Moderate to severe	106	246	174	1	427
	Total	743	505	388	158	1,794

beech and three times higher in red maple, relative to other species.

The risk of crown damage, broken tops, and major broken branches increased with stand elevation, but this increase was always larger in nonsugarbush maple stands than in sugarbushes. In sugarbushes, damage decreased with increasing basal area of sugar maple. Low elevation sugarbush stands, with larger but fewer sugar maple stems, were more resilient to the ice storm. In nonsugarbush maple stands there was increased damage due to the presence of more smaller diameter trees. These trees, with smaller crowns, could not withstand ice loads as well and were more prone to breakage.

Additional Sugarbush Surveys

Since many commercial sugarbushes did not fall within the NAMP plot system, additional sugarbush sites were measured to better determine the effect of the ice storm on the maple industry. The additional sugarbush sites were surveyed in New York, coordinated by Lewis Staats of Cornell University, and in New Hampshire, by the State Division of Forests and Lands. Within the additional sugarbush stands, the plot size, core data elements, and damage categories were the same as the regional and FIA surveys to provide consistency with the regional assessments. Also, NAMP dieback and transparency measurements were recorded for all trees greater than 5 inches d.b.h. to relate to the NAMP database. Three to five 24-foot fixed radius plots were established within each sugarbush, depending on the relative size of the sugarbush.

New York

Damage to sugarbushes was especially severe in northern New York, with damage to trees and tubing lines. In two of the six counties, estimates suggested a near total loss of production in 1998. Between 2 and 4 inches of ice accumulated on the maple branches, causing them to collapse. In many sugarbush stands almost all of the trees lost significant portions of their crowns. The six northern counties of New York account for 25 percent of the state's maple syrup producers and 35 percent of the syrup. It is estimated that 380,000 fewer taps were placed in 1998, a direct result of the damage by the ice storm.

In Clinton, Franklin, and St. Lawrence Counties, damage was observed in over 90 percent of the sugarbushes, with over half of the producers reporting heavy damage, including significant crown loss, broken main trunks, and uprooting. Fallen trees and branches blocked accessibility to the sugarbush and took down tubing lines. Hanging branches created a hazardous situation for any landowner attempting access to a sugarbush. Tapping guidelines were formulated in response to concerns related to tapping damaged trees.

Cornell University researchers surveyed sugarbushes in northern New York, then conducted an assessment on 12 selected ice storm damaged sugarbushes. Sugarbushes were selected based on damage level, access, cooperation of landowners, age, management history, and topography. Selected sugarbushes needed to have a minimum of 300 taps and to have been in active production prior to the ice storm. The assessment included five sugarbushes in Clinton County, five in St. Lawrence County, one in Essex County, and one in Franklin County. The sample sites in New York were established as permanent plots for long-term monitoring.

The average crown damage for sugar maple within the sampled sugarbushes ranged from 23 to 82 percent (Figure 5). The overall average crown damage on the sampled sugar maple in New York was about 49 percent. On average, about 26 percent of the sugar maple within the sampled damaged sugarbushes were severely damaged and most likely will not survive (Table 8). Another 25 percent were heavily damaged. About 44 percent were in the light/moderate damage category. The survey results indicated that sugar maples greater than 10 inches d.b.h. were more heavily damaged than smaller diameter trees.

