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Ice Storm Damage to Virginia Coastal Plain Forests during the Christmas 1998 Ice Storm

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ABSTRACT

On December 23-25, 1998, a major ice storm struck southeastern Virginia. The storm-deposited glaze ice felled trees and limbs, causing a power outage and highway blockage. Between February and April, 1999, we recorded occurrence, severity, and type of damage to trees over 2.5 cm dbh in nine mostly gently sloping plots in Matoaka Woods at the College of William and Mary. Frequency and severity of damage varied with species and with size of trees. Canopy damage occurred in 75% of large *Fagus grandifolia* trees, but in only 6% of small *Sassafras albidum* stems. As a group, small (2.5 to 15 cm dbh) trees were less likely to be damaged than large (15 cm dbh) trees, but about as likely to be severely damaged. Damage type also varied among the species and size. Despite severe damage to public utilities, damage within the forest was not great. Since few trees lost their entire crown, canopy gap sizes were small, and it not clear that much change in forest composition will result from this storm. However, increased density of ground litter will contribute to greater mineral release, and this plus small gaps may promote growth of already present seedlings and saplings.

INTRODUCTION

On December 23, 24, and 25, 1998, a major ice storm affected southeastern Virginia. Precipitation in the form of sleet and freezing rain accumulated to 1-3 cm of ice across the region, with Williamsburg reporting 3 cm of precipitation for the three-day period. In the City of Williamsburg and surrounding counties, 400,000 customers lost power for three to ten days following the storm. Many roads, including portions of Interstate 64 near Lightfoot, VA, were rendered impassable by fallen branches and trees (NCDC 1998a,b). The storm's impact on the community was certainly severe, and much of the infrastructure damage was caused by ice-felled branches and trees along roadsides and on forest margins.

Based on the degree of damage readily observable from the roads, we felt that this storm presented an ideal opportunity to determine the effects of ice accumulation on local forests. The great damage to roadside and forest margin trees, however, was due to their peculiar location. Without adjacent vegetation of comparable height to support their accumulated weight in ice, and with either asymmetric or fuller crowns due to lack of competition for light, individuals in the open would likely be more susceptible to damage than those in the forest. Nevertheless, preliminary investigation of our potential study sites indicated that, although the damage within the forest was not as heavy as on its margins, it did appear significant enough to provide data for a meaningful study on the dominant tree species of the area.

We surmised that the College Woods (also called Matoaka Woods), a forested area owned by the College of William and Mary, was an ideal place for a small-scale investigation into the susceptibility to ice of several major tree species on the Coastal Plain of Virginia. Matoaka Woods is made up of a variety of small, homogenous stands dominated by canopy species such as tulip poplar (*Liriodendron tulipifera*), oaks (*Quercus* spp.), beech (*Fagus grandifolia*), and loblolly pine (*Pinus taeda*). The mosaic pattern of the woods (farmed and forested patches were abandoned or last timbered at various times for various reasons) has allowed for a diversity of species, and also has ensured equal representation of a broad spectrum of size classes. In this study, our primary goal was to survey the amount and type of damage to each of the more abundant tree species in Matoaka Woods. Of secondary interest was the comparison of damage among different size individuals of the same species.

METHODS

Our field survey was conducted in the Matoaka Woods of the College of William and Mary between February 3 and April 7, 1999. No further forest-ravaging natural phenomena occurred between the end of the Christmas storm and the completion of our survey. Sampling sites were chosen based on the constituent species and apparent age of the dominant individuals: younger and older stands dominated by oak species, tulip poplar, loblolly pine, and beech were sought out with the hopes of comparing damage between different aged canopy trees of the same species or genus, as well as among the different species. The sampling sites were widely spread throughout the woods.

We chose to follow Seischab et al. (1993) in our methodology. We marked a 20x40-meter plot at each sampling site. Each of these was broken into four 10x20 meter subplots for ease in sampling. In each subplot, trees larger than 2.5 cm dbh were identified by species and were placed in one of two size categories: between 2.5 and 15 cm dbh and over 15 cm dbh. In general, trees in the smaller size class were subcanopy, and those in the larger size class were in the canopy. Though we took measures to avoid bias toward areas likely to be heavily damaged (such as steep slopes above ravines; Warrillow and Mou 1999), beech-dominated stands could not be found in the more level portions of the woods. Thus, in order to sample beech, it was necessary to place two plots on slopes. Effects on the results due to this difference in topography will be discussed later.

