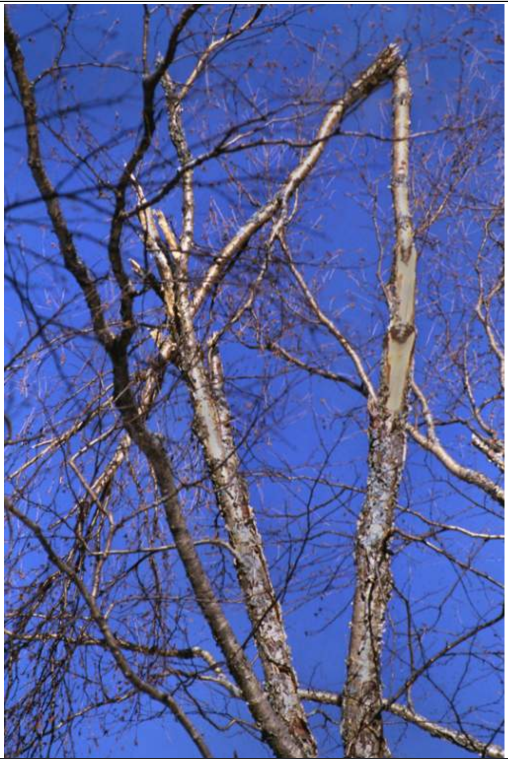
Tree Response Following the 1998 Ice Storm- Walter Shortle, Northern Research Station, Forest Service

Nearly 25 million acres of forest from northwestern New York and southern Quebec to the south-central Maine coast were coated with ice from a 3-day storm in early January 1998. This storm was unusual in its size and duration of icing. Trees throughout the region were injured as branches and stems broke and forks split under the weight of the ice. These injuries reduced the size of tree crowns and exposed wood to infection by wood-destroying fungi.



Yellow birch with broken branches, a snapped top, and split forks. Note the dark V-shaped included bark found in branches with steep branching angles creating a zone of weakness unlike branches with shallow branching angles and a branch-bark ridge with interlocking branchwood and bolewood.

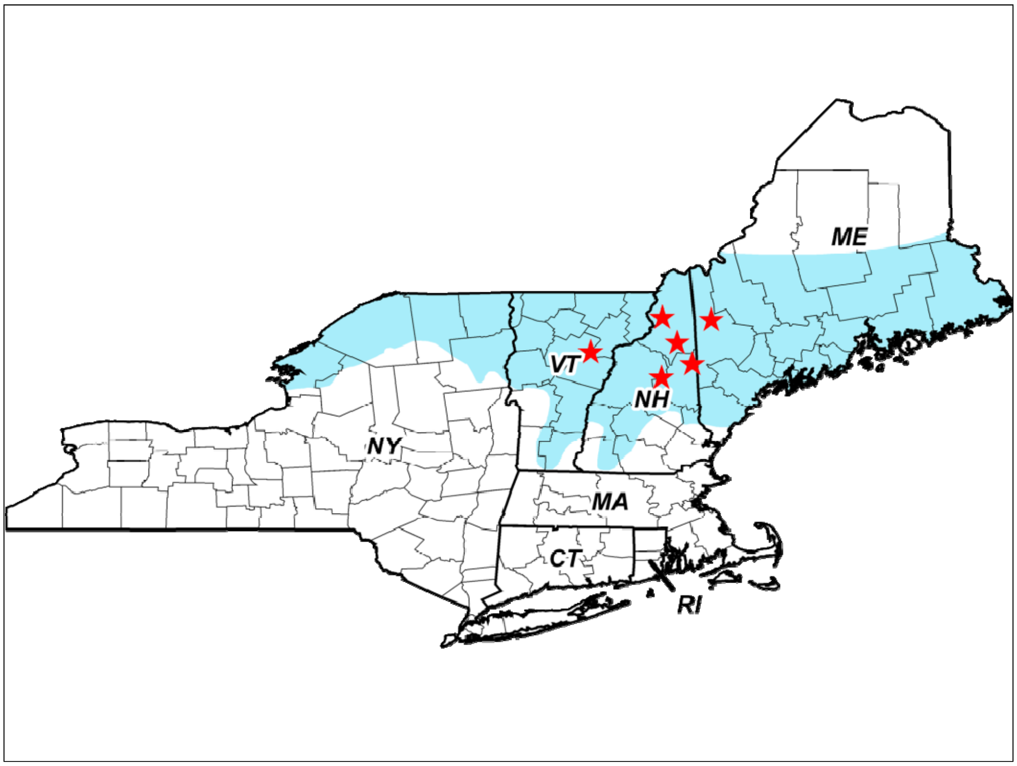
See the same dark layer of included bark in this larger tree with a low crotch formed by two codominant stems leaving a zone of weakness ready to break under a heavy load.

Young poles may loose a lot of crown, but vigorous sprouting during the growing season may quickly rebuild a crown.

Branches of large mature trees may have breakage similar to small poles, but only a small fraction of the crown is lost and trees will survive without serious problems. (As a “rule of thumb” branches and stems less than 2 inches bend without breaking, breakage increases from 2 to 4 inches, breakage declines from 6 to 8 inches and stops around 8 inches.)

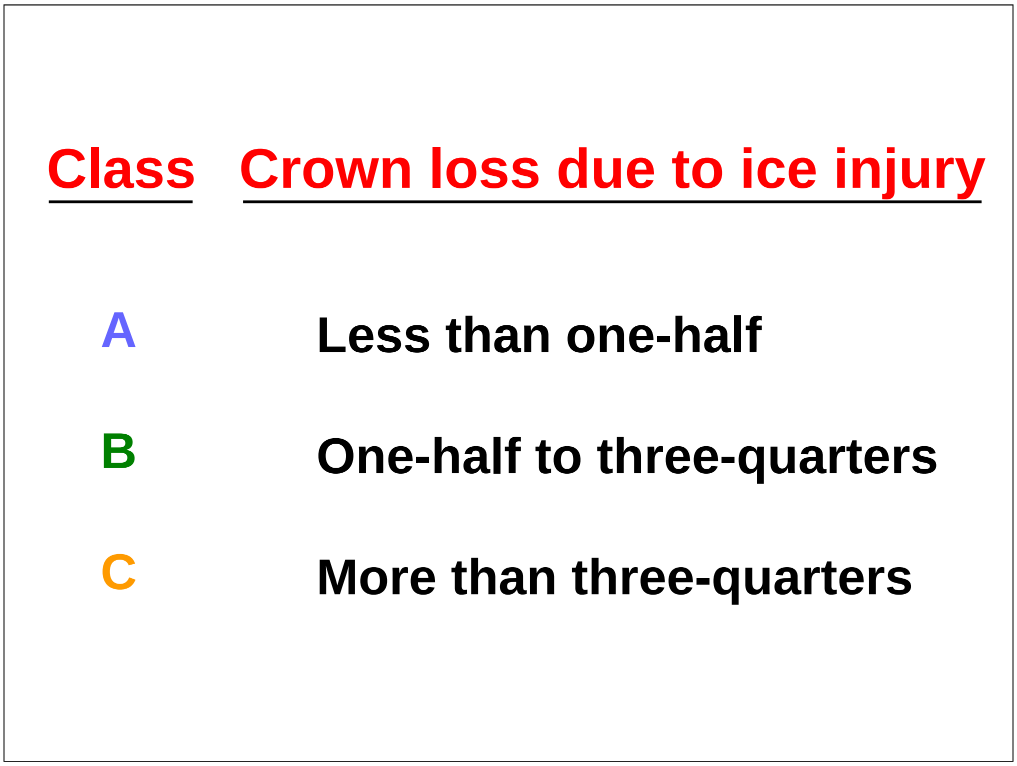
This is a generic northern hardwood with a full crown which likely has twice as much foliage as needed. Studies in orchard trees and saplings indicate that loss of less than half the foliage has no adverse effects on tree function. This is consistent with the fact that in most years trees loose some foliage to various insects, foliage diseases, etc. so a certain amount of redundancy has been incorporated into trees. It is also known that most foliage is working at only a fraction of its photosynthetic capacity and leaves can work harder to supply energy to the tree if needed. The storm came in winter when shoots are fully charged with stored starch, leaves are already formed in primary buds, and axillary buds are available to sprout and replace lost shoots. Trees have a highly developed protective system called codit (compartmentalization of decay in trees) which will slow the spread of infection entering wounds from top breakage. Healthy northern hardwood trees are well suited to sustain winter storm damage, but there are limits.