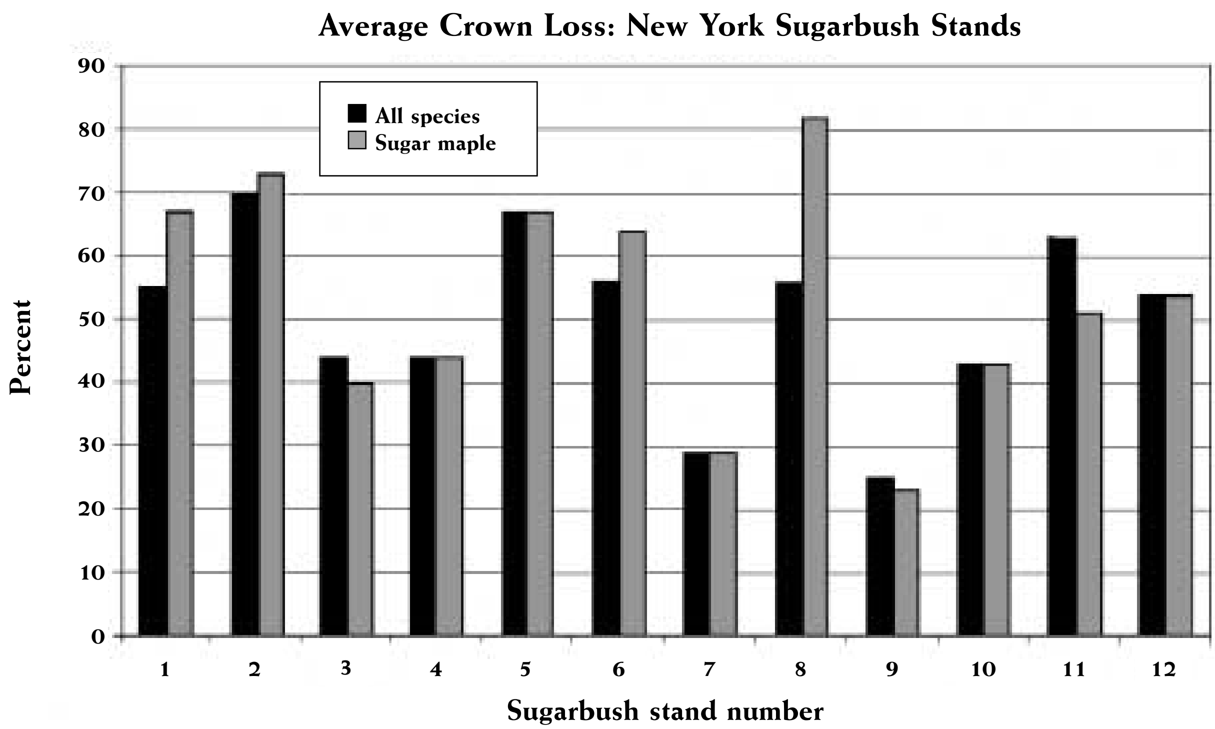


Figure 5. Average crown loss in selected New York sugarbush stands

Other species, comprising 27 percent of the sampled trees within the sugarbushes, were also significantly affected. A higher proportion of these other species were in the severe damage category than the sugar maple (37 percent compared to 27 percent).

New Hampshire

Seven damaged sugarbushes which were not part of the NAMP network of plots were visited in New Hampshire. Within the selected sugarbushes, the average crown damage for sugar maple ranged from 11 to 64 percent (Figure 6). The overall average crown damage was 34 percent for sugar maple and about the same for all species within the sugarbushes. On average, about 14 percent of the sugar maple and 16 percent of all other species within the sugarbushes had severe crown damage and will most likely die (Table 9). Approximately 18 percent of the sugar maple had heavy damage and their vigor was greatly reduced. About 50 percent of the sugar maple sampled had light/moderate damage.

Vermont Hardwood Health Survey Sites

The Vermont Department of Forests, Parks and Recreation began the Vermont Hardwood Health Survey in 1985 to assess the condition of Vermont's hardwood forests. This plot system consists of 84 ground plots distributed throughout the state, which were randomly selected based on mortality classes from interpretation of 1985 photography. Each plot consists of five 10-factor prism points. Ron Kelly, Forest Health Specialist, coordinated a resurvey of the plots to determine the impact from the ice storm and provided the data analysis.

All plots that fell within areas aerially mapped as having been impacted by the ice storm were visited in the spring of 1998 before the trees leafed out. The number of trees

Table 8. Crown damage in selected New York sugarbush stands

Crown	Sugar maple		Other species		Total	
damage	Number	Percent	Number	Percent	Number	Percent
No damage	8	4.0	4	5.3	12	4.3
Light/moderate	89	44.3	34	44.7	123	44.4
Heavy	51	25.4	10	13.2	61	22.0
Severe	53	26.4	28	36.8	81	29.2

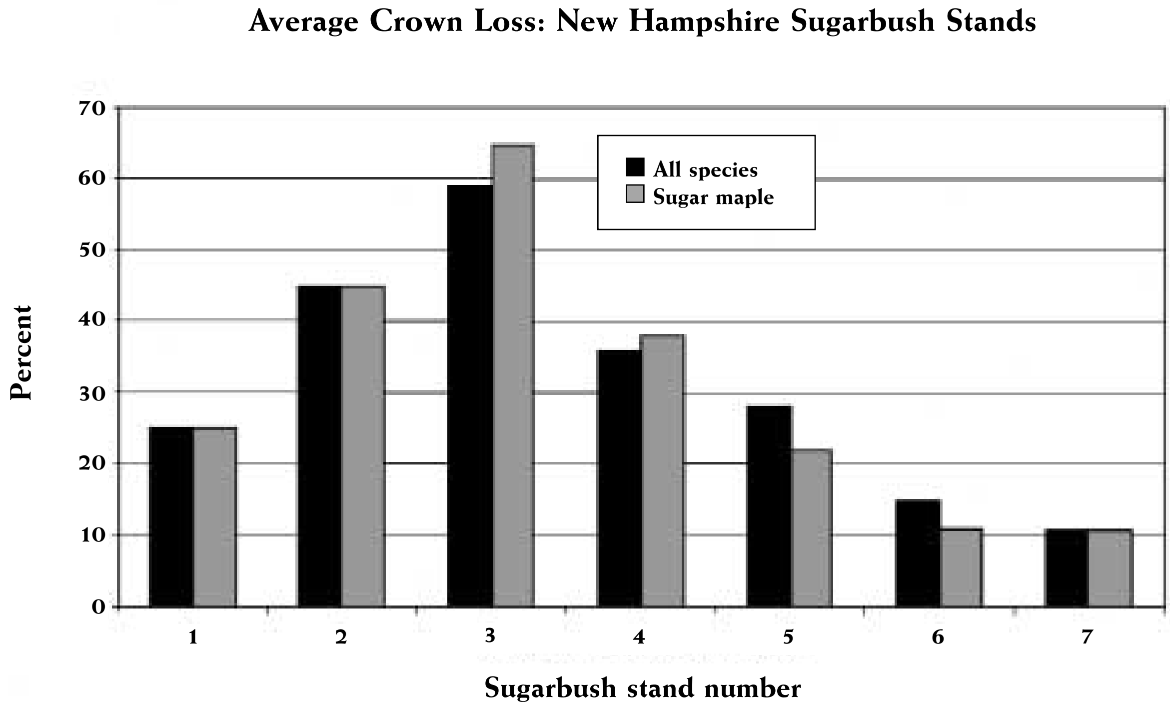


Figure 6. Average crown loss in selected New Hampshire sugarbush stands

that were observed was small, compared to the regional and FIA surveys, due to the limited number of plots located in the ice storm impacted area. The ice storm damaged 17 of the plots but some of these had only light damage. It was decided that those plots that had two or more dominant/codominant trees with more than 25 percent crown loss due to the ice storm would be revisited for summer crown evaluations. Data analysis was done for the 9 plots (containing 437 trees) that exceeded that threshold. Five of these plots were located in Shelburne and South Burlington in the Champlain Valley at elevations of 300 to 400 feet. Three were in Jay at elevations above 2,100 feet, and one was in Roxbury at an elevation of 2,000 feet.