Each tree surveyed was placed in a damage class between 0 and 7 based on percent canopy loss due to ice damage. A rating of 0 corresponded to no perceptible damage, 1 to ≤ 5 % canopy loss, 2 to 6-10% canopy loss, 3 to 11-25% canopy loss, 4 to 26-50% canopy loss, 5 to 51-75% canopy loss, and 6 to 76-99% canopy loss. A rating of 7 was given where damage was so severe that mortality was likely. Though we quantified canopy damage as an estimate of percent of canopy lost, the accuracy of our estimates was necessarily subject to error, for we were not able to observe the leafed out canopies of deciduous trees, nor had we previously documented canopy sizes for any of the trees surveyed. However, every effort was made to be consistent.

We recorded the nature of the damage to each tree, noting whether each damaged tree was uprooted (symbolized by o- in the tables), had its main stem broken (symbolized by / \), had its main stem bent or bowed (Ç), had one or more branches completely broken from the tree (o), had one or more branches broken but still attached to the tree (/\). We also noted whether the damage, of whatever type, was direct (as a result of ice accumulation on the tree in question) or secondary (a result of ice-laden branches,

TABLE 1. Field data for individuals ≥ 15 cm dbh. See text for description of damage classes and types.

Species	Sample size	Damage class 0	1	2	3	4	5	6	7	Damage type o	- / \	Ç	Λ	o	s
Pinus taeda	53	29	2	7	3	3	1	2	6	-	7	2	1	12	-
Liriodendron tulipifera	47	27	5	6	2	3	2	2	-	-	-	-	-	15	-
Quercus alba	35	21	6	1	3	3	1	-	-	-	-	-	5	4	-
Fagus grandifolia	28	7	5	4	4	3	4	1	-	-	1	-	4	16	1
Oxydendron arboreum	23	13	4	-	4	1	-	1	-	-	1	2	-	5	2
Liquidambar styraciflua	15	12	1	-	-	-	1	1	-	-	-	-	-	2	-
Quercus velutina	11	6	2	2	1	-	-	-	-	-	-	-	2	1	-
Acer rubrum	9	4	-	-	2	1	-	2	-	-	1	-	2	4	-
Carya glabra	8	6	-	-	-	1	1	-	-	-	-	-	2	-	2
Quercus falcata	6	3	1	1	1	-	-	-	-	-	-	-	-	2	-
Nyssa sylvatica	5	3	-	-	2	-	-	-	-	-	-	-	1	1	-
Quercus rubra	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilex opaca	3	1	2	-	-	-	-	-	-	-	-	-	1	-	-
Quercus coccinea	3	2	-	-	1	-	-	-	-	-	-	-	-	1	-
Cornus florida	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Carya tomentosa	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Fraxinius americana	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Prunus serotina	1	-	-	-	-	-	-	-	1	-	1	-	-	-	-

canopies, or entire trees falling on individuals below). Recently fallen live branches ≥ 2.5 cm at the broken base (butt end) found in the plots were tallied by species and size; any above 10 cm diameter at the base were further noted. We did not attempt to quantify the deadwood since it was impossible to distinguish dead material felled by this storm from that previously on the ground.

By performing our investigation in the winter and early spring immediately following the ice storm, we were able to easily determine the most recent open wounds and fallen branches, for the infection and decay dependent on warm temperatures had not begun. We also avoided the possibility of additional damage from other natural disasters (such as windstorms, including the hurricane that struck the study area the following summer). Because no new growth had begun on bent or wounded stems, we could distinguish fresh bending from older bending or breaking, since trees previously damaged had redirected their foliage or sprouted new stems during the last growth season. The lack of intervening foliage in the understory made it easier to examine damage to canopy trees, but, as mentioned previously, percent canopy loss was harder to estimate accurately without foliage.

RESULTS

We found no significant differences in damage between older stands and younger stands with the same dominant species. Because of this finding, descriptions of individual plots have not been included, and all data from each species have been merged to reflect interspecific differences and differences between the canopy and understory classes. The amount and type of damage incurred by the 27 species we encountered during our survey is shown in Tables 1 (individuals ≥ 15 cm dbh) and 2 (individuals < 15 cm dbh).