Mature sugar maple lost a 5-inch top decades ago. The next branch below the break became the new leader. Wood-destroying infection was compartmentalized within the wood exposed by wounding and the tree survived to grow large and produce lots of healthy wood.



Area affected by the 1998 ice storm (shaded) and study locations (stars). A 5-year “tag and track” study was initiated to determine the effects of the storm on injured trees of species initially identified as being at high risk of loss of utilization value. The study focused on tree survival, stem growth, wound closure, and internal defect. At 6 locations (see map) surviving northern hardwood trees were permanently tagged and classified in October 1998.

Stand of northern hardwoods hit hard by the ice storm at Weeks Brook in the White Mountain National Forest in October 1998.



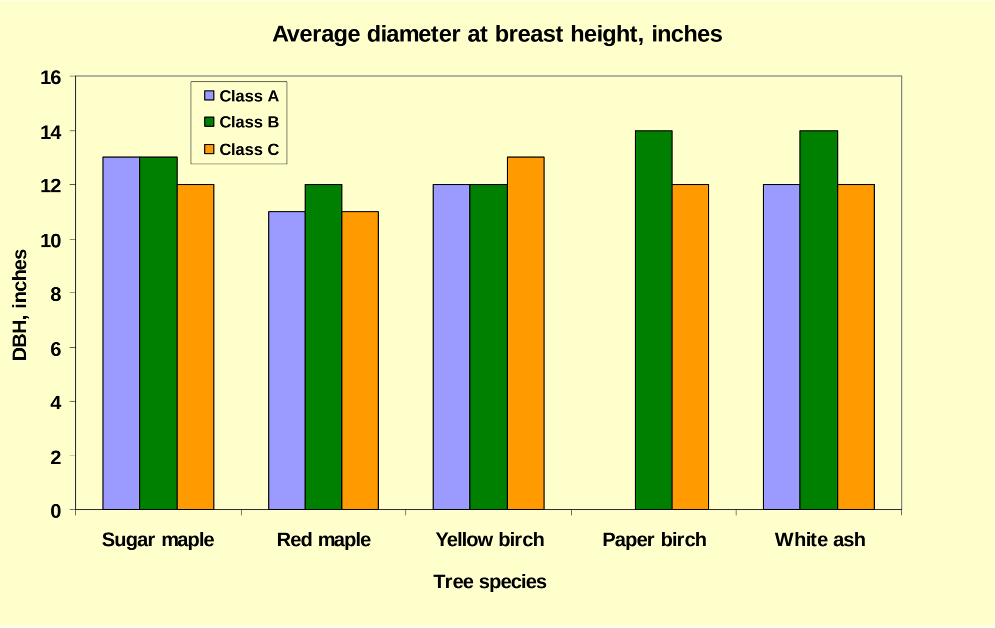
Class	Crown loss due to ice injury
A	Less than one-half
B	One-half to three-quarters
C	More than three-quarters

Crown loss classification: Class A trees had crown loss due to the storm of less than one-half, Class B trees had a crown loss of one-half to three-quarters, and Class C trees had crown loss of more than three-quarters.

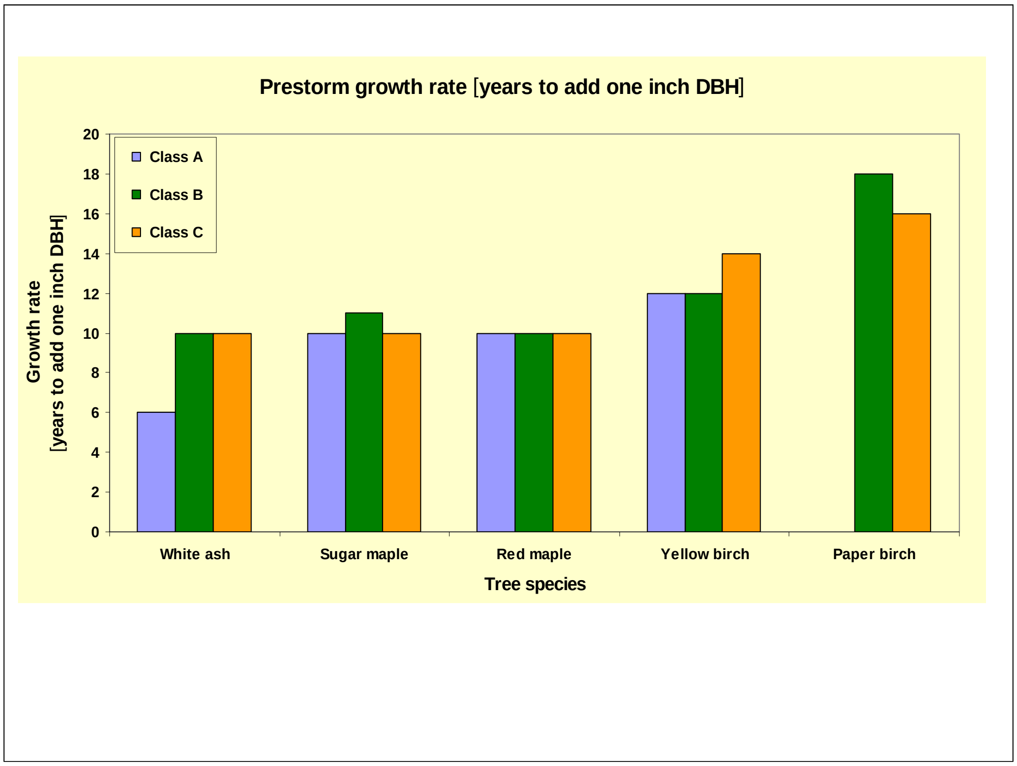
Number of trees observed in the tag-and-track study

Tree species	Crown loss class		
	A	B	C
Sugar maple	64	41	29
Red maple	24	16	12
Yellow birch	42	40	32
Paper birch	None	19	21
White ash	18	18	24

In the primary study 400 trees of 5 tree species were tagged; in a supplemental study 60 sugar maple and 60 American beech were tagged.

