Long-term Impact of an Ice Storm and Restoration Cutting in a Rare Pine Barren

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ABSTRACT

One of the more significant natural disturbances in the northeastern United States and southeastern Canada in recent memory was the ice storm of January, 1998. In northern New York, thick accumulations of ice on tree branches caused severe crown damage across 280,000 ha of forest, including a rare pine barren in Clinton County. More than half of the trees in the pine barren were severely damaged by the ice storm, especially small-sized jack pine (*Pinus banksiana*) and mid-sized pitch pine (*P. rigida*) and red pine (*P. resinosa*). Over 60 percent of the sampled trees were dead after 10 growing seasons. Survival of damaged pitch pine trees was enhanced by growth of new branches from epicormic buds on the main stem. Experimental restoration cuttings were used in portions of the ice-damaged barren to decrease hazardous fuel loadings, reduce the density of ericaceous shrubs, scarify the soil surface and stimulate the release of jack pine seeds from the serotinous cones attached to broken branches. After 10 growing seasons, jack pine seedling density in the restoration cuttings averaged 9,500 stems per ha. The experimental cuttings successfully regenerated new jack pine stands without fire. Meanwhile, tree regeneration in the ice-damaged, unmanaged stands was sparse and most of these seedlings were generally red maple (*Acer rubrum*) or red oak (*Quercus rubra*). This study demonstrated that ice-damaged, fire-structured pine stands can be successfully regenerated using mechanical site treatments in northern New York.

Key words*: ice storms, pine barrens, fire adaptations, restoration cuttings*

INTRODUCTION

Ice glazing and ice storms are common forest disturbances in northeastern North America (Downs, 1938; Lemon, 1961; Irland, 2000). Affecting more than 10 million ha across four Canadian provinces, three New England states and northern New York, the "great ice storm" of January, 1998 was one of the most widespread natural disturbances of the Northeast in the 20th century (Irland, 1998). Ice accumulations greater than 5 cm caused severe damage to more than two million ha of forests (Irland, 1998; Lautenschlager and Nielsen, 1999; Hopkin *et al*., 2003).

In northern New York, approximately 280,000 ha of forests were severely damaged by the ice storm of 1998 (Irland, 1998). One of these severely damaged areas was the Altona sandstone pavement pine barren in Clinton County. With fewer than five examples of this ecological community type in New York State, the New York Natural Heritage Program (NYNHP) (Reschke, 1990; Edinger et al., 2002) considers sandstone pavement barrens rare.

Jack pine (*Pinus banksiana*) is the dominant species in the Altona pine barren, locally known as "Flat Rock" (Adams and Franzi, 1994; Franzi and Adams, 1999). A red pine (*Pinus resinosa*) stand is located along the ridge of an escarpment on the southern side of Flat Rock. The southeastern portion of Flat Rock includes a stand comprised of pitch pine (*Pinus rigida*) and jack pine (Woehr, 1980; Adams and Franzi, 1994). The NYNHP classifies this ecological community type as a pitch pine-heath barren (Reschke, 1990; Edinger, *et al*., 2002). The uniqueness of the ecological communities at Flat Rock is enhanced by the presence of both pitch pine and jack pine, each of which are near the limits of their natural distribution (northern limit for pitch pine and southern limit for jack pine) (Burns and Honkala, 1990; Harlow, *et al*., 1991).

Each of these pine species is well adapted to fire. Red pine is well adapted to fires of low to moderate intensity due to its thick bark (Van Wagner, 1970; Bergeron and Brisson, 1990; Engstrom and Mann, 1991). Pitch pine's thick bark, basal sprouting, epicormic branching and semi-serotinous cones provide survival mechanisms during a variety of fire regimes (Cryan, 1980; Bernard and Seischab, 1995; Meilleur, et al., 1997; Barnes, 2003). Jack pine's canopy storage of seeds in serotinous cones provides a means of stand regeneration following moderate- to high-intensity surface fires and crown fires (Wein and MacLein, 1983).

The shallow soils at Flat Rock make this a droughty site, prone to fire (Stergas and Adams, 1989; Hawver, 1993; Adams and Franzi, 1994). During the period of commercial blueberry (*Vaccinium* spp.) production, human-caused fires were frequent at Flat Rock (Gooley, 2005). While red pine, pitch pine and jack pine are known to regenerate on sites following a high-intensity fire (Boerner, 1981; Rouse, 1986, 1988), the concern for managers of Flat Rock was the future of this rare pine barren following a high-intensity ice storm.

The objectives of this study were:

1. Assess the mortality and recovery of trees in the pine barren after 10 post-ice storm growing seasons; and
2. Evaluate tree regeneration in even-aged stands created by restoration cuttings after the ice storm of 1998.

