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Ice storms and forest impacts

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Abstract

Ice storms, or icing events, are important meteorological disturbances affecting forests over a surprisingly large portion of the USA. A broad belt extending from east Texas to New England experiences major ice storms at least once a decade; and truly major events occur in the heart of this belt once or twice a century. In the areas most affected, icing events are a factor that shapes stand composition, structure, and condition over wide areas. Impacts of individual storms are highly patchy and variable, and depend on the nature of the storm. Impacts also depend on how (or if) forest managers conduct subsequent salvage cuttings. Important research needs remain to be considered by the forest ecology and meteorology communities. At present, how ice storm frequency and severity may change with future climate change is unknown. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Ice storms; Forest impacts; Abiotic influences; Extreme weather events; Disturbances

1. Introduction

This paper reviews the frequency of occurrence, effects on forests, and issues in damage assessment of ice storms. Brief remarks are added on 'coping'. Ice storms, also known as glaze events, can produce massive effects on power systems, roads and buildings, traffic safety, forests, and agricultural crops. According to the National Weather Service in the United States, 'from 1990 to 1994, ice storms caused a yearly average of 10 fatalities, 528 injuries, and $380 million in damage' (Robbins and Cortinas, 1996). Across the United States, from 1982 to 1994, ice storms averaged 16 per year and were more frequent than blizzards (Branick, 1997, and see Table 1). These should be considered rough estimates, and could be low.

The amount of ice accumulation on surfaces, branches, or power lines depends on a host of factors (Fig. 1). Occurrences of glaze ice immediately following heavy snowfalls can be highly damaging to vegetation, due to increased loading on branches. The January 1998 Northeastern storm

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Table 1
Winter weather event data, United States, 1982–1994 (Percentages add up to more than 100 because many events included more than one hazard)[a]

	Annual average	Percent of all event days (%)
Event days	160	44[a]
Events with heavy snow	103	81
Events with significant ice	31	24
Ice storms	16	12
Blizzards	13	10
Events with downed power lines	34	27

[a] Percentage of all calendar days in the 13-year period.

generated considerable photo documentation (Abley, 1998; Central Maine Power Co, 1998; NCDC, 1998; Weiner, 1998).

An 'ice storm' is an event assessed on the ground in terms of one result of a storm — ice accumulation. The National Weather Service (NWS) defines an 'ice storm' as an occurrence of freezing precipitation, resulting in either structural damage, or at least 6.35 mm of ice accumulation. The ice accumulation actually occurs in limited areas traversed by a large storm event that often generates rainfall or snow elsewhere, and that is moving over time. Since the US rarely measures ice accumulation during ice storms, it is difficult to assess the effects of a storm while it is occurring. The general weather conditions producing ice storms are well understood (see, e.g. McQueen and Keith, 1956; Bennett, 1959; Stewart and King, 1987; Bernstein and Brown, 1997; Jones, 1996; Cortinas, 1999) and need not be recounted here. Briefly:

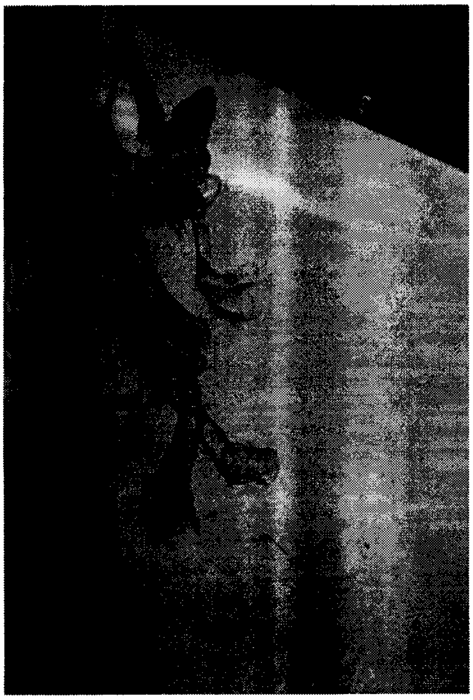

Fig. 1. Two inches of ice on white birch (*B. papyrifera*), January 1998 storm, central Maine. Photo by author.