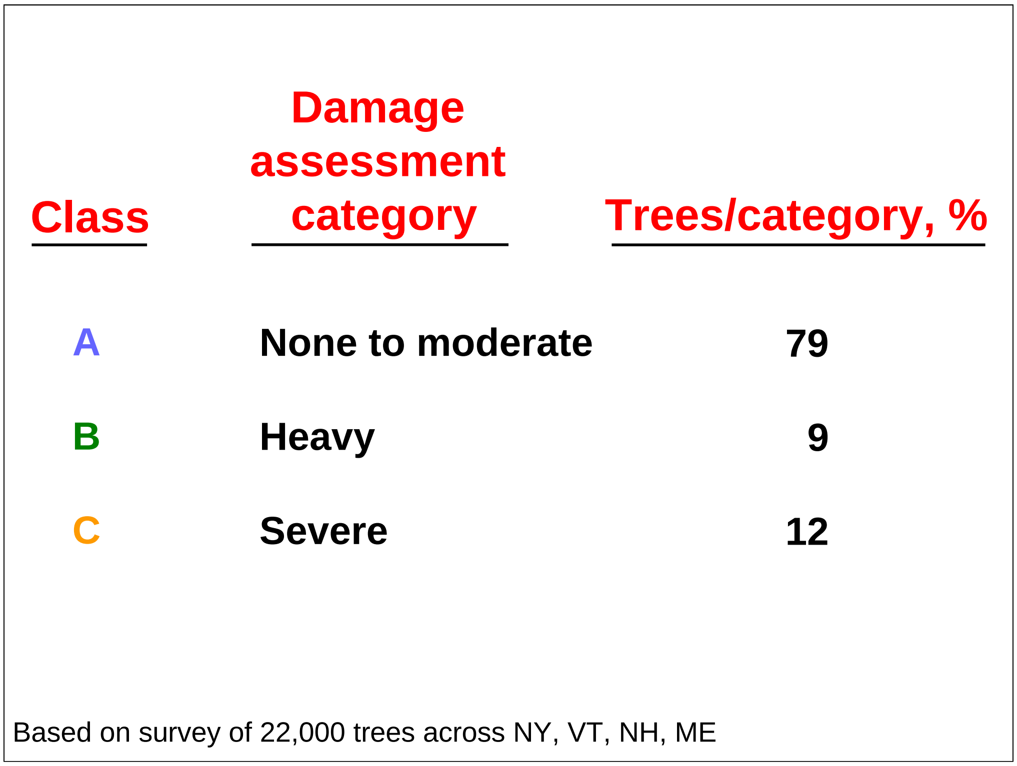


Trees of major concern for damage over the first several decades following the storm were large poles and smaller sawtimber that have lost more than half the crown. The tagged trees were 9-18 inches in diameter at breast height and averaged about one foot in diameter for each species and crown class.



Prestorm stem growth rates given as years to add one inch of stem diameter were about 10 years for white ash, red maple, and sugar maple (except class A ash, 6 years), 12-14 years for yellow birch, and 16-18 years for paper birch.

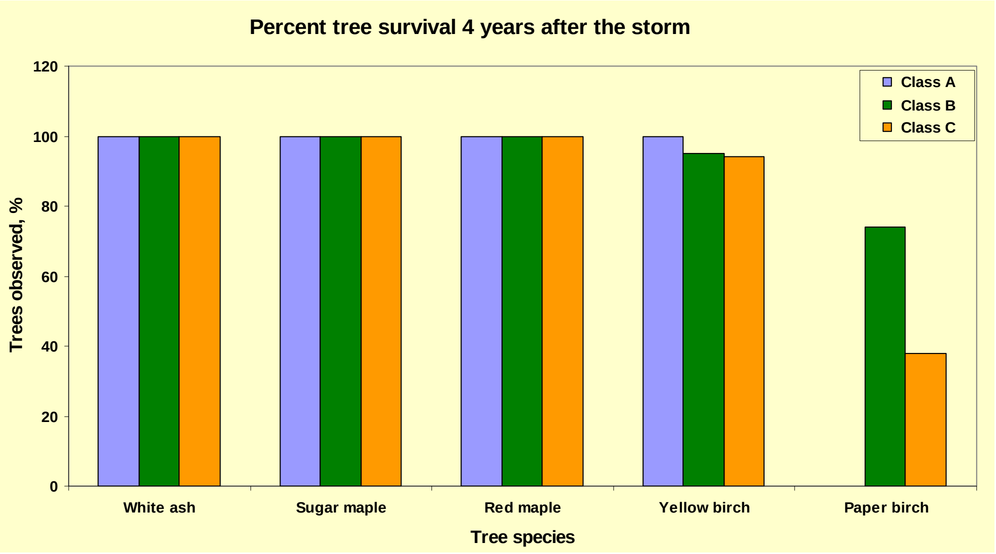
Each tagged tree received a borehole wound 3/8 inch in diameter to a depth of 2 inches. This treatment provided an injury to evaluate wound closure and the protective response of sapwood (codit) to limit the internal spread of wood-degrading infections following wounding. The tree response to wounding and infection in the butt section could then be compared to wounds in the broken tops when sample trees were cut and dissected. The borehole provided a simple test to evaluate how damage varied among crown loss class and tree species without having to fell trees to inspect the damage to tree tops.



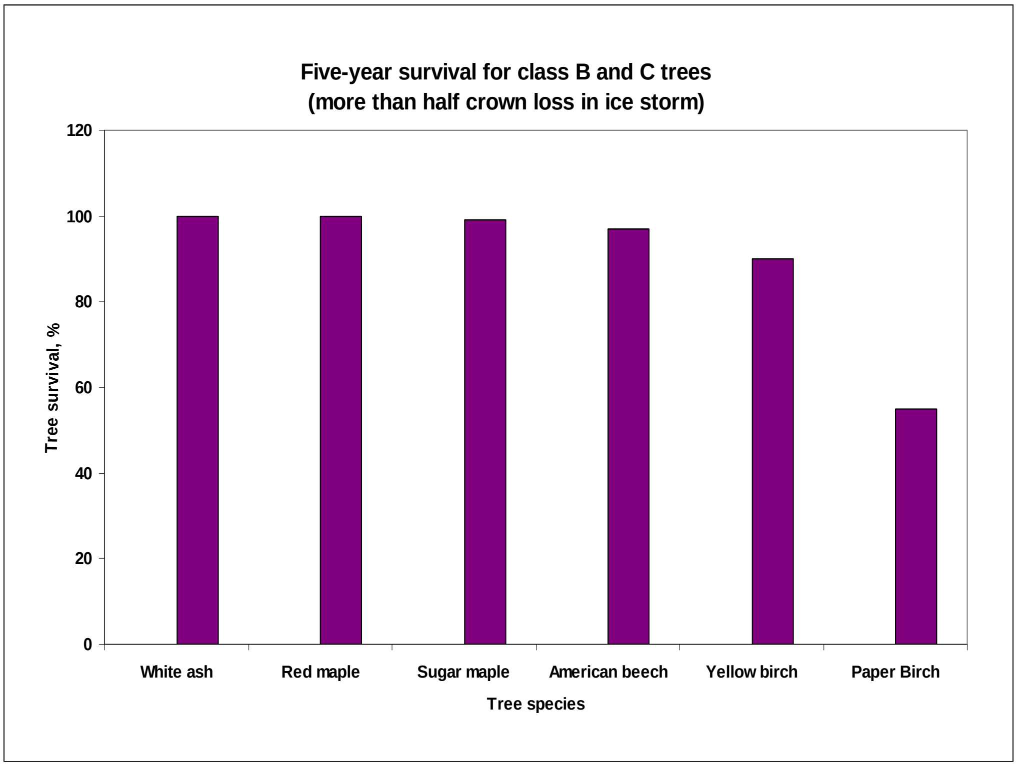
Class	Damage assessment category	Trees/category, %
A	None to moderate	79
B	Heavy	9
C	Severe	12

Based on survey of 22,000 trees across NY, VT, NH, ME

Chart showing frequency of crown loss classes across the region impacted by the storm based on a survey of 22,000 trees in the summer of 1998. About 80% of the trees examined had lost less than half their crown and are not expected to have long-term damage related to the storm; whereas 20% had lost more than half their crown and are at higher risk of having some adverse effects from ice storm injury. Our goal was to track the response of representative trees in the three crown loss classes in common northern hardwoods over the first 5 years after the storm.