North American Maple Project guidelines were followed for the early spring ice damage evaluations. Bole breakage was recorded as none, single bole broken, multiple bole with at least one unbroken, or multiple bole, all broken. Crown loss due to breakage was recorded as none, 1-10 percent, 11-25 percent, 26-50 percent, 51-75 percent, or 76-100 percent. Crown dieback and transparency were recorded to the nearest 5 percent during a follow-up summer visit, to be consistent with FHM protocols.

Results

The majority of trees in these plots received either light or no damage — less than 25 percent crown loss (Figure 7). Dominant/codominant trees received more crown damage than trees in other canopy positions, except for trees down on the ground or with boles broken below the crown (100 percent crown loss). The smaller pole-size trees were the ones most likely to break due to heavy ice loading. About 15 percent of the dominant/codominant trees had heavy or severe crown damage with more than 50 percent crown damage.

About 40 percent of the dominant/codominant black cherries and hickories had greater than 50 percent crown loss. One-quarter of the red maple lost more than 75

Table 9. Crown damage in selected New Hampshire sugarbush stands

Crown damage	Sugar maple		Other species		Total	
	Number	Percent	Number	Percent	Number	Percent
No damage	42	17.4	34	45.9	76	24.1
Light/moderate	122	50.6	18	24.3	140	44.4
Heavy	43	17.8	10	13.5	53	16.8
Severe	34	14.1	12	16.2	46	14.6

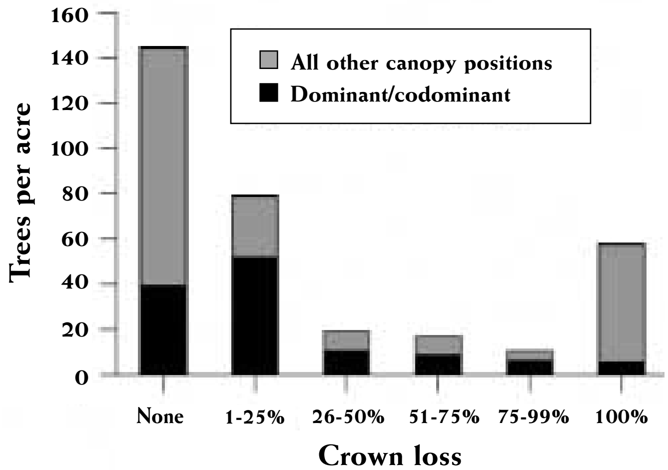


Figure 7. Average crown loss in dominant/codominant trees in Vermont Hardwood Health Survey plots

percent of their crowns and almost 20 percent of the sugar maple lost more than half their crowns. About 5 percent of the sugar maple and aspen were killed by the ice storm. Beech trees suffered the greatest damage in the survey, with all trees having lost more than 50 percent of their crowns, but all of these trees were located in one very heavily damaged plot. Most of the yellow birch, paper birch, and oak had less than 25 percent crown damage. Less than 3 percent of the pine had any significant ice damage.

Average dieback and transparency increased dramatically in these ice damaged plots compared to when evaluations were last conducted in 1996 (Figure 8). Many of the heavily damaged trees were observed to have poor foliage production along many of the remaining branches, as well as smaller than normal leaf size. These trees will continue to be monitored to determine whether they survive.

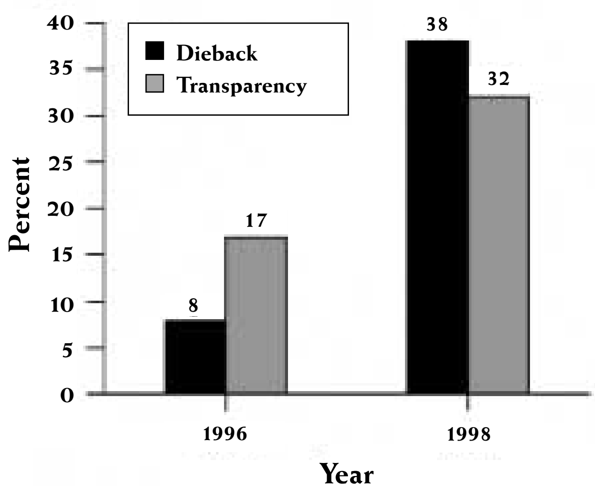


Figure 8. Average crown dieback and transparency for dominant/codominant trees before (1996) and after (1998) the ice storm

Remote Sensing Activites Related to the Ice Storm

The ice storm provided some unique opportunities for incorporating remote sensing technology to evaluate the damage caused by this event. Aerial photography, satellite imagery, and digital camera imagery were used by the USDA Forest Service and state forestry agencies to collect information about the location, severity, and pattern of the damage.

Aerial Photography

The State of Maine acquired photography covering more than 2.8 million acres affected by the ice storm. The photography is being used to define the extent, pattern, and severity of the damage caused by the ice storm. This aerial photography is also being made available to county extension groups who, in turn, make prints available to individual landowners in order to help them make land management decisions.

Aerial photography was collected over the Long Trail on the Green Mountain National Forest by the USDA Forest Service to evaluate the damage caused to the trail and huts by the ice storm. Aerial photography was also acquired also over selected sites covering 88,000 acres in Maine, New Hampshire, Vermont, and New York. This photography was used to evaluate the accuracy of the aerial sketch mapping that was conducted soon after the ice storm to determine the extent of the damage.