> "The simple occurrence of warm air lying over cold air is necessary for formation. As frozen precipitation falls through the warm layer, ice crystals absorb heat, begin to melt and subsequently refreeze in the colder air near the ground. If the snow is partially melted and then refreezes, sleet is observed at the ground. If fully melted, the cold air can supercool the water, which will freeze upon impact and produce freezing rain. With a very deep layer of cold air and higher wind velocities, sleet can be formed from completely melted raindrops." (Gay and Davis, 1993).

While often thought of as occurring primarily in the north-east, extensive and damaging icing events occur elsewhere. The February 1994 storm produced heavy ice accumulations in northern Mississippi and caused severe damage over parts of nine states (Lott and Ross, 1994). This storm damaged more timber than Hurricane Camille (R. Myers, Mississippi Forestry Comm., personal communication, 1994), including damage to 1 500 000 ha of forest and heavy losses to urban trees and pecan orchards. This was said by foresters to be the worst ice storm to strike Mississippi since 1931. Other widespread south-eastern storms during 1972–1998 are well documented (NCDC RCG, 1998; Jones, 1999). Ice storms also damage forests in the north-west. A storm in November 1996 in eastern Washington and adjacent Idaho caused widespread tree damage and heavy losses to yard and street trees in Spokane (K. Thompson, Wash. DNR, personal communication). In this storm, heavy snowfall preceded accumulations of 25–37 mm of ice from freezing rain, causing the most severe ice storm in the Spokane area in 60 years. Power was knocked out for several weeks in some areas. Intensified by the dry summer of 1998, bark beetle infestations developed in damaged pine and Douglas fir stands, and large volumes of timber have been salvaged from Washington State lands alone.

There is insufficient historical climatology on ice storms to allow an assessment of whether their frequency and severity has changed in line with other past climate changes. How future changes in climate might affect the frequency, regional location, areal extent, and impacts of ice storms is not known. This paper, then, confines itself to discussing what is known about ice storms and their impact on forests.

2. Ice storm occurrences

It is useful to think of ice storms in terms of their frequency, areal extent, and severity. With normal weather station equipment, it is not possible to record ice accumulations in the course of normal observations. Ice accumulation can vary dramatically with topography, elevation, aspect, and areal extent of the region in which conditions favor glaze accumulation. In extreme events, weather observers often make informal observations of ice deposition, but such records are on such a sparse grid that they cannot provide high-resolution depiction of a storm's impact beyond identifying a very general 'footprint'.

Occurrence of freezing rain is often used as a proxy for ice storms, by necessity in view of the available measurements. A careful Canadian case study reported a very low correlation between inches of freezing precipitation and measured ice accumulation (MacKay and Thompson, 1969). A map prepared by Robbins and Cortinas (1996) for the United States (Fig. 2) showed areas of high frequency of freezing rain between 1982 and 1990 in:

1. the Columbia Basin in eastern Washington and Oregon;
2. a roughly triangular region of east Iowa, north-east Missouri, and central Illinois;
3. along the lee (eastern) slope of the Appalachians; and
4. from central Ohio through New England.

In assessing historical records, reliance has been placed on simulations (Jones, 1996), on detailed observations in local areas for specific purposes (see the extensive compilation in Bennett, 1959 and Ludlum, 1976), on newspaper and similar reports, on the NWS/NOAA Storm Data databases, and on collection of anecdotal obser-