TABLE 2. Field data for individuals < 15cm dbh. See text for description of damage classes and types.

Species	Sample size	Damage class 0	1	2	3	4	5	6	7	Damage type o-	/\	Ç	Λ	o	s
Liriodendron tulipifera	146	109	12	5	1	1	4	4	9	-	12	9	3	5	8
Cornus florida	132	106	8	2	6	5	-	2	3	-	-	8	1	[illegible]	12
Acer rubrum	75	46	6	5	6	2	2	5	3	-	4	6	10	4	5
Oxydendron arboreum	54	27	4	4	4	2	-	6	7	3	2	11	4	4	12
Ilex opaca	49	31	3	4	5	5	1	-	-	-	-	7	3	6	8
Liquidambar styraciflua	44	36	3	1	-	2	-	1	1	-	1	4	1	1	3
Fagus grandifolia	40	36	3	-	-	-	-	1	-	-	1	2	-	-	1
Nyssa sylvatica	37	31	3	2	1	-	-	-	-	-	-	-	2	1	-
Sassafras albidum	17	16	-	-	-	-	1	-	-	-	-	-	-	1	-
Carya glabra	14	9	2	-	1	1	-	-	1	-	1	2	-	-	2
Quercus alba	6	5	1	-	-	-	-	-	-	-	-	-	-	-	-
Pinus taeda	5	1	-	-	2	-	-	-	2	-	2	2	-	-	-
Carya tomentosa	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Castanea dentata	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Cercis canadensis	5	3	1	1	-	-	-	-	-	-	-	1	1	1	1
Quercus velutina	5	4	1	-	-	-	-	-	-	-	-	-	-	-	-
Juniperus virginiana	4	2	2	-	-	-	-	-	-	-	-	1	-	-	-
Vitis rotundifolia	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Diospyros virginiana	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Kalmia latifolia	1	-	-	-	1	-	-	-	-	-	-	-	1	-	-
Quercus rubra	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Vaccinium corymbosm	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Viburnum nudum	1	-	1	-	-	-	-	-	-	-	-	1	-	-	1

Tables 3 through 6 show the occurrence and severity of damage to the most abundant species in Matoaka Woods. When the Chi square test was applied to these data, only the outlying values (those furthest apart) proved statistically different. That is, in Table 3 the degree to which *Fagus grandifolia* was affected by the storm was significantly different only from that of *Liquidambar styraciflua* of the same size—there were no statistically significant differences among the other species. When the results for occurrence and severity of damage to all small trees combined versus all large trees combined were compared (Table 7), statistically significant differences between size classes were achieved. Of the 908 trees surveyed, 32% were damaged by this ice storm, and 12% were severely damaged (placed in damage class 4 or above, which means they have lost 25% of their crown). Smaller trees were less likely to be damaged than larger trees, but when damaged, smaller trees were about as likely to incur severe damage as larger trees. Table 8 shows the results from our tally of fresh fallen branches

DISCUSSION

Although it was impossible to gather quantitative data on damage in open areas or on forest margins (the necessity of quick cleanup to restore community infrastructure prevented it), our final results suggest that the severity of roadside damage greatly overrepresents the damage from the storm as a whole. Compared to other studies of ice storm damage to forests, the occurrence and severity of damage in Matoaka Woods

TABLE 3. Frequency of damage in large trees (dbh ≥ 15 cm). Species with sample size < 10 are not included.

Species	Sample size	Number damaged	% damaged
Fagus grandifolia	28	21	75
Pinus taeda	53	24	45
Quercus velutina	11	5	45
Oxydendron arboreum	23	10	43
Liriodendron tulipifera	47	20	43
Quercus alba	35	14	40
Liquidambar styraciflua	15	3	20

TABLE 4. Frequency of ice damage in small trees (dbh < 15 cm). Species with sample size < 10 are not included.