New Hampshire is planning to acquire aerial photography over the entire state. This photography will be made available for making better management decisions related to ice storm damage and other activities.

Satellite Imagery

Satellite imagery from the Landsat and Spot satellite programs, both before and after the ice storm occurred, has been acquired by the states and the USDA Forest Service. The imagery will be used in a change detection analysis project to evaluate the use of this scale and resolution of imagery for detecting and mapping ice storm damage.

Color Infrared Digital Camera

Images from this camera system are being evaluated by the USDA Forest Service for its ability to detect and map ice storm damage as well as damage caused by other natural disasters.

Monitoring Effects of the Ice Storm

What will be the long-term impact from the ice storm on the trees, forest stands, wildlife, and landowners of northern New England? Will the ice storm change the way we manage forests? The Federal Emergency Appropriation for ice storm recovery includes funds for studying the storm's long-term effects. The following section describes research projects that have been initiated or proposed in each of the affected states and the project contact.

New York

Forest Plant Communities — Quantifying the nature of losses in various stands to assist managers in planning responses for future events. Relating post-damage condition and future growth of surviving trees to their pre-ice storm canopy position and extent of crown breakage. Documenting size, species, and conditions of trees lost to ice loading and describing structural changes in forest plant community and effect on plant and animal habitat. *(D. Leopold, SUNY Environmental Science and Forestry, Syracuse, NY)*

Forest Health — Continuing random sampling of ice damage to assess impact to forested areas. Establishing plots to determine the relative damage within tree species and across forest types. Also assessing the proportion of managed forest and how management affected impacts and recovery from the ice storm. Determining the relationship of previous disease-induced defects to ice storm damage and the long-term impact of ice damage on future forest health. *(Paul Manion, SUNY Environmental Science and Forestry, Syracuse, NY)*

Wildlife Communities — Focusing on faunal diversity response to disturbance and potential forest management alternatives, and the interaction of deer and regenerating plant communities. Examining species abundance, richness, and diversity of breeding birds, amphibians, land snails, ground beetles, and burying beetles; how forest floor complexity affects amphibian communities; and how management practices affect songbird and beetle communities. Assessing how deer browsing affects overall stand composition and relative abundance of various tree species in ice damaged stands. Also examining if deer affect regeneration differently in highly disturbed areas compared to undisturbed areas and if deer browsing intensity can be predicted by local landscape characteristics, such as the scalfe of the disturbance and distance to agricultural areas. *(J. Gibbs, SUNY Environmental Science and Forestry, Syracuse, NY)*

Forest Insects — Evaluating the economic impact of various bark beetles and wood borers on commercially valuable northern hardwood and white pine in heavily damaged stands. Assessing damage by sugar maple borer, peach bark beetle, and ambrosia in hardwood stands and the impact on white pine by ambrosia beetles, red turpentine beetle, and sawyer beetles. Assessing impact from these secondary insects on sawtimber-quality wood 2 to 4 years after ice storm injury. Investigating secondary insect diversity, abundance, and temporal patterns in damaged and undamaged stands. *(Doug Allen and Stephen Teale, SUNY Environmental Science and Forestry, Syracuse, NY)*

Economic Impact Analysis — Determining the financial impacts of the ice storm on forest resources, with emphasis on short- and long-term impacts on timber and forest-related recreation. Incorporating data on the quantity and extent of timber loss volume and the extent and future development over the next 10 to 20 years of accelerated volume and grade loss due to ice storm damage. A schedule of expected product and grade recovery will be developed, along with an estimate of losses due to inability to recover material. Regional estimates will be determined regarding number of recreationists affected and financial losses. *(J. Wagner, SUNY Environmental Science and Forestry, Syracuse, NY)*

Social and Policy Issues — Assessing various public policy questions associated with natural catastrophic events, including threat of increased fuel load to landowners, fire dangers, funding mechanisms for rural fire districts, and regulations related to sanitation and salvage. Also evaluating public assistance to private landowners to assess damage, private-public partnerships for better management, and response of communities to loss of street trees. *(D. Floyd, SUNY Environmental Science and Forestry, Syracuse, NY)*

Evaluation of Stewardship Incentive Program (SIP) — Evaluating the delivery of technical assistance to landowners affected by the ice storm. Assessing the awareness and understanding of landowners, state forestry agency staff, and consulting foresters regarding how to apply for SIP funds. Evaluating the ease of the application process and the communication between the various agencies and landowners. *(Tommy Brown, Cornell University, Ithaca, NY)*

Educational Efforts — Assessing educational efforts and needs of private woodland owners, maple producers, and tree care professionals. This project will characterize the degree to which educational materials and programs have assisted landowners, and if any additional educational assistance is needed. *(Tommy Brown, Cornell University, Ithaca, NY)*

Aquatic Habitats — Assessing the immediate and long-term impacts on streamsides and aquatic habitats. Investigating the immediate impacts of the ice storm on riparian zone trees and assessing the resulting effects on the fish and invertebrate communities and on physical processes in associated streams. The second component will consist of a long-term monitoring program of the recovery of the streamside and stream habitats. *(Rebecca Schneider and Cliff Kraft, Cornell University, Ithaca, NY)*

Sugarbushes — Evaluating the recovery of sugarbushes in northern New York. Examining growth rates, stocking levels, tree vigor and quality, changes in successional patterns and invasion of species, rate of compartmentalization of taphole wounds, and increased susceptibility to insects and disease. Establishing permanent plots in impacted stands that were active in sap production prior to the ice storm, to be remeasured over a 4-year period. *(Lewis Staats, Marianne Krasny, and Peter Smallidge, Cornell University, Ithaca, NY)*