METHODS

Study area

The sandstone pavement barrens of Clinton County, New York originated geologically more than 12,000 years ago when an ice-marginal river draining glacial Lake Iroquois scoured the area down to the underlying sandstone (Figure 1) (Franzi and Adams, 1999; Rayburn *et al*., 2007). The organic soils in these pine barrens are extremely shallow and the Potsdam sandstone bedrock is commonly exposed (Krill *et al*., 2004). Typically, soils in these pine barrens are a dysic lithic borofolist. The Altona, New York pine barren is approximately 2000 ha in size and is primarily owned by The W. H. Miner Agricultural Research Institute, Chazy, New York. Study stands were dominated by jack pine, pitch pine or red pine (*Pinus resinosa*). Important understory shrubs were black huckleberry (*Gaylussacia baccata*) and late low blueberry (*Vaccinium angustifolium*).

Sampling Uncut, Ice-damaged Stands

Table 1. GPS coordinates for the 1998 and 2007 study areas in the Altona Flat Rock pine barren.

Stand Designation	Location Coordinates	
Jack Pine (JP)	N 44° 51.396'	W 73° 35.657'
Jack Pine-Pitch Pine (JPPP)	N 44° 49.965'	W 73° 34.477'
Pitch Pine (PP)	N 44° 50.149'	W 73° 34.232'
Red Pine (RP)	N 44° 49.971'	W 73° 35.931'
Restoration Cut Area #1 (RC#1)	N 44° 50.321'	W 73° 34.919'
Restoration Cut Area #2 (RC#2)	N 44° 50.011'	W 73° 35.231'

During the fall 1998 semester, students of the Forest Ecology class at Plattsburgh State University assessed ice storm damage to overstory trees in four pine stands in the barren. The GPS locations of these stands are listed in Table 1. Study plots were 10 m by 10 m and all trees greater than 2.5 cm dbh were assessed for ice storm damage. Seven ice storm damage categories that were used in the 1998 sampling (Table 2).

Table 2. Ice storm tree damage (1998) and tree recovery (2007) categories.

Damage Category	Description (Fall 1998)	Recovery Category	Description (Fall 2007)
1	Undamaged Tree	1	Undamaged Tree
2	Less than 50% Crown Loss	2	Epicormic Branching
3	50-75% Crown Loss	3	Basal Sprouting
4	Greater than 75% Crown Loss	4	Epicormic Branching & Basal Sprouting
5	Stem Broken Below Crown	5	Basal Sprouts on Dead Tree
6	Uprooted Tree	6	Live Tree Without Epicormic Growth
7	Tree Leaning or Arched Position	7	Dead Tree (No Live Foliage)

Each stand had a different dominant species composition and was described as follows: Jack Pine (JP), with five study plots; Pitch Pine (PP), with ten study plots; Jack Pine-Pitch Pine (JPPP) with five study plots; Red Pine (RP) with five study plots. Plot locations were recorded for relocation and followup sampling.

During Fall 2007 semester, the authors relocated these same study plots and the trees were assessed for recovery status, ten growing seasons post-ice storm. Figure 2 illustrates the condition of unmanaged, ice-impacted stands in the pine barren, ten years following the ice storm. The seven tree recovery categories used in 2007 are described in Table 2. The number of pine trees sampled in each of the four study stands is as follows: JP (122); PP (129); JPPP (69); and RP (105).

Tree regeneration in the uncut, ice-damaged stands was sampled in the same plots used for overstory tree assessment. Tree seedlings at least one meter in height and less than 2.5 cm dbh were counted and recorded, by species.

Sampling Restoration Cuts

Miner Institute's consulting forester, Mr. Herbert Boyce of Northwoods Forest Consultants LLC, recommended hiring a timber company to cut and remove broken and severely damaged trees in the pine barren. A contract was signed with Green Mountain Forest Products to cut and chip dead and dying trees on approximately 180 ha at Flat Rock between 1998 and 2000.
Equipment used to conduct this operation included Timbco feller bunchers and skidders with rubber-tires and chains. Operators were instructed to drive over the broken branches and scarify the soil surface as much as possible. The objectives were to reduce the fire hazard by decreasing the depth of woody debris, create an exposed mineral soil seedbed, temporarily reduce competition from shrubs, initiate seed release from the unopened, serotinous cones by pushing cones closer to the ground surface and perhaps mechanically forcing some cones to open. We termed this silvicultural method a "restoration cutting" (Yorks and Adams, 2003; 2005).

Tree regeneration was sampled in two of the restoration cuttings during September to October, 2007. Tree seedlings at least one meter in height were counted and recorded, by species, in 5 m by 5 m plots. Five, 90-m transect lines, each radiating from a point at 30-degree intervals in a "sunburst" pattern, were installed in each restoration cut area. Three sample plots were positioned 30 m apart, along each transect line, for a total of 15 sample plots in each restoration cut area.

Data Analysis

Due to the low frequency of sample trees in some of the potential damage and recovery classes, the damage and recovery categories used for analysis were as follows:
Damage category "None" = damage class 1;
Damage category "Low" = damage classes 2 and 7;
Damage category "Intermediate" = damage class 3;
Damage category "High" = damage classes 4, 5, and 6;
Recovery category "A" = recovery class 7;
Recovery category "B" = recovery classes 2,3,4 and 5;
Recovery category "C" = recovery classes 1 and 6.