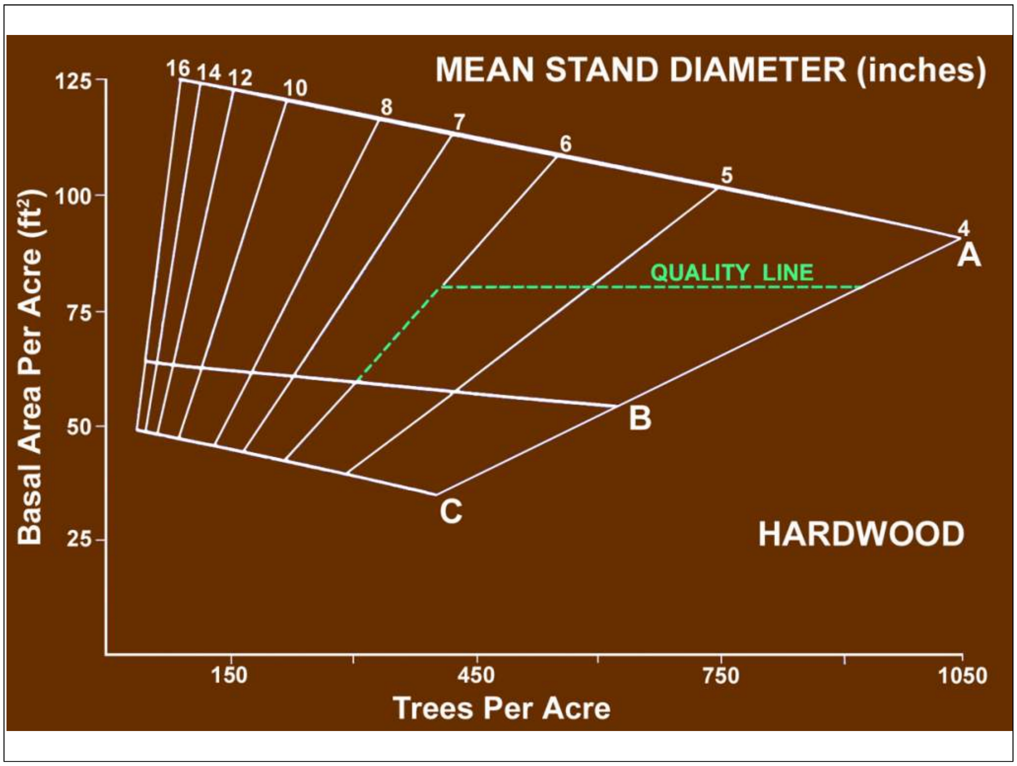
After 4 years all class A trees survived (remember we had no class A paper birch included in the study) as expected. All ash, maple and nearly all yellow birch of class B and C also survived. However, only 75% of class B and 40% of class C paper birch survived after 4 years. These sawtimber-size paper birch had suppressed stem growth prior to the storm (see slide 13). They were past maturity and should have been harvested once growth was suppressed and yet all had survived for 2 years after substantial crown loss. If harvested before the third year the wood could have been salvaged.



After 5 years not much had changed. All ash and maples, and nearly all beech and yellow birch of class B and C had survived.

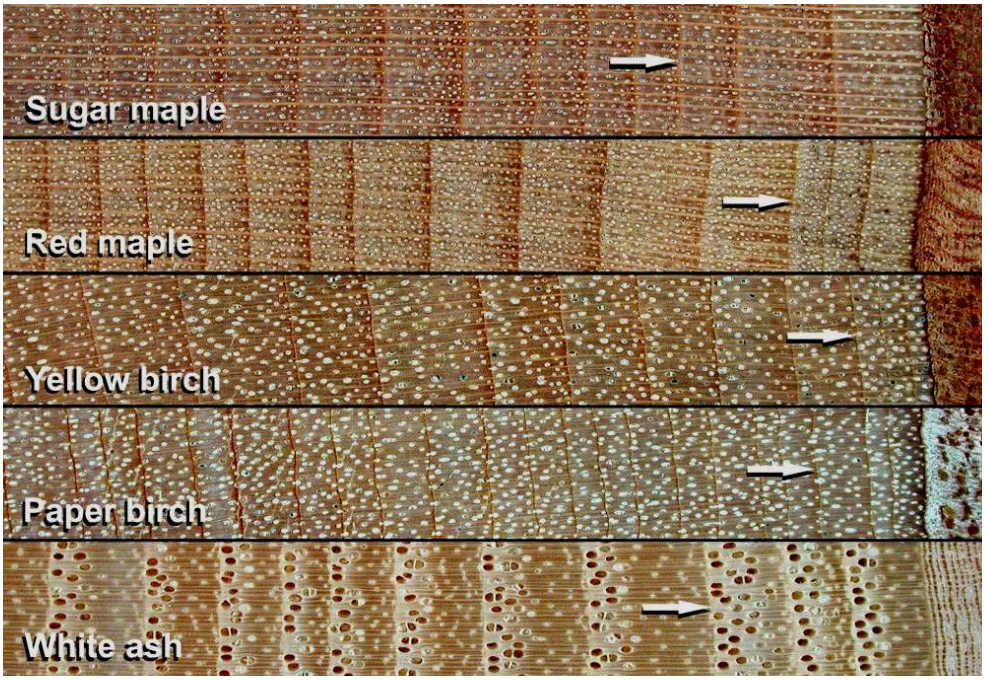
The few yellow birch that died and all the paper birch that died were all found to have advanced root-rot disease. Beneath the bark of roots were the mycelial fan of the Armillaria root-rotting fungus and on some roots the mushroom-type fruiting bodies were observed.

Central columns of advanced decay in the stumps of the dead trees indicated the root and butt rotters had been active for some time. With many roots lost to disease below ground and many shoots lost from the crown due to ice breakage, trees cannot survive for long. If roots were healthy then trees can survive substantial crown loss as new crowns are formed by sprouting.

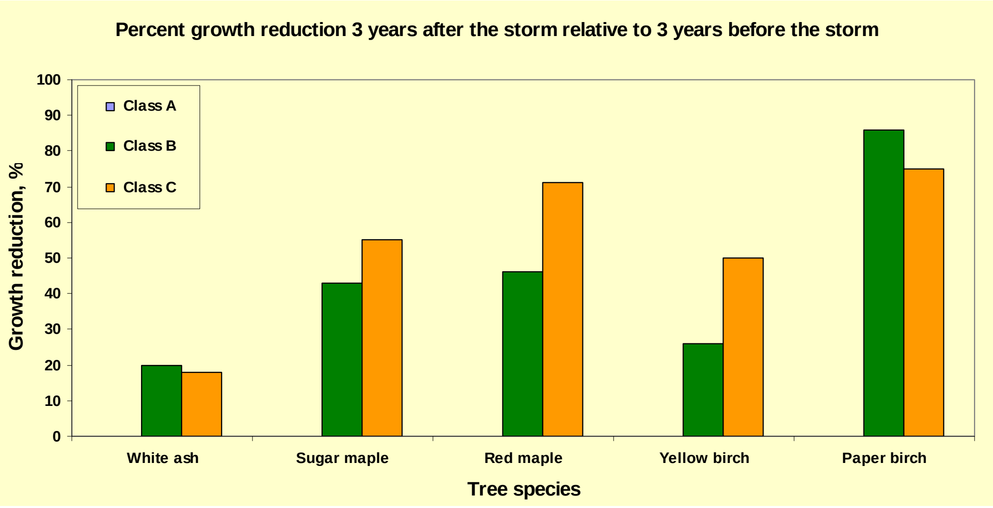


We need to consider that as tree stands mature most smaller, younger trees must die and decay to have healthy larger, older trees as illustrated in this stocking chart for northern hardwoods. Moving along the A or B lines and starting with 4-inch dbh saplings, 70% of the trees die and decay to have 8-inch dbh poles, and 90% die to have 16-inch sawtimber. This means that only a small fraction of young trees are long-term survivors and that periodic events like an ice storm, an insect defoliation, a tree disease, etc. will thin the stand. The dead trees decompose to maintain forest fertility and to support wildlife. Stocking levels can also be maintained by proper harvesting, but enough wood must remain on-site to sustain forest life (we are studying this subject to learn the right amount). So when evaluating potential tree survival kept the baseline mortality to sustain a healthy forest in mind.