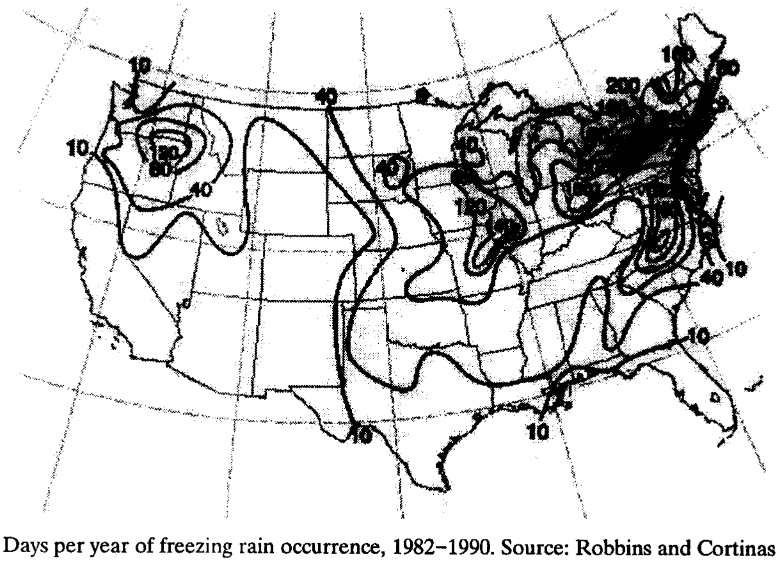

Fig. 2. Days per year of freezing rain occurrence, 1982–1990. Source: Robbins and Cortinas, 1996.

Table 2
Examples of major ice storms[a]

Location	Date	Year	Extent
North-east		1929	N/a
	Jan. 6–9	1930	6 states
	March	1936	6 million A, 2 states
	January	1998	4 states
Buffalo, NY		1973	N/a
S. Quebec	Winter	1983	Southern Quebec
Rochester, NY	Mar. 3–4	1991	13 cities
Iowa		1991	N/a
South-east	Feb. 9	1994	10 states, 1.5 mm ha
Washington, ID	November	1997	N/a
Georgia, SC	Jan. 22–23	2000	One third of Georgia

[a] Sources: various.

vations by interested groups, such as utilities, railroads, and highway authorities. A few formal, detailed regional climatologies exist (Gay and Davis, 1993; Robbins and Cortinas, 1996; Jones and Mulherin, 1998). None of this yields information with consistency over long periods of time, precision in describing variation in time and space, or ready availability for analysis. A useful overview of data issues is given by Branick (1997), whose results permit showing ice events in a context of other significant winter weather events (Table 1).

Examples of major ice storms are given in Table 2. A historian familiar with observations of climate in early diaries and other materials observes that ice storms were considered 'part of winter' and not noted in particular (D.C. Smith, University of Maine, personal communication). So comparisons of frequency and severity over long periods of time are not possible. Extensive listings of events, in varying degrees of detail are available (e.g. NOAA).

2.1. Frequency of occurrence

Ice storms have important impacts on structures. Engineers have made several efforts to characterize return periods and intensities of ice storms as an aid in designing structures such as power lines to withstand expected ice loads (extensively reviewed by Jones and Mulherin, 1998). Only along the south-western border of the United States, and through part of the Plains, are there regions where ice storms never occur. Isolated pockets on the West Coast have experienced ice storms. Generally, both the frequency and the severity of ice storm events increase toward the north-eastern United States. An early and comprehensive review (Bennett, 1959) spoke of a 'glaze belt' extending from north Texas to southern New England, in which a storm yielding ice accumulations of 6.35–12.7 mm can be expected once in 3 years. A standard engineering reference on design loads by the ASCE (1994) provides a map giving estimated ice thicknesses and return periods for the entire United States. A revision was to be published in 1999. A detailed climatology of the south-east, using 40 years of data for 44 stations (Gay and Davis, 1993) found no evidence that the frequency of rain and sleet occurrence is increasing there. At present, it is not known whether the frequency or severity of such storms is related to El Nino conditions.

2.2. Extent of storms

Because of the measurement difficulties noted, it is difficult to determine the boundaries of an ice storm event with any precision. As Bennett (1959) noted, most storms are local, while region-wide storms are rare (see also Jones, 1999 for the south-east). Bennett observed that:

> "the average storm of more than local size probably is 200–600 miles (332–1000 km) in length and covers parts of one to three states" (p. 44).

While maps of general 'footprints' of storms have been reconstructed, these provide little of the spatial detail that would be needed to characterize storm impacts on forests.

2.3. Severity

Severity of ice storms can be viewed in terms of the amount of ice accumulation, the duration of that accumulation and the resulting damage, and the areal extent of severe damage. The severity of damage is influenced by the total sequence of weather conditions, including temperatures, windspeeds, and gusts during and following the storm. In the January 1998 Northeastern storm, for example, in many areas the weather was unseasonably mild following the storm, allowing a certain amount of thawing of accumulated ice and thus easing the working conditions for repair crews.