Urban Trees — Initially re-examining trees damaged in the Rochester, NY, 1991 ice storm to supply background for a sound urban canopy monitoring project in the northern portion of the state. Eventually, a parallel study of the rural forest recovery project that has already been initiated will be implemented. Determining the long-term effects of urban ice storm damage, evaluating the consequences of leaving trees with 50 to 70 percent crown damage, and planning to provide better guidelines for tree managers. *(Jerry Bond, Cornell University, Ithaca, NY)*

Remote Sensing — Utilizing satellite imagery to precisely locate and describe the degree of forest cover damage resulting from the ice storm. Current forest damage data was collected via aerial sketch-mapping with additional processing. This information is of a small scale and tends to generalize damage intensity, as it ignores small intensely impacted or protected components of forest stands. It is hypothesized that greater detail of damage intensity and smaller, more specific locations of isolated forest cover impact may be determined through use of modern satellite technology. *(Kurt Swartz, NY Department of Environmental Conservation, and William Elberty, St. Lawrence University, Plattsburg, NY)*

Vermont

Impact on Butternut — Evaluating butternut trees in the Champlain Basin of northwestern Vermont to determine the overall extent and impact of ice damage. Evaluating the extent and impact of ice damage on other tree species growing in association with butternut. *(Dale R. Bergdahl, Department of Forestry, University of Vermont, Burlington, VT)*

Bird Populations — Assessing changes in breeding bird populations in ice damaged forests. Investigating the effect of the ice storm on the relative abundance, diversity, and composition of forest breeding bird populations in Vermont. *(Steve Faccio, Staff Biologist, Vermont Institute of Natural Science, Woodstock, VT)*

Growth and Survival of Sugar Maple — Examining the relationships among crown damage, root and stem carbohydrate storage, and subsequent growth and survival in sugar maple trees in stands in Vermont. *(Timothy Perkins and Betty Wong, Proctor Maple Research Center, University of Vermont, and USDA Forest Service, Northeastern Research Station, Burlington, VT)*

Crown Canopy Changes — Following the recovery or decline of tree crowns in ice damaged stands compared to nearby nondamaged stands using image analysis as a means to monitor changes over time in canopy cover, leaf area, and standard crown health ratings. *(Ronald Kelley, Department of Forests, Parks and Recreation, Stowe, VT)*

Remote Sensing — Assessing ice-affected foliage using remotely sensed infrared imagery to detect ongoing stressed vegetation. Attempting to provide additional information on the location and extent of forest damage based on visible imagery analysis. *(Lesley-Ann Dupigny-Giroux, University of Vermont, Geography Department, Burlington, VT)*

Changes in Forest Stands — Monitoring changes in growth, composition, and health throughout the forest vegetation structure in a severely ice damaged stand and a comparable undamaged site on state-owned land in Vermont. *(Jay Lackey, Vermont Department of Forests, Parks and Recreation, Barre, VT, and Florence Peterson, USDA Forest Service, Northeastern Area, Durham, NH)*

Ecological Effects — Monitoring long-term ecological effects on vegetation using monitoring plots at Shaw Mountain preserve. *(Ana Ruesink, Vermont Nature Conservancy, Montpelier, VT)*

New Hampshire

Land Cover Type Mapping — Developing a digital mapped data layer to support identification and assessment of areas damaged during the ice storm. Cooperative effort will rely on remotely sensed data (Landsat Thematic Mapper imagery) and imaging radar data (Radarsat, ERS-1, ERS-2) to characterize landscape patches. The project will incorporate a pre-event vegetation type map of susceptible areas above a specific elevation and post-event imagery to provide data on specific locations of damage. The overlay will provide an assessment of damage areas by location and vegetation type, and provide baseline information to managers to assist in monitoring long-term impacts. *(Barry Rock, Complex Systems Research Center, University of New Hampshire, Durham, NH)*

Natural Heritage Assessment and Management — Assessing the condition of rare plant populations and natural communities influenced by the ice storm. Planning to identify appropriate management actions to ensure their survival. Currently 281 occurrences on non-Federal lands in New Hampshire. Planning reconnaissance on the ground in ice storm damaged areas to assess condition, habitat, and management options. Will coordinate with the White Mountain National Forest on USDA Forest Service lands. *(NH Division of Forests and Lands, Concord, NH)*

Wildlife Habitat — Working within ice storm damaged areas to develop long-term plans for ice damage recovery, forest stewardship, and wildlife habitat conservation. Collaborating with NH Fish and Game Department, Regional Planning Commissions, and Conservation Commissions. *(Extension Wildlife Specialist, Cooperative Extension, University of New Hampshire, Durham, NH)*

Amphibian Populations — Researching amphibian responses to changes in forest structure associated with ice storm damage. Studying changes in amphibian populations, which can potentially have a significant impact on the forest food web. Provides a model for examining the effects of natural disaster events. *(Kimberly Babbitt, University of New Hampshire, Durham, NH)*

Maine

Tree Damage — Investigating long-term damage from ice storm injury, related to stocking and stand condition, and post-ice storm harvest impacts. Looking at various stand conditions: precondition (undamaged) stands, damaged stands, and post-harvest stands. Planning training sessions to share management recommendations based on research. *(Bill Ostrofsky, University of Maine, Orono, ME)*

Secondary Insect Impacts — Conducting general surveys for various insect pests such as callous borers, sugar maple borers, bronze birch borer, and ambrosia beetles. Planning to compare previous years' insect populations with future population development. Have already observed significant increases in beetle populations in affected red pine plantations. Will also be looking at potential buildup of larch beetle populations. *(Dick Dearborn, Maine Forest Service, Entomology Lab, Augusta, ME)*