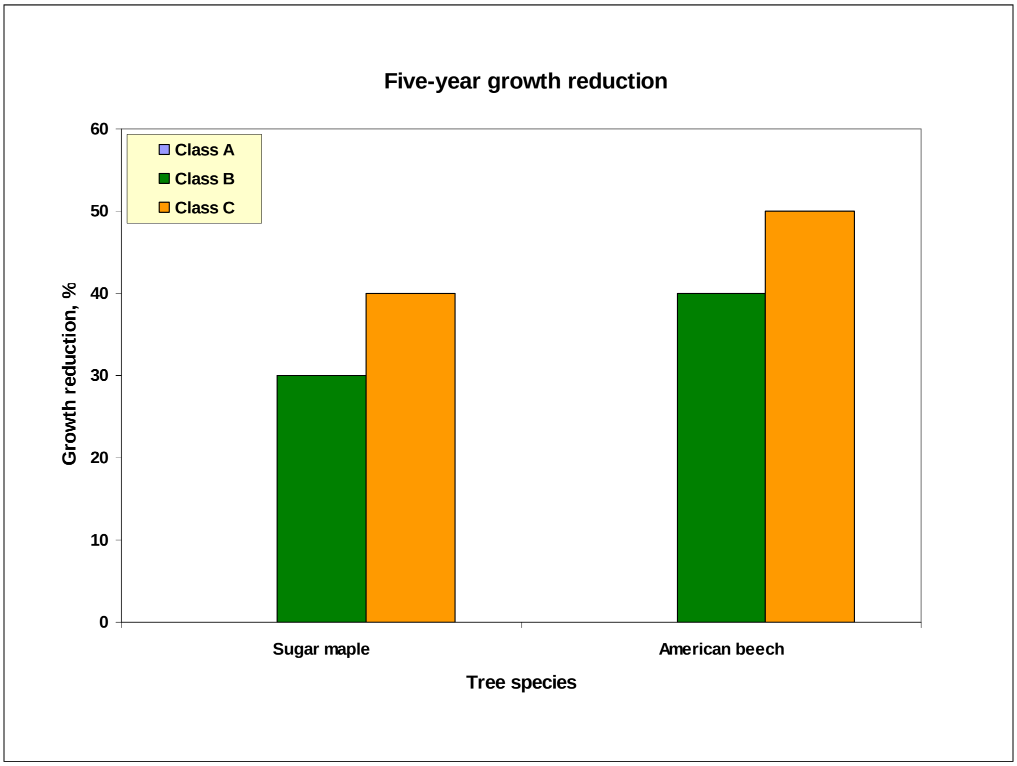
Stem growth following the storm was determined using 12 mm increment cores taken with a power borer. Cores were taken after 3 years in the primary study and 5 years in the supplemental study.



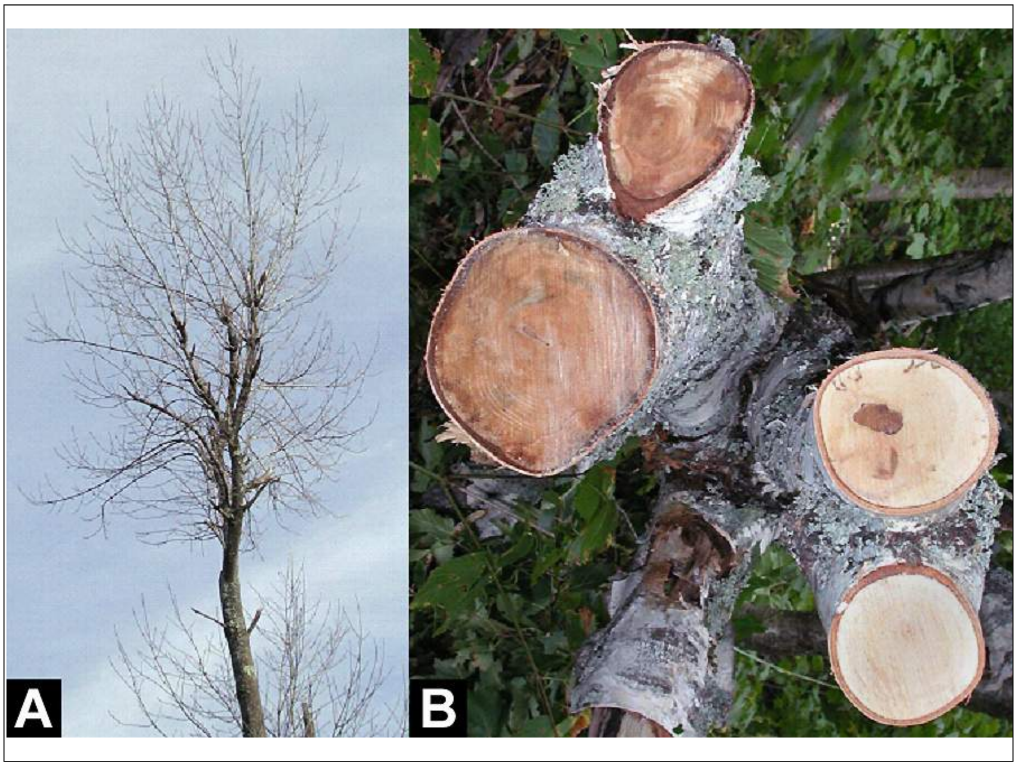
The cores were well sanded and growth ring widths were measured for 3 years after the storm and compared to 3, 5, and 10 years before the storm (arrows indicate the time of the 1998 storm after the 1997 growing season).



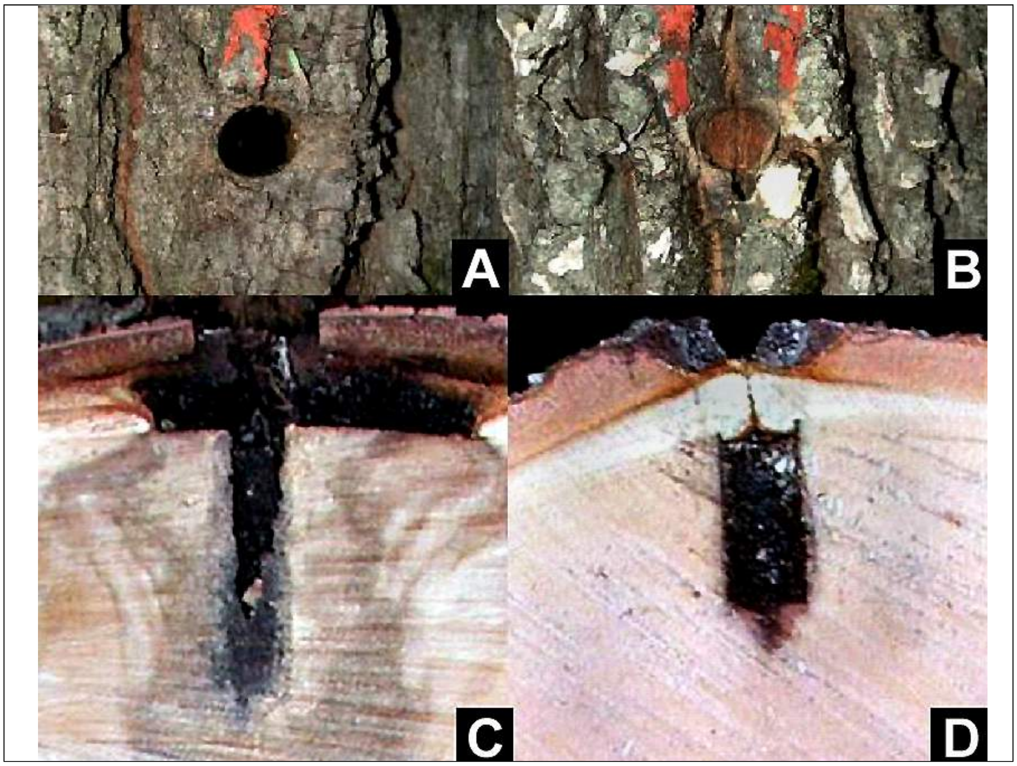
Class A trees had no growth reduction 3 years after the storm relative to 3, 5, or 10 years prior to the storm (remember again there were no class A paper birch). For class B trees, growth reduction ranged from 20% in ash to 70% in paper birch with maples and yellow birch in the intermediate range of 25 to 40%. Growth reductions were about the same or greater in class C trees.