The net long-term impact on forests will be determined by the severity, frequency, timing, and extent of storms over time as they affect local areas. At present, we can gain only a fuzzy and partial picture of these important facts. Emerging analysis on ice storm frequency has not yet been fully integrated into long-term climate change assessments (e.g. UNHCCRC, 1998), nor into our understanding of disturbances in forest ecology.

3. Impacts on forests

Icing impacts may best be understood by treating spatially larger scales, starting with individual trees (Table 3), proceeding to stands, and finally to forest landscapes.

3.1. Individual trees

Ice damage to trees can range from mere breakage of a few twigs, to bending stems to the ground, to moderate crown loss, to outright breakage of the trunk (Cannell and Morgan, 1989; Smith, 2000). Ackley and Itagaki (1970) conducted an extensive study of branch loading by ice in the New England storm of 26–27 December, 1969. In the 1998 Northeastern ice storm, icing lasted long enough that many trees which were bent over had their crowns glued to the snow surface by the ice, in many instances for as long as 3 weeks. Some of those trees actually

Table 3
Vulnerability ratings of trees to ice storm damage

Sensitivity to sap coloration	Resistance to ice damage to crown		
	Low or average	Average or strong	Strong
Sensitive	Manitoba maple[a] Pennsylvania maple Silver maple Norway maple[a] Red maple[b] White birch[b] Grey birch/Jack pine Red pine[b] Aspens Pin cherry Choke cherry Willows and Alders Mountain ashes[a] Linden[b] Locusts and Honeylocusts[a]	Yellow birch (sweet cherry) American beech[b] White ash[b] Elms[a] Sugar maple[b] White pine[b] Apple trees Balsam fir Littleleaf linden Hawthorns	Spruces
Insensitive	Eastern white cedar[a] American larch Black cherry[b] Red ash[b] Common hackberry	Bitternut[b] Bitternut hickory Red oak[b] Black ash Shagbark hackberry	Eastern hemlock Burr oak[b] White oak[b] Swamp white oak Hop hornbeam Black walnut[b] Hornbeam Saskatoon berries

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[a] Mainly trees in cities and city parks.

[b] Greater impact of sap coloration fungi, which change the appearance of the wood and reduce the commercial value of the main lumber species. Source: Boulet (1998).

recovered erect posture after release from the snow, while many others remain bent over after 2 years. Trees with lopsided crowns on the edges of openings or roads may be especially vulnerable, as may open-grown trees with broad crowns. For some species, however, open-grown trees may have developed enough branch strength to bear ice loads well. The severity of damage is generally believed to be closely related to the severity of winds following the heaviest ice accumulations. Generally, softwoods seem to suffer less damage from the same degree of ice loading than do hardwoods. In the 1998 January storm, it was observed that exotics and trees planted outside their natural ranges, such as *Robinia*, and *Salix* spp. suffered severely, while nearby native species suffered far less damage. An early compilation of resistance to ice damage was by Bennett (1959, p 159 ff.); more recent is Hauer et al. (1996). Vulnerability to ice damage has been examined recently by Jones (1999) and by Simpson (1999) Table 3.

Fig. 3. Red oak (*Q. rubra*) split at crotch in crown, January 1998 storm, central Maine. Photo by author.

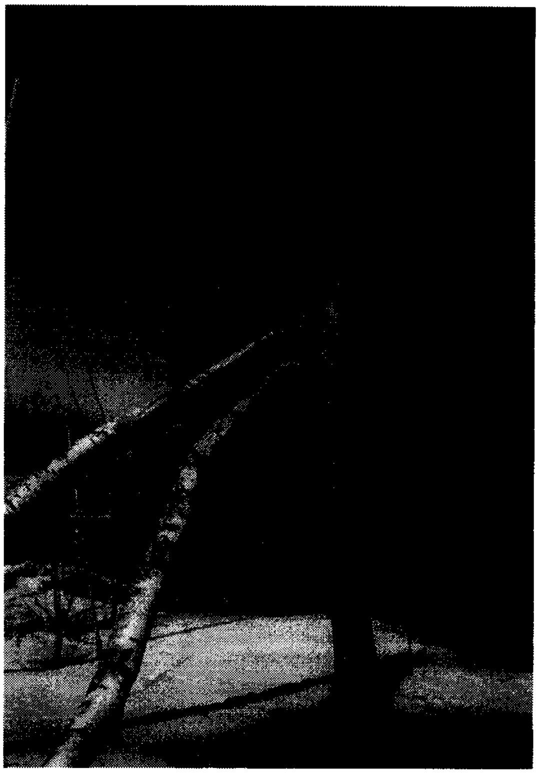

Fig. 4. White birch broken by ice, January 1998 storm, central Maine. Photo by author.