Species	Sample size	Number damaged	% damaged
Oxydendron arboreum	54	27	50
Acer rubrum	75	29	39
Ilex opaca	49	18	37
Carya glabra	14	5	36
Liriodendron tulipifera	146	36	25
Cornus florida	132	26	20
Liquidambar styraciflua	44	8	18
Nyssa sylvatica	37	6	16
Fagus grandifolia	40	4	10
Sassafras albidum	17	1	6

places the December 1998 storm among the less destructive of these reported in published studies. Whitney and Johnson (1984) documented that 46% of all trees surveyed after a southwestern Virginia glaze storm were severely damaged. In another study following an Ohio icing event, 15.5% of trees surveyed were severely damaged (Boerner et al., 1988). Our results indicate that 8% of stems were severely affected by this storm. That is not to say that the storm was not severe from a Coastal Plain perspective, for we found no previous study describing glaze damage in this area.

The results show that throughout the area surveyed, large trees were more frequently damaged than small ones. Given the lack of foliage in the canopy and the duration of the precipitation during this storm, it is likely that in hardwood stands subcanopy stems were exposed to icing on the same order as larger trees. In addition, the occurrence of secondary damage (that caused by the falling limb or crown of a neighbor, usually a canopy tree) was much greater in the smaller size class than the larger. Note Tables 1 and 2: small trees suffered 53 instances of secondary damage vs. 5 such cases large trees. Thus, except for stands dominated by evergreens, one would expect that the absence of canopy shelter and the likelihood of secondary damage would make subcanopy trees even more susceptible to storm damage. As this was not the case, some other factors must account for the smaller trees' resistance.

TABLE 5. Severity of damage in large trees (dbh ≥ 15 cm).

Species (over 15 cm dbh)	Number damaged (all damage classes)	Number severely damaged (damage class 4 or above)	% of all trees with severe damage	% of damaged trees with severe damage
Pinus taeda	24	12	23	50
Fagus grandifolia	21	8	29	38
Liriodendron tulipifera	20	7	15	35
Liquidambar styraciflua	3	2	13	33
Quercus alba	14	4	11	29
Oxydendron arboreum	10	2	9	20
Quercus velutina	5	0	0	0

TABLE 6. Severity of damage to small trees (dbh < 15 cm).

Species (under 15 cm dbh)	Number damaged (all damage classes)	Number severely damaged (damage class 4 or above)	% of all trees with severe damage	% of damaged trees with severe damage
Sassafras albidum	1	1	6	100
Oxydendron arboreum	27	15	28	56
Liriodendron tulipifera	36	18	12	50
Liquidambar styraciflua	8	4	9	50
Acer rubrum	29	12	16	41
Carya glabra	5	2	14	40
Cornus florida	26	10	8	38
Ilex opaca	18	6	12	33
Fagus grandifolia	4	1	3	25
Nyssa sylvatica	6	0	0	0

Many small trees suffering from secondary damage were simply bowed over, some with their crowns forced all the way to the ground, but they were rarely broken. Accordingly, we observed 54 events of bending in small trees and only 4 in large trees (Tables 1 and 2). Whitney and Johnson (1984) and Boerner et al. (1988) have also noted the relative elasticity of younger wood as a factor in glaze damage susceptibility. Therefore, it is likely that in the month interim between the melting of the ice and the beginning of our investigation, small trees temporarily bent under the weight of the ice had already straightened themselves due to their youthful resilience.

Among the various species, several deserve attention due to their exceptional tendency toward, or resistance to, damage. While individuals in the large tree category were generally canopy trees, one case deserves special attention. Our initial survey of damage seemed to indicate that tulip poplar would be among the most susceptible, but results show that it falls near the mean value for occurrence of damage in the large tree category. One possible explanation for our initial impression of high damage to tulip poplar is that the usual type of damage to large trees of this species was loss of complete

TABLE 7. Frequency and severity of damage in all trees surveyed.

	Total number	Number damaged	% damaged	Number severely damaged (damage class 4 or above)	% severely damaged
Over 15 cm dbh	264	119	45	44	16
Under 15 cm dbh	644	173	27	71	11
Combined (all sizes)	908	292	32	115	12

TABLE 8. Branches over 2.5 cm in diameter at butt end found in plots.