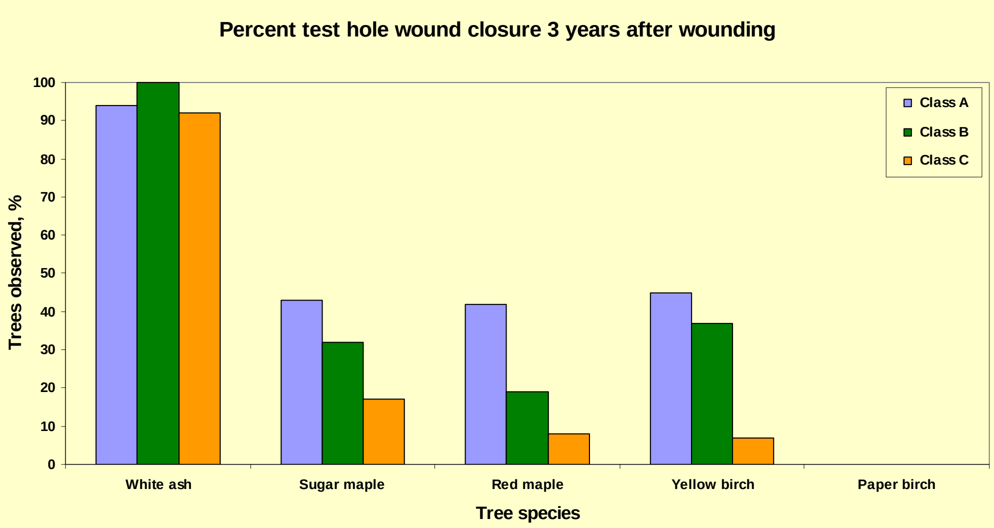
The stem growth in the supplemental study of sugar maple and American beech after 5 years gave essentially the same results as at 3 years; no growth reduction relative to prestorm growth in class A trees, 30-40% reduction in class B and C maple, and 40-50% reduction in class B and C beech.



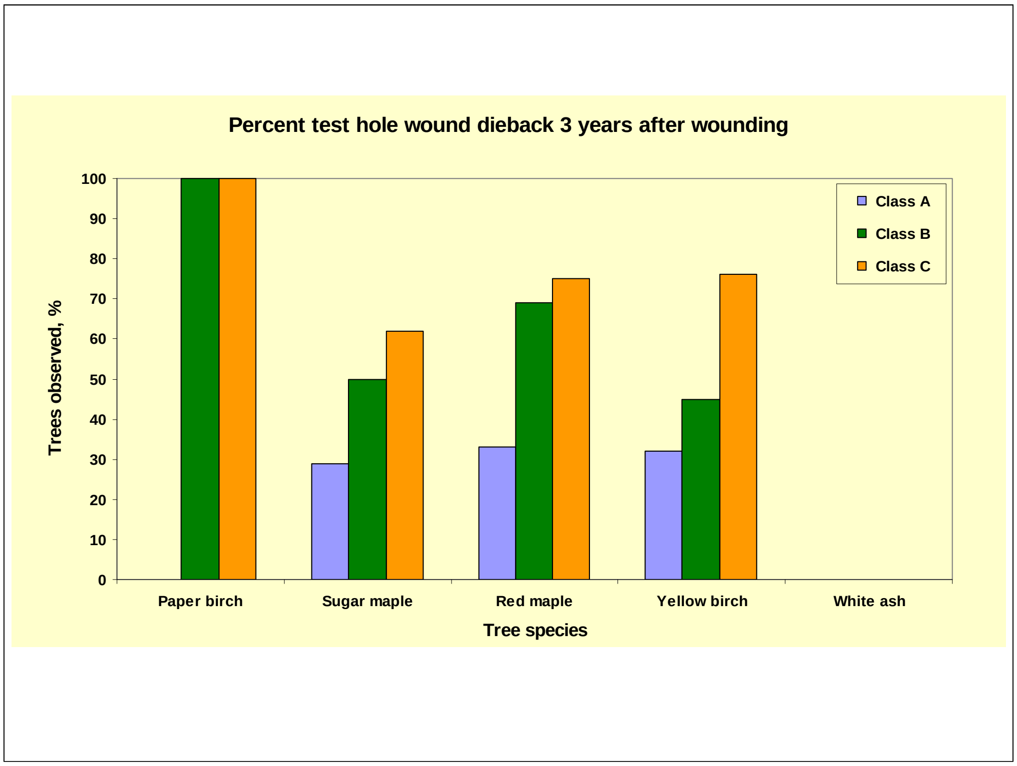
Growth reduction, or lack of it, depended primarily on sprouting of the upper stem to restore the crown lost to ice breakage. White ash sprouted vigorously (25A). Many class C ash trees lost most or all of their branches, but sprouts 6 feet or more in length and an inch or more in diameter were formed in the summer of 1998. The over-mature paper birch trees sprouted poorly with a few small sprouts and many stem stubs left by broken tops failed to sprout and soon died and began to decay (25B). If the stubs did sprout, the stub lived and infection spread slowly from the open wound leaving much of the sapwood healthy. Red maple, sugar maple, and yellow birch generally sprouted well, but lagged behind ash in crown replacement. Sprouting of the lower stem to produce epicormic branches occurred infrequently in yellow birch and rarely in other species.



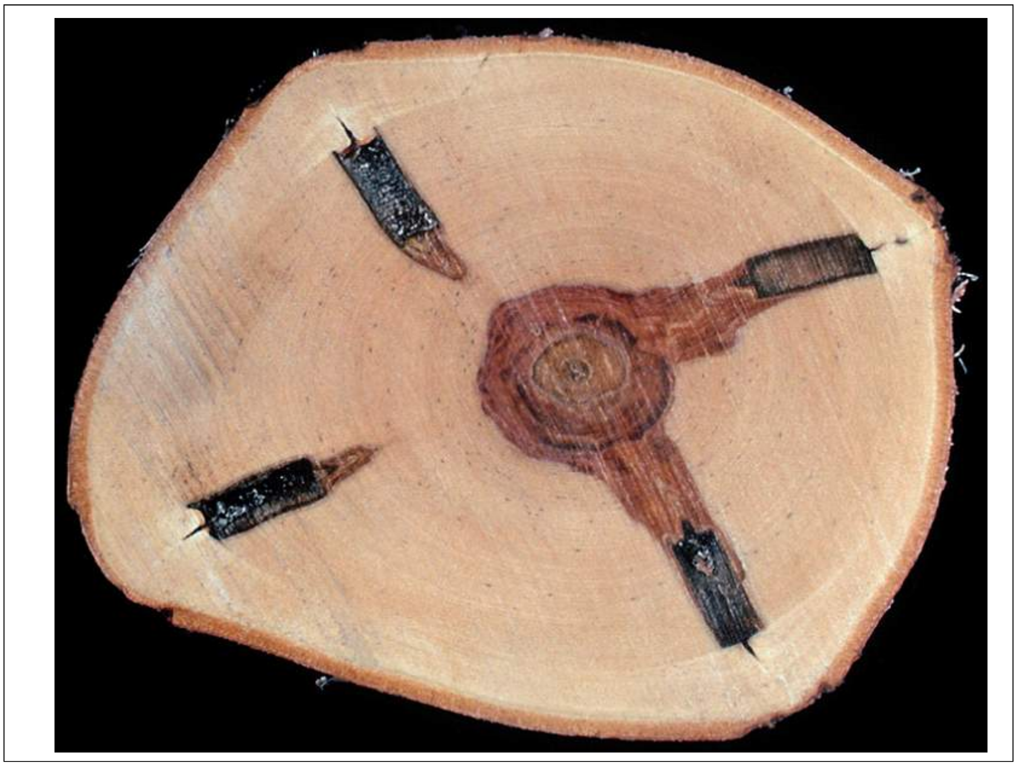
Wound closure failed to occur in some trees (26A). This was due to cambial dieback which made the wound larger and exposed sapwood to insect attack and to infection leading to more internal defect (26C). Wound closure was complete in 1 to 3 years in some trees (26B) and little internal defect was observed (26D).