Damage varies across a range of severity and subtlety:

- minor branch breakage;
- major branch loss, up to total crown loss;
- bending over of crowns on a temporary or permanent basis;
- at seasons when soil is not frozen, winds and ice loads can cause root damage;
- breakage of trunks within or below the crown; and
- in some hardwoods, trunks can be split.

It is not known whether material but invisible damage occurs to branch junctions with trunks as a result of severe bending. When branches are broken off, the injury can be sealed off in a healthy tree, and may not result in the migration of decay columns down into the trunk of the tree. In some instances, non-lethal stain fungi may enter through such injuries, reducing lumber values. Trees are capable of surviving considerable crown damage, and can steadily rebuild leaf area and crown volume in time. During this period, however, they are likely to lose growth.

During the January 1998 Northeastern storm, aspens as large as 15 cm were broken off below the crowns; white pines had stems snapped at 20 cm diameters, oaks as large as 50 cm were split along the trunks where divided trunks weakened the stems (Fig. 3), and birches as large as 20 cm broke off entirely (Fig. 4).

3.2. Stands

Depending on the stand composition, the amount of ice accumulation, and the stand history, damage to stands can range from light and patchy to the total breakage of all mature stems. Complete flattening of stands occurred locally in the Northeastern 1998 storm. In response to more moderate damage, effects on stands could include: shifts in overstory composition in favor of the most resistant trees; loss of stand growth until leaf area is restored; and loss of value of the growth due to staining or damage to stem form. When damaged wood is salvaged, logging damage to soils and to residual trees is possible, given the likelihood that operations may be conducted in haste. In some stands, the damage caused by sloppy salvage-logging could exceed the damage caused by the storm, as basal damage to trees is more serious than branch breakage.

In some regions, such as the south and the interior west, trees damaged by ice storms or wind-throw can become breeding grounds for bark beetles or other pests, which then attack green trees. This is now occurring in the wake of the recent storm in eastern Washington and nearby Idaho. In lightly damaged stands, undamaged individuals may increase crown widths to fill in unused growing space, so that the stand growth very quickly returns to pre-storm levels.

Plantations suffered varying degrees of damage in the January 1998 Northeastern storm, depending on management history, species, and location. Even within small plantations, damage was not uniform, making it difficult to tell whether the variation was caused by minute differences in stand conditions, or differences in the amounts of ice accumulated. Anecdotal evidence suggests, however, that managed hardwood stands suffered extreme damage at times, even to the point of total flattening of stands. This could be because stands, which were recently partially cut, have experienced significant widening of crowns, thereby increasing ice loading on their crowns.

Recently-thinned stands can be highly vulnerable, as crowns have spread into newly-opened growing space, but branch strength may not be fully developed. For example, in the 1994 Mississippi ice storm, managed pine stands suffered the most severe damage. Damage to timber in that storm covered parts of 26 counties. Timber damage reached 18,000,000 m^3 of sawtimber and 23,000,000 m^3 of pulpwood. Sawtimber losses exceeded the annual log requirements of the state's sawmill industry. Blockage of access for fire fighting was a major post-storm concern. The Mississippi Forestry Commission (1994) estimated that the storm increased fuel loadings by three to six times above normal.