Aerial Photography — Planning to compare current true color (1:9,000 scale) photography to aerial photos obtained 5 and 10 years after the ice storm to determine change in stand condition. The information on the photos will be augmented by information from permanent plots within the photographed area, including Forest Health Monitoring, Forest Inventory and Analysis, Beech Survey, and Birch Survey plots. *(Dave Struble, State Entomologist, Maine Forest Service, Augusta, ME)*

USDA Forest Service

Response of Forests — Monitoring the response of the entire plant community, including herbaceous and understory woody species dynamics, to openings created by the ice storm. Assessing the fate of injured trees. Using detailed, permanent vegetation study sites to be located throughout Vermont, New Hampshire, and Maine. *(Christopher Eagar, USDA Forest Service, Northeastern Research Station, Durham, NH)*

Tree Damage — Examining the damage to northern hardwoods caused by ice storm injury. Determining the effect of crown loss due to ice injury on stemwood formation 5 years after injury and the effect of wood exposure on wood quality. Assessing the types of wood stains and rots that develop after injury. Creating a library of digital images to produce photo guides and educational materials. Study trees located in Maine, New Hampshire, and Vermont. *(Water Shortle and Kevin Smith, USDA Forest Service, Northeastern Research Station, Durham, NH)*

Stress Detection — Assessing short- and long-term ice damage through detection of stress in foliage using biochemical markers. Selecting trees in various damage categories to collect samples of visually healthy leaves and establish the relationship between the stress marker, putrescine, and tree recovery. *(Rakesh Minocha, USDA Forest Service, Northeastern Research Station, Durham, NH)*

Appendix

Management Recommendations for Landowners

Fact sheets were produced shortly after the ice storm to provide information on tree damage and response, including crown loss, effects on hardwood quality, approaches to stand management and inventory, harvesting damaged timber, and impacts on wildlife. The fact sheets are available on the USDA Forest Service ice storm web site (see contact page).

Two have been included in this publication:

Will Winter Storm Injury Affect Hardwood Quality and Maple Sap Production?

and

Silvicultural Approaches for Managing Ice-Damaged Stands.

Ice Storm 1998

Information Sheet #2 February 27, 1998
USDA Forest Service, Durham, NH

Will Winter Storm Injury Affect Hardwood Quality and Maple Sap Production?

Ice glazing, snowstorms, and high winds cause dramatic changes in the appearance of forests and sugarbush. Broken branches, snapped tops, and bent saplings are alarming to see. Fortunately, there is no need to panic or rush to change forest management plans.

While recent storms have been extensive, severely injured stands are highly localized. Trees with poor form are injured more frequently than trees with good form. In lightly to moderately affected stands, some trees will benefit from reduced competition. The greatest potential harm is in recently thinned, understocked stands.

After a storm, removal of hazardous trees and branches is an immediate priority. While the hazard cleanup is underway, there is time to learn how the storm damage and tree biology affects hardwood quality and maple sap production.

Key concepts:

- Trees can survive the loss of much their crown.
- Stain and decay take years to develop in living trees and standing snags.
- Stain develops rapidly in improperly handled logs and green lumber.
- Sugar in maple sap was formed in last year's leaves.
- Closure of tapholes made in previous years indicates tree vigor and vitality.

Winter buds contain the new leaves that will capture energy during the growing season. When next season's foliage is lost due to winter branch breakage, the tree compensates by increasing the efficiency of the remaining leaves and by producing leaves from buds that would have remained dormant. Although trees compensate very well, trees do decline and may die following the complete or near-complete loss of crown.

The spread of stain and decay depends on wound size and position, tree vigor and vitality, and local insects and pathogens. Stain initiated by breaks or snaps in the crown is not likely to extend into the butt log for three or more years following wounding. In a vigorously growing tree, new wood production may more than compensate for the loss in value due to a column of stain in the center of the tree. More damaging are wounds on the lower part of the stem or root flare such as those caused by logging.

Sugar maples with crowns completely destroyed this winter are likely to produce sap and are safe to tap this spring as they are likely to die. Trees with extensive but not complete crown loss are at risk, however, and should be tapped lightly, if at all. The stress due to tapping is not from the removal of sap, but in the additional wounding of the tree. Previous tapholes with good closure are indicators of healthy trees. Allow trees with poor closure of tapholes made in previous years to "rest".

Unlike living trees, dead wood has no active defense systems. Stain spreads rapidly in improperly handled and stored logs and green lumber.

Over the next several years, landowners and managers need to watch for:

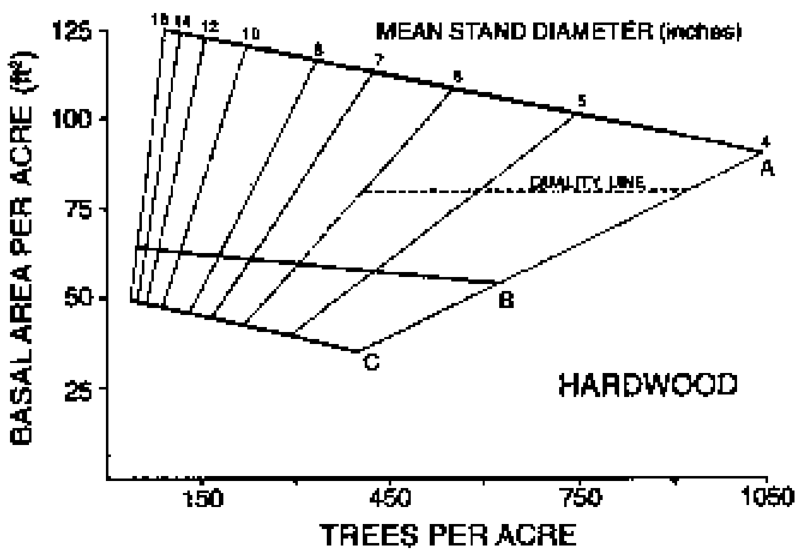
- Hazard trees;
- Stem sprouts (epicormic branches) that reduce wood value;
- Outbreaks of insect pests.