Species	Number of storm-felled branches over 2.5 cm diameter butt end	Number of those branches over 10 cm diameter butt end	Total number of damaged trees	Felled branches/ damaged trees
Liriodendron tulipifera	154	7	56	2.8
Pinus taeda	42	14	28	1.5
Fagus grandifolia	36	8	25	1.4
Pinus virginiana	6	1	6	1.0
Quercus velutina	5	1	6	0.83
Quercus alba	10	4	15	0.67
Acer rubrum	13	0	34	0.38
Oxydendron arboreum	9	0	37	0.24

branches (Table 2), resulting in a high abundance of broken tulip poplar branches on the ground (Table 8). Another fact that directly affects our data is that in our older pine stand, there were a large number of tulip poplar stems just over 15 cm dbh growing beneath the canopy. It is likely that the full canopy of the evergreens shielded these tulip poplars from an otherwise destructive ice load, and thus skewed the damage results for the large size class of tulip poplar.

The large value for percent of *Fagus grandifolia* stems damaged requires explanation. While most of the dominant species in Matoaka Woods could be represented in plots with little or no overall slope, American beech occurred as the dominant canopy species only on the steep slopes of drainage ravines. Trees located on slopes often have asymmetrical crowns which, when laden with ice, become unbalanced and more susceptible to breakage than similar trees with uniform crowns. These observations are echoed by Boerner et al. (1988), Bruederle and Stearns (1985), Seischab et al. (1993), Warrillow and Mou (1999), and Rhoades (1999). The few smaller American beech individuals located in plots dominated by other species were normally unbroken, and though their branches were typically bowed, we could not confidently attribute that bowing to the December icing event. On the other hand, the residential neighborhoods in the Williamsburg Area with the most severe infrastructure damage were neighborhoods carved out of a beech-rich forest some 40 years ago, and fallen beech branches were a major cause of the damage. Thus, we can't rule out the possibility that older beech trees are particularly susceptible to ice storm damage. We did not observe frequent uprooting of beech or any other species in the beech-dominated slope plots, however, in contrast to observations of frequent uprooting on steep slopes during ice storms in mountainous areas of Virginia (Warrillow and Mou 1999; R. W. Rhoades 1999 and pers. comm.).

We observed that Virginia and loblolly pines were literally wiped out on roadsides throughout the storm's path. When standing alone, growth patterns of loblolly and Virginia pine create a top-heavy tree. When loaded with ice, these species tend to lose their entire canopies. Especially in Virginia pine, this was usually by snapping of the main trunk two to four meters above the ground, rather than by uprooting (in contrast to the findings of Warrillow and Mou (1999) in western Virginia). The roadside condition of asymmetrical canopies and the increased surface area presented by their needles makes evergreens particularly susceptible to primary ice damage. Boerner et al. (1988) also observed high instance of crown loss in evergreens, which they attributed to the accumulation of ice on needles. Total crown loss was less prevalent in the forest due to the support offered by neighboring trees, but we did witness several cases of 100 % canopy loss from the pines in our plots (see also Buttrick, 1922). Whitney and Johnson (1984) observed, as we did, that both pine species and tulip poplar were often severely damaged. Their inability to sprout adventitious stems makes severe damage particularly destructive for pines; three-fourths of the severely damaged Virginia pine stems surveyed in Whitney and Johnson's study were dead after two years, but only 5 percent of severely damaged tulip poplar stems had perished.

Fallen branches in plots make up a third subset of data. The quantity of branches found on the ground for a given species supports earlier conclusions about frequency and type of damage. For instance, Tables 1 and 2 indicate that *Liriodendron tulipifera* was prone to lose branches or whole crowns (in the case of smaller stems) by clean break. Table 9 supports this tendency in tulip poplar, as most of the ground litter tallied could be attributed to this species.

Although not recorded, the number of already dead branches that fell during the storm was apparently extremely high, especially in oak-dominated areas. We had no quantitative records of pre-storm ground deadwood in our study area, but in a forest elsewhere in the county, H. Sahli and S. Ware observed a several-fold increase in amount of litter from already dead branches on the ground between October 1998, before the storm, and February 1999, after the storm. After severe ice storms the large increase in ground layer biomass from recently broken branches is usually regarded as increasing the threat of forest fires in the following summer. Though less than the biomass from newly broken branches, the contribution to litter of already dead wood brought to the ground by the storm should not be overlooked. Further, this dead wood is already in a state of partial decay, and may provide quicker flush of minerals to the soil than newly broken branches. The mineral flush from the increased amount of decaying gound litter (both already dead and newly broken) in combination with storm-induced openings in the canopy will probably lead to a thickening of the understory in the more damaged locations in the forest.

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