3.3. Landscapes

The degree of damage is typically highly skewed by area. For example, in the January 1998 Northeastern storm, 1,800,000 ha of damage in Quebec was assessed by the Ministry of Natural Resources as follows:

- very severe 4.2%
- severe 32.0%
- moderate 29.9%
- slight/trace 33.9%

In Maine, using a slightly different system, the Maine Forest Service initially assessed damage in broad areas containing varying levels of damage:

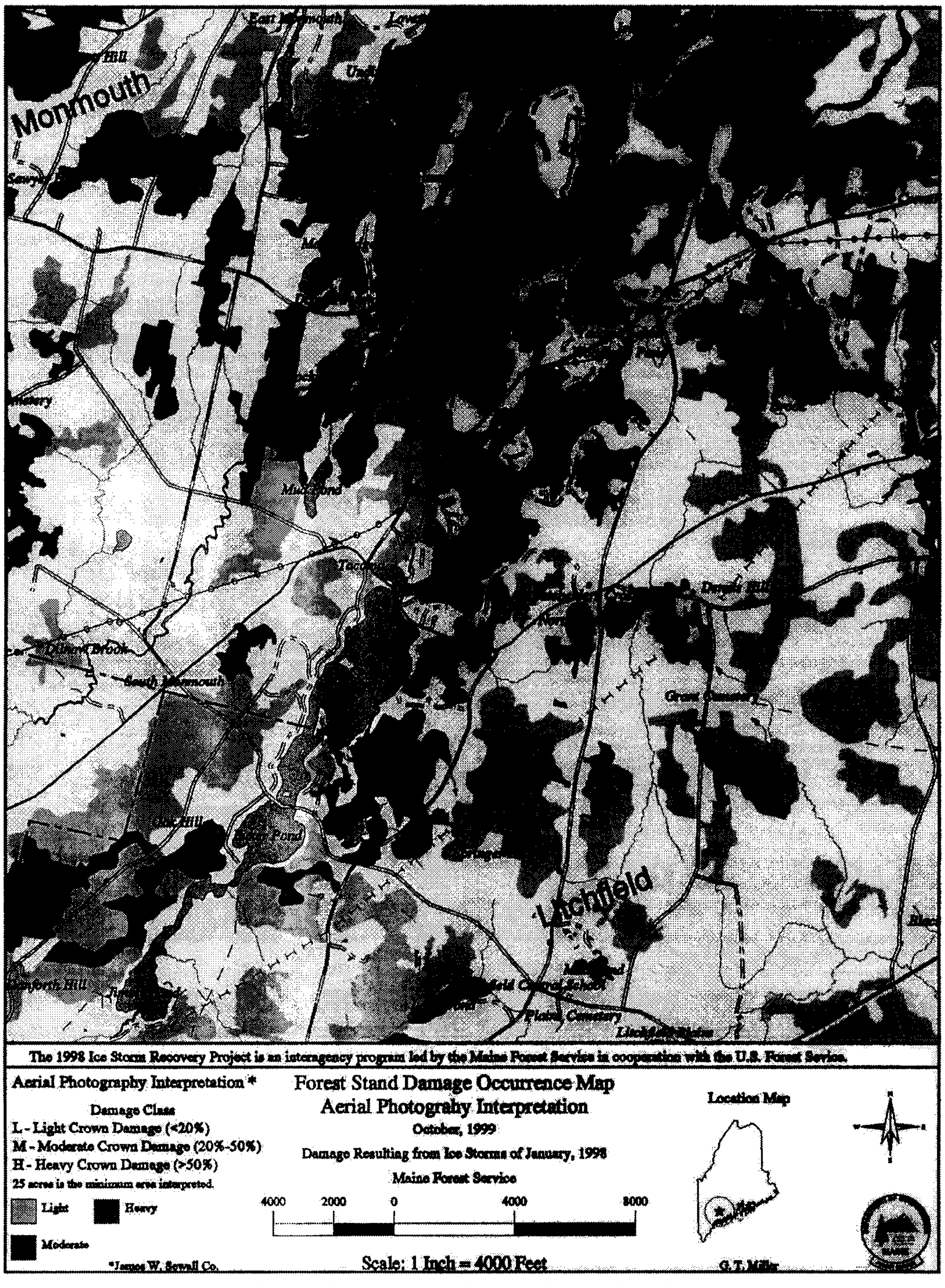

Fig. 5. Color map of 1998 ice storm impacts in Maine.

	Thous. Ha	Percent
None/trace	1904.45	35.4%
Trace/light	660.73	12.3%
Light	497.98	9.3%
Light/moderate	655.06	12.2%
Moderate	104.05	1.9%
Moderate/heavy	1441.70	26.8%
Heavy	115.38	2.1%
Total	5380.16	100.0%

The total area affected noticeably (trace/light or more) by the storm was two-thirds of the state's area.