(over)

Survival and the response of individual trees to storm injury involves several factors, most of which are difficult to determine, including tree genetics and the condition of the trees prior to injury. However, expectations of individual tree survival and potential damage can be related to the amount of crown remaining after crown loss due to breakage:

Crown		
% lost	% remaining	Expectations
>75	<25	Few trees survive. Heavily infected survivors.
50 to 75	25 to 50	Many trees survive. Extensive infection from large broken tops and lower branches. Shattered crotches and torn bark increase severity Growth suppression likely.
<50	>50	Most trees survive. Growth in some trees will slow. Lightly damaged trees on gap edges may grow more rapidly.

Survival and mortality of trees after storm injury are part of the larger process of forest stand development. Trees increase in size and decrease in number as a forest stand matures. The expected relationship among tree size, basal area, and numbers of trees per acre is contained in a hardwood stocking chart. The forest manager needs to ask whether the storm damage affected the stocking level of the stand from being overstocked (A line), optimally stocked (B line and quality line), or understocked (C line).



Acknowledgments: Kevin T. Smith and Walter C. Shortle of the USDA Forest Service, Northeastern Research Station.

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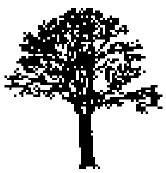


Ice Storm 1998

Information Sheet #4 February 27, 1998
USDA Forest Service, Durham, NH

Silvicultural Approaches For Managing Ice-Damaged Stands

The severe ice storm of January 1998 caused damage on an estimated 17 million acres of forestland across Maine, New Hampshire, Vermont, and New York. Damage was highly variable within stands. Some trees suffered broken branches and tops, others were bent over, and in some cases trees were uprooted.

Evaluate the damage. It is important that forest landowners get an accurate estimate of the damage to their stands. This can best be done by a professional forester. It is usually necessary to take some sort of inventory plots to estimate the severity of damage. Generally, three classes of ice damage are recognized for standing trees: less than 50% crown loss, 50-75% crown loss and over 75% crown loss. Trees with less than 50% crown loss have a good chance of fully recovering. Trees with 50-75% crown loss can be retained, but may develop stain and decay, and as such should be reevaluated in 3 to 5 years. Trees with over 75% crown loss are at risk of dying or heavy infestation of insects and diseases and should be considered for harvest within the next year.

Conifers, if stressed enough by crown loss, will be susceptible to attack by bark beetles and wood borers this summer, especially if they were not vigorous when winter arrived. Along with these insects will come blue stain, which may degrade the value of lumber sawed from infested trees. Severely damaged, low vigor conifers and downed conifers should be harvested this summer. There is no immediate need to harvest standing hardwoods. The spread of discoloration and decay in hardwoods is much slower than it is in conifers. Downed hardwoods will be degraded within one or two growing seasons.

Silvicultural Considerations

Several silvicultural considerations need to be addressed when managing stands that have a significant amount of ice damage.

1. **Stocking.** To minimize development and persistence of epicormic branches on hardwoods, and to maintain optimum volume growth per acre, stocking should remain at or slightly above the B-line (optimal stocking -- about 65 sq. ft./ac. for hardwoods and 100 sq. ft./ac. for conifers). B-level stocking can be visualized as removing about every third tree from a fully stocked stand. If removing all the ice-damaged trees would reduce the stocking below the B-line, then it might be appropriate leave some of the less severely damaged trees.

2. **Epicormic branches.** Exposure to light can lead to epicormic branching on hardwood species. If the stocking is below 80 square feet per acre in northern hardwood stands, these newly formed epicormic branches may persist and lead toward lower timber quality. Epicormic sprouting is of less concern i.e., less sprouting and higher on the bole, in dominant trees with full crowns, in sawtimber-sized trees as compared to pole-sized trees, and in trees with lower levels of damage. It may be advisable to retain some damaged trees to reduce the epicormic sprouting on the highest value trees.

(over)

3. **Consider group selection.** The ice damage seemed to be very patchy. Individual 1/4 acres may be heavily damaged adjacent to lightly damaged areas. Patches of heavily damaged trees are logical places for groups. Groups less than 1/4 acre in size will have a high proportion of shade tolerant species, like beech and sugar maple. Groups over 2/3 acre in size will have a higher amount of shade intolerant regeneration like fire cherry, aspen, and paper birch. Groups between 1/4 and 2/3 acre in size will have a mixture of tolerant and intolerant species as well as some intermediately tolerant like white ash, yellow birch, and red oak. Generally, group selection harvesting guidelines call for putting 10-15% of the stand area into groups at each stand entry. The entire stand would be cut over to 7 to 10 entries, which would be up to 150 years if a 15-year entry cycle were used. Improvement cutting is applied between the groups to reduce the basal area to about 70 square feet per acre. Marking guidelines harvest trees that would significantly decrease in value and would release residual crop trees. It may be advisable to leave some dominant, fully- crowned trees with little damage or defect within some groups.