Wound closure occurred most frequently in white ash with no differences among crown classes. About half the ash trees had full closure after 1 year and nearly all by 3 years. No ash trees showed any indication of cambial dieback associated with borehole wounds (slide 28). The strong cambial activity needed to produce woundwood ribs (formerly called callus) to close the wound was associated with good prestorm stem growth (slide 13) and vigorous sprouting to maintain that growth (slide 25). Wound closure did not occur in any paper birch trees and all the holes were fully open after 3 years. All holes had cambial dieback (slide 28). As with stem growth maples and yellow birch were intermediate to ash and paper birch with varying amounts of wound closure and cambial dieback 3 years after wounding. Wound closure in these species decreased from class A to B to C (slde 27) and dieback increased from A to B to C (slide 28). The greater the amount of dieback the longer closure was delayed and the greater the potential for internal development of wood discoloration and decay. Reduced cambial activity before and after the storm as lost crown needed to be replaced to increase food energy supply contributed to poor closure and dieback, and more infection.

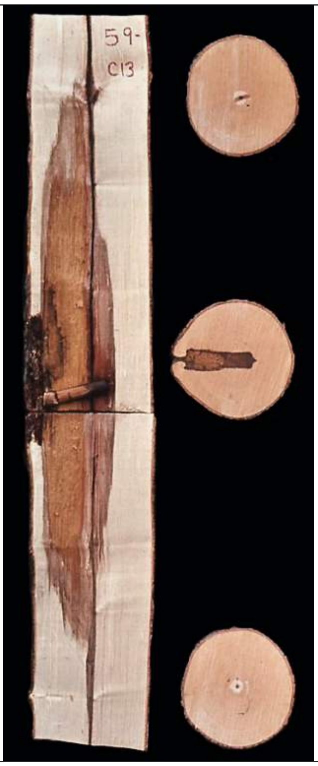


Cambial dieback occurred in all paper birch trees, increased with degree of crown loss in yellow birch and maples, and did not occur in any white ash. The greater the dieback, the greater the amount of wood degradation (see slide 26).

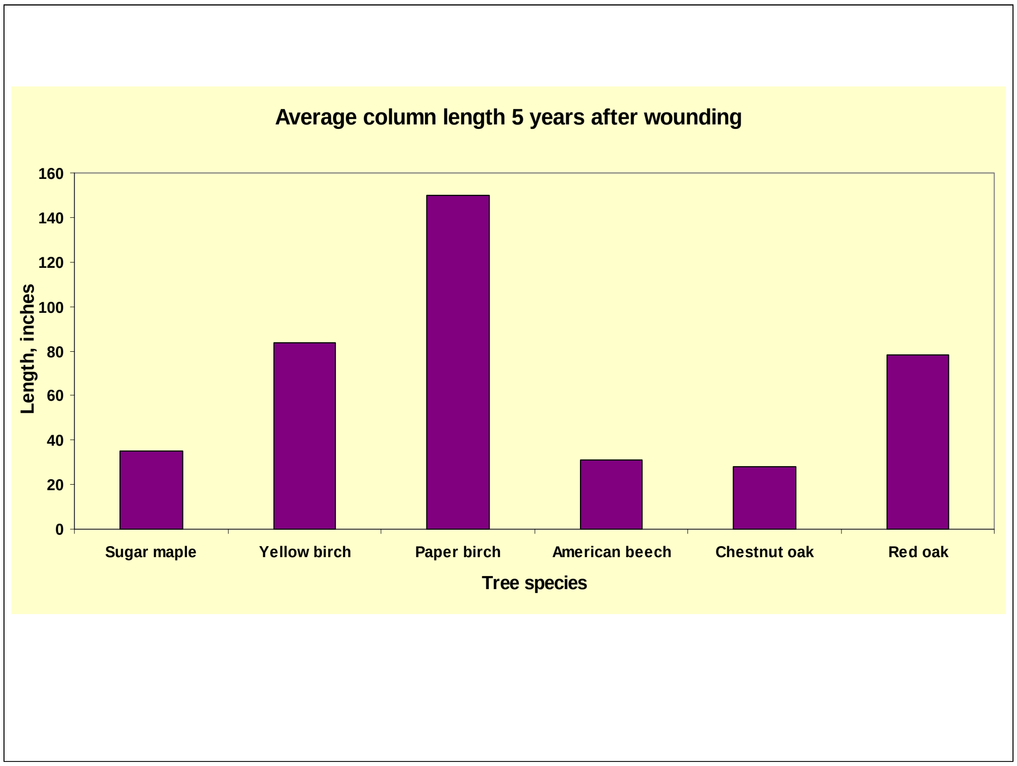


Young, vigorous pole-size paper birch trees with healthy roots given 4 borehole wounds had complete wound closure and little defect after 20 years unlike the over-mature paper birch with diseased roots in our storm study.

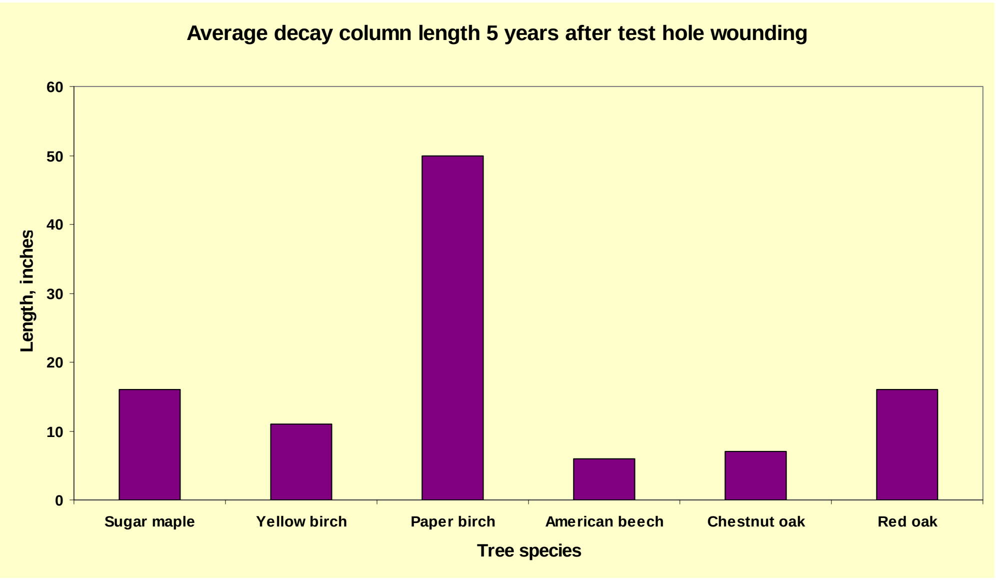
Even with good wound closure, wood discoloration can develop because of genetic factors, but wood decay needs open wounds to aerate the infection for decay-fungi to decompose wound-initiated discolored wood.



The basic biology that governs tree response to injury and infection has been studied by making borehole wounds in trees followed by cutting and dissection for many years. These data help us predict how different species of trees at different stages of development in their life history are likely to respond to a variety of wounding events taking place in the forest. Much of this work was begun in the 1960s by Alex Shigo and has been continued by Walter Shortle and Kevin Smith.



In our experiments birch was found to discolor more rapidly than maple and beech.