Ice accumulations vary significantly along elevational gradients, as in the following transect at Hubbard Brook (Woodstock, Grafton County) New Hampshire, United States:

Elevation, m.	Diameter of ice accumulation, mm
564	4
619	7.9
645	8.2
671	11.1
710	14.9
794	13.1
832	13.6
855	17.4

(Accretion on canopy-exposed 3–5-mm twigs, diameter added to twig on major axis)

Amounts measured elsewhere included Dixville Notch (Coos County) New Hampshire, at 606 m, 24.4 mm and at 871 m, 29.4 mm (data from Charles V. Cogbill, Hubbard Brook LTER, personal communication). In addition, accumulations are often strikingly affected by aspect (the compass direction faced by the slope).

The effects on entire forest landscapes, as suggested, are highly patchy and variable (Fig. 5). They also depend significantly on how landowners respond to the damage. To what extent do they attempt to salvage all damaged timber? What steps do they take in the cases of severely damaged stands — do they rely on natural regeneration or planting? How will extremely large contiguous areas of damaged stands be handled? What policies are followed along streamcourses and in other sensitive areas? All of these factors will affect how the managed forest landscape as a whole is affected. In reserved areas, stands will recover naturally without disturbance. In limited areas, fire hazards can increase if severe fire weather follows severe ice storm damage.

From an ecological perspective, ice storms are a normal occurrence. They occur at variable frequencies and intensities. The pre-settlement forest included extensive mature stands of long-lived individuals, with tree lifetimes as long as two to four centuries. In the north-east, a stand in a vulnerable topographic position would probably have been affected by a severe ice storm at least once each century. In some locations, additional impacts of periodic hurricane damage would occur. It is easy to imagine that stands containing a mix of hemlock (a species resistant to ice damage), maple, yellow birch, and white pine, could have their composition subtly shifted towards hemlock by a few such events. Abell (1934) considered ice storms to be a significant factor affecting at least tree condition in the Southern Appalachians, but he did not suggest that species composition was affected.

The understanding of how events like ice storms fit into the entire suite of long-term influences is in its infancy (Foster et al., 1997). Such disturbances certainly have the potential to affect the condition and numbers of trees and shrubs among the species most highly vulnerable to damage. Yet, they are episodic and unpredictable, and their effects are confounded by a host of other factors. So estimates of the long-term ecological effects of ice storms alone would be little more than conjecture. Furthermore, in today's second-growth forests managed on shorter rotations, some stands could escape a severe storm entirely during their lifetimes. In the south-east, for example, intensively managed plantations are managed on 20–25-year rotations, and some experts consider even shorter rotations to be feasible, in regimes described as 'fiber farming.'

4. Damage assessment methods

Damage assessment is an inexact science. A common method of quickly assessing forest pest infestations is to conduct careful aerial overflights, with a trained observer noting crown conditions on a map. This method has been adapted for the purpose of assessing ice storm damage. It can produce a quick sketch of the location and severity of impact that is often needed for planning and assessment. Unfortunately, in the rush to obtain quick assessments, neighboring jurisdictions often adopt different practices for classifying observed damage, so that no comparable regional information can be developed.

A far more expensive method is specially commissioned aerial photography, as was carried out in Maine in 1998 and 1999. Interpretation of such photography is very costly and time consuming. The detailed information must then be captured in a suitable form to be aggregated for analysis. The resulting maps can be very useful for interpretation to the public and landowners, and for management planning. For a rough proxy of geographic distribution, county or area data on outage experience of public utilities can provide a useful indication of the extent and severity of damage to forests and trees.

In the wake of the January 1998 storm, an extensive effort was undertaken by state forestry agencies to document forest impacts through air photos and ground plots (Irland, 1998; NFA, 1998). Extensive field measurements were taken on existing forest health monitoring plots, as well as on permanent forest inventory plots. A regional effort to analyze this information is under way, at the USDA Forest Service station in Durham, New Hampshire (Dr Chris Eagar, personal communication). Other scientific efforts are also under way. In a few years, this research should yield significantly improved understanding.

5. Coping with ice storms

'Coping' could be considered to include a variety of activities: (a) allowing for icing risks in management plans and prescriptions; (b) preparing for individual events; and (c) planning post-storm management responses to damage.