4. **Concentrate on sawtimber/large poletimber stands.** Although sapling and regeneration stands may have a lot of bent over trees, most of these stems will recover from ice damage. It would be advisable to reevaluate damaged sapling stands in 3 to 5 years. If patches of the stands have not fully recovered then perhaps consider group selection. For sawtimber and poletimber stands, usually 5-7 cords per acre or 2,000 board feet per acre are needed for a commercial harvest.

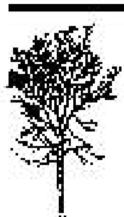
5. **Wildlife trees.** Not all damaged trees need to be removed. In particular, trees over 18 inches dbh with broken tops or large broken limbs have a good chance of developing into valuable wildlife cavity trees. This is true for both hardwoods and softwoods. It is a good idea to retain some of these damaged trees.

6. **Residual stand damage.** Damage to residual trees during ice damage harvest operations should be avoided. A wound on the butt log is far more serious in terms of economic value loss than a wound from a broken limb in the crown. It makes little sense to harvest storm damaged trees if the residual trees are damaged in the process. Some things to consider are:

   Consider marking the trees to be removed on both sides of the stem and near groundline. This allows the harvester to see the cut and residual trees from all angles, which helps to reduce residual stand damage.

   Don't harvest during the spring when soft ground will cause excessive root injury. If possible, don't harvest during the growing season (May-July) when the "bark is slipping." Residual trees are much more susceptible to wounds caused by felling and skidding during the growing season.

Every stand is different and each landowner has unique goals for her or his property. These general guidelines can help landowners and professional natural resource managers make decisions about managing ice-damaged stands, but they must be tempered with knowledge of local ecology and economic conditions.



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Neil Lamson or William Leak
USDA Forest Service
PO Box 640
Durham, NH 03833
Or visit our website:
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Contacts & Web Sites

■ New York

James Beil
Ice Storm Recovery Coordinator
NY Dept. of Environmental Conservation
50 Wolf Road
Albany, NY 12233-4250
Phone: 518-457-2475
Fax: 518-457-5438
E-mail: jabeil@gw.dec.state.ny.us
Website: www.dec.state.ny.us/website/dlf/privland/forprot/icestorm/index.html

■ Vermont

Neil Lamson
Ice Storm Recovery Coordinator
Vermont Dept. of Forests, Parks and Recreation
103 South Main Street – 10 South
Waterbury, VT 05671
Phone: 802-241-3678
Fax: 802-244-1481
E-mail: nlamson@fpr.anr.state.vt.us
Website: www.state.vt.us/anr/fpr/index.htm

■ USDA Forest Service

Margaret Miller-Weeks
Ice Storm Damage Assessment Coordinator
Northeastern Area, State and Private Forestry
USDA Forest Service
PO Box 640
Durham, NH 03824
Phone: 603-868-7712
Fax: 603-868-1066
E-mail: mweeks/na_du@fs.fed.us
Website: www.fs.fed.us/na/durham/ice/index.htm

Chris Eagar
Research Ecologist
Northeastern Research Station
USDA Forest Service
PO Box 640
Durham, NH 03824
Phone: 603-868-7636
Fax: 603-868-7604
E-mail: ceagar/na_du@fs.fed.us

■ New Hampshire

J.B. Cullen
Ice Storm Recovery Coordinator
New Hampshire Division of Forests and Lands
PO Box 1856
Concord, NH 03302-1856
Phone: 603-271-3457
Fax: 603-271-2629
E-mail: jb_cullen@dred.state.nh.us
Website: ceinfo.unh.edu/ice98.htm

■ Maine

Dave Struble
Ice Storm Technical Contact
Maine Forest Service
State House Station #22
Augusta, ME 04333
Phone: 207-287-2791
Fax: 207-287-8422
E-mail: dave.struble@state.me.us
Website: www.state.me.us/doc/mfs/icefrnt.htm

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State Foresters

- **Philip Bryce**
  Director
  Division of Forests and Lands
  NH Dept. of Resources and
  Economic Development
  PO Box 1856
  Concord, NH 03302-1856
  Phone: 603-271-2214
  Fax: 603-271-2629
  E-mail: p_bryce@dred.state.nh.us

- **Tom Doak**
  State Forester
  Maine Forest Service
  Maine Dept. of Conservation
  State House Station #22
  Augusta, ME 04333
  Phone: 207-287-2791
  Fax: 207-287-8422
  E-mail: tom.doak@state.me.us

- **Frank Dunstan**
  Director, Division of Lands & Forests
  NY Dept. of Environmental Conservation
  50 Wolf Road, Room 410C
  Albany, NY 12233-4250
  Phone: 518-457-2475
  Fax: 518-457-5438
  E-mail: fmdunsta@gw.dec.state.ny.us

- **David Stevens**
  State Forester
  VT Dept. of Forests, Parks and Recreation
  103 South Main Street – 10 South
  Waterbury, VT 05671-0601
  Phone: 802-241-3678
  Fax: 802-244-1481
  E-mail: dstevens@fpr.anr.state.vt.us

USDA Forest Service, State & Private Forestry

- **Gail Michaels**
  Planning & Information Coordinator
  USDA Forest Service, State & Private Forestry
  271 Mast Road
  PO Box 640
  Durham, NH 03824
  Phone: 603-868-7694
  Fax: 603-868-1066
  E-mail: gmichael/na_du@fs.fed.us

NEFA Executive Director

- **Charles A. Levesque**
  Executive Director
  NEFA
  PO Box 2911
  Concord, NH 03302-2911
  Phone: 603-229-4965
  Fax: 603-226-0499
  E-mail: inrscal@aol.com

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