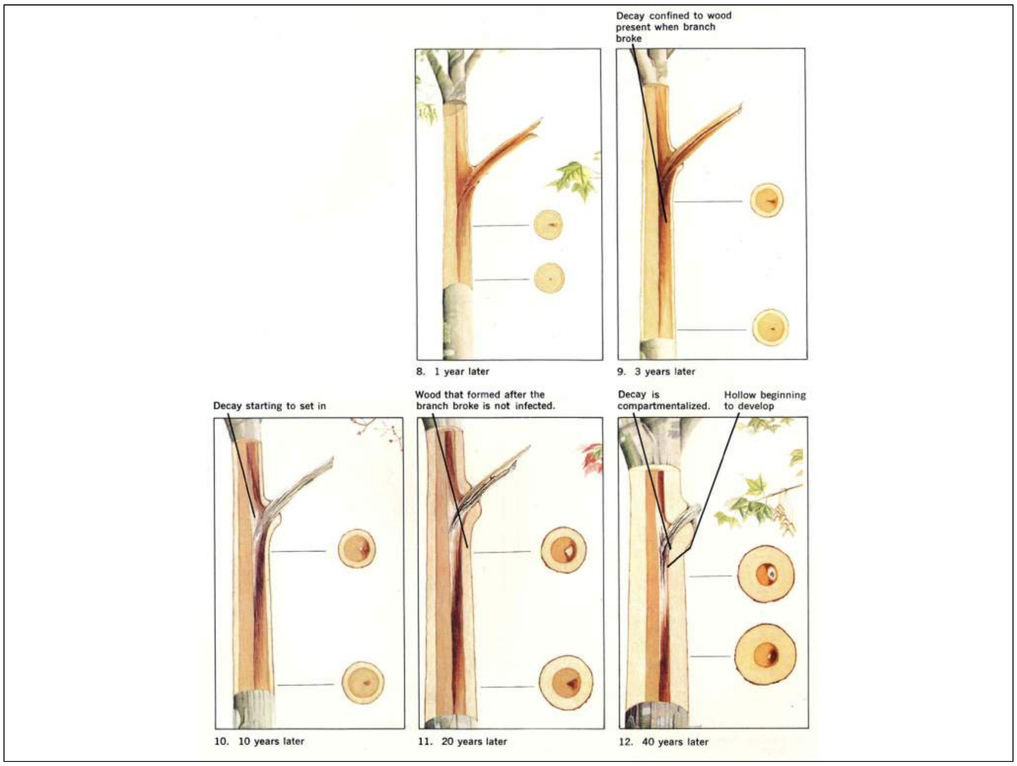
However, decay rates were about the same in sugar maple, yellow birch, and beech, but paper birch had more decay probably due to more cambial dieback keeping wounds open in older, larger trees with suppressed stem growth.

Neil Lamson of State and Private Forestry found where large sugar maple (> 30 inches dbh) had been damaged 10 years before cutting by a local ice storm and had the top 18 feet of 9 trees saved for dissection. The broken tops were 6-8 inches in diameter (8 inches is about the upper size limit for breakage). The tops were dissected using a portable bandsaw mill using the “worst opening face” to show the maximum possible extent of defect that developed 10 years after ice storm breakage. The wood discoloration merged into central columns of discolored wood arising from prior wounds. Visibly decayed wood extended to a maximum of 30 inches (3 inches per year after 10 years). Earlier results in sugar maple from an ice storm in Pennsylvania had 4 inches of decayed wood from a 6-inch broken top after 4 years (1 inch per year). People gathered to watch the dissections were surprised to see so much white wood associated with major top breakage, but sapwood close to branches that supply plenty of food energy from leaves in maple has a strong protective (codit) response within certain genetic limitations. Discoloration and decay from broken branches, snapped stems, and split forks in the crown due to icing will seldom, if ever, extend below the sawlog top of northern hardwood sawtimber damaged by an ice storm.

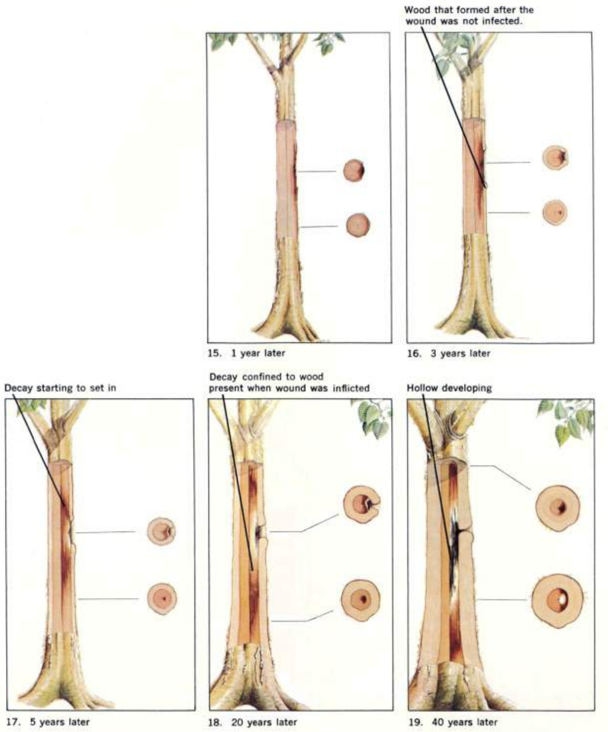
We dissected trees 2 and 4 years after the storm and observed wound-initiated discoloration of generally less than a foot in ash, maple, and beech and up to several feet in birch as expected. Central columns from stem stubs connected with columns resulting from the usual mixture of wounds unrelated to the storm. Decay was very limited as we see in this birch. All internal defects associated with top breakage were above the sawlog top (9 inches dob) with the exception of a few split forks that extended below the top.

A common column of discolored and decaying wood arising from a branch stub observed 4 years after the storm.

A larger split fork in ash observed 4 years after the storm with localized discoloration and decay on one face.



Wound-initiated discoloration and decay is a slow process in healthy trees with good growth rates. The columns that develop in smaller, younger trees from branch and stem stubs and from scars (slide 39) take decades to develop in long-term survivors (remember most of these trees will not survive to become mature sawtimber because their protective systems fail due to internal lack of disease resistance or external environmental influences). However, if the protective system works well and stem growth is sustained defect stays in the center and occupies very little of the total wood volume. If protection is weak and growth is poor the tree dies and decays to provide space and improve forest fertility for the survivors.



We see the same long-term pattern in scar type wounds as well as stub type wounds (slide 38).

A large class C yellow birch with a basal logging scar 7 years after the storm. Fruiting bodies of a wood-decay pathogen that would normally be confined to the open face of the wound are now coming through the bark beyond the woundwood ribs. The protective system has failed and cambial activity has been suppressed. The surviving crown is too small and too far away from the wound to provide enough food energy to maintain normal function. Energy has been diverted to sprouting to replace lost branches and to protect against infections developing in wood exposed by ice breakage. Roots and the lower bole must survive on food stored over past years, but as it runs out and is not replaced, life processes begin to fail. As with the case of preexisting root-rot infections in dead trees, wood infections from preexisting major wounds leads to loss of value before loss of life.

A large class C sugar maple with basal injury 7 years after the storm. The crown is alive and is large enough to support the functions of a pole-size tree but not a sawtimber-size tree. Fruiting bodies of a wood-decay pathogen are appearing on the dying side of the bole. The growth and protective functions are failing. If the lower bole and roots had been healthy, the large maple would have suppressed growth, but would likely to continue to survive as a sound tree for some time.

Based on our borehole wound studies, the butt section of class B and C trees will be more sensitive to basal wounding following the ice storm. This should be considered when planning harvests in ice damaged stands.

Conclusions:

Tree damage from the ice storm was strongly related to:

Tree health before the storm

Ability to rebuild tree crowns

Rate of wound closure

Ice storms are a natural feature of forests of the northeastern United States and will surely occur again. Trees that are healthy and responsive before the storm are more likely to survive and will recover more quickly from storm injury. Timber stand improvement to enhance tree health may be a prudent preventative treatment. Reduced residual logging damage may decrease the chance of root infection and spread of infection within the tree.

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