To allow for icing risks, managers could develop risk-ratings for local areas, based on past events. These ratings could be considered in estimating future yields, and in designing prescriptions in ways that minimize the creation of vulnerable conditions. The simplest step would be to avoid planting highly vulnerable species in high-risk areas. Yield expectations could be adjusted to recognize potential ice storm effects; this has not always been done in the past. In areas where post-storm bark beetle outbreaks or high fire hazard can be expected, topographic situations and stand conditions of high vulnerability could receive priority in access, pre-suppression planning, and silvicultural work. When ice storms are predicted, contingency plans for prompt assessment and response planning could be activated. Finally, in planning management responses to ice damage, a multitude of factors must be considered, including landowner education, wood markets, risks to non-timber values, and the usual silvicultural considerations. Practical application of the above points will vary widely in urban forests, recreation areas, managed timberlands, and reserves.

6. Research needs

This discussion suggests a number of areas for further research attention.

1. Since weather stations do not systematically measure ice accumulations, forest-pest monitoring agencies and landowners should devise practical systems for promptly surveying ice storm areas, to document the extent and severity of ice accumulation for all major events.
2. It is striking that in the wake of major regional icing events, thorough documentation of the effects is often not conducted. Standardized methods should be devised for post-storm documentation of the extent and severity of damage resulting from ice storms. Such methods would enable learning over time, and would allow the testing of meaningful hypotheses about damage and its effects on trees and stands. It would also enable the comparison of damage assessments across states and regions.
3. Methods should be considered for including

signs of past ice damage as a part of routine Forest Inventory plot data, and in ongoing Forest Health Monitoring plots.

4. Reconstructive studies in representative areas should be carried out to attempt to determine the long-term influence of successive ice storm episodes on forest conditions.
5. Case studies should be conducted to precisely identify the physical and economic impact of ice damage on managed forests in different forest regions, and to develop recommended management responses.
6. Studies should be carried out to determine long-term tree and stand responses to ice storm damage for up to 5–10 years after the event. Most of this type of research to date has been conducted in the immediate aftermath of storms.
7. In some regions, research may be desirable to identify the effects of ice damage on unmanaged forests, such as wilderness areas.
8. Meteorological research is needed in four areas: firstly, improve the characterization of ice accumulation in relation to storm characteristics and associated weather, especially delineating affected areas in more detail by the amount of ice accumulation; secondly, it would be interesting to determine if there is any association between ice storm occurrence, size or intensity, and El Nino conditions; thirdly, national coverage by detailed regional ice storm climatologies is needed; and finally, meteorologists should develop and test hypotheses concerning how future climate changes will affect ice storm occurrence.
9. The experiences of arborists and urban foresters should be systematically reviewed to develop research and assessment needs for urban forests.
10. Impact assessment, valuation, and practices for coping provide a fruitful field for research work across the disciplines of meteorology, forestry, recreation, entomology and pathology, as well as engineering, management, and economics.

7. Conclusion

Ice storms occur frequently in many parts of the United States and Canada. Storms of sufficient intensity to damage trees occur in limited areas in the core of the 'glaze belt' once every 50 years or less. In some areas, broken-topped hardwoods provide mute testimony to the effects of ice storms long ago. In pre-settlement times, ice storm effects could have been sufficient to affect stand composition in some areas. In today's younger, managed forests, the distinct effects of ice storms intergrade with those of snow and windstorms, and are obscured by management activities. In the past, ice has not seemed to be a material factor affecting the selection of species for planting except in limited instances. Now that meteorologists have quantified geographic differences in the frequency of freezing precipitation (a useful proxy), this could change.

An extraordinary trait of ice events is their occurrence in such widely differing climatic zones. At present, we can only speculate as to how future changes in climate could change the location, extent, and severity of icing events. One might suppose that a warming climate would simply shift the entire 'glaze belt' in a northerly direction. If this were to occur, southern forests would be affected less frequently or severely, and so on. The elevational belts affected in mountainous areas would possibly shift upslope. It is also possible that a far more complex pattern of changes from past ice storm regimes could occur. In some regions, changes in growing-season climate regimes, or in vegetation, could affect the impacts of icing events, even if the climatology of icing events themselves does not change.

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