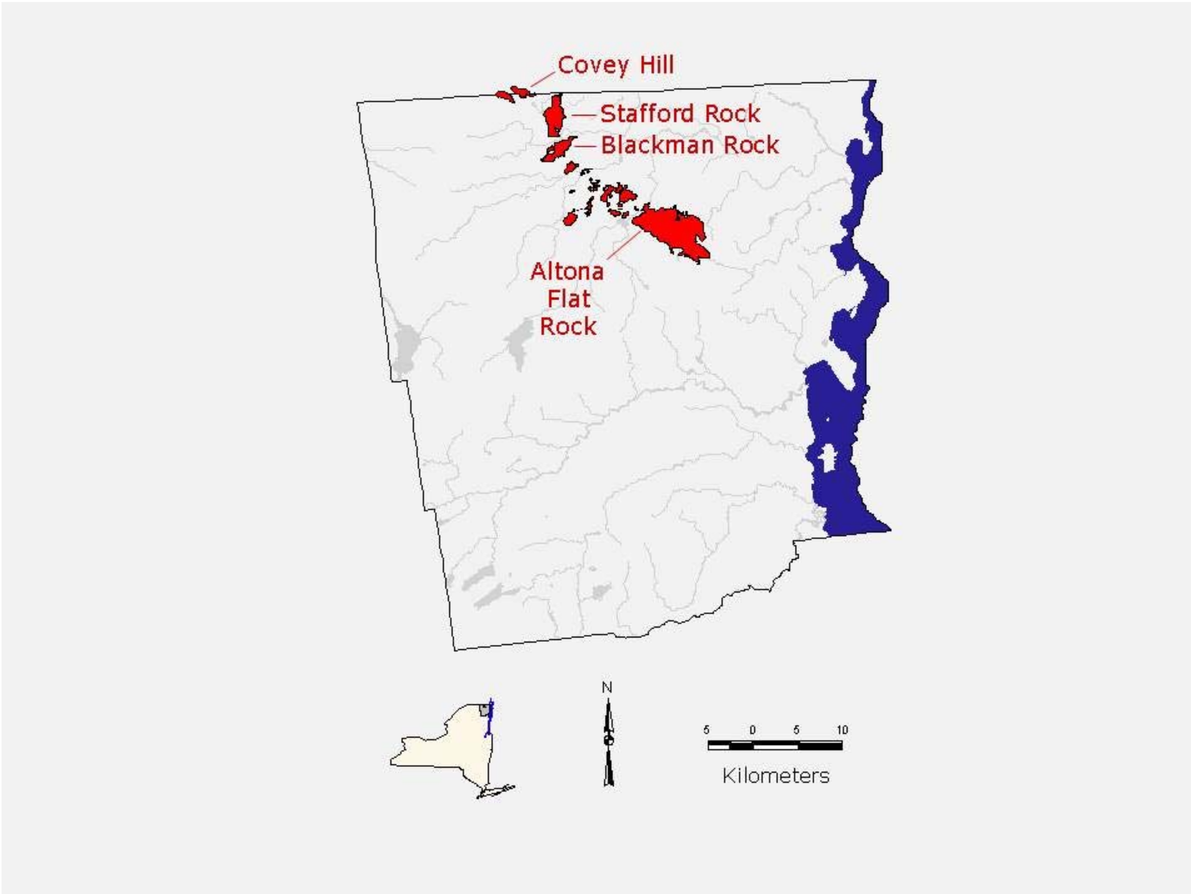

Figure 1. Location of the Altona Flat Rock sandstone pavement barren study area, Clinton County, New York. Courtesy of D. Franzi.

Figure 2. Typical appearance of an ice-storm damaged stand in the Flat Rock pine barren, 10 years after the disturbance.

RESULTS

Tree Damage and Recovery Assessment

A total of 425 pine trees were assessed for ice storm damage in 1998 and recovery status in 2007(Table 3). The three most abundant pines in the sample stands were pitch pine, jack pine and red pine. White pine (*Pinus strobus*) was an important understory species in the red pine stand. The majority of jack pine trees were in the smallest dbh class (2.5 to 10.0 cm) and most of the pitch pine and red pine trees were intermediate in size (10.1 to 20.0 cm dbh) (Table 3 and Figure 3).

Ice storm impact was strongly bimodal; 52% of the 1998 sample trees were severely damaged by the ice storm while 39% showed low or no damage. Fifty-six percent of the jack pine trees were severely damaged, with most of these trees in the smallest size class (2.5 to 10.0 cm dbh) (Table 4 and Figure 5). Fifty-nine percent of the pitch pine trees were severely damaged, mostly mid-sized trees (10.1 to 20.0 cm dbh). Almost half of the red pine trees were severely damaged and most of these trees were mid-sized. Most of the white pine trees were in the smallest size class and were undamaged by the ice storm.

Sixty-two percent of the trees sampled in 1998 were dead in 2007 and nearly half of the dead trees were in the smallest dbh class (Table 5 and Figure 5). Tree mortality, by species, was 83% for jack pine, 77 % for red pine, 38% for pitch pine and 41% for white pine. The proportion of live trees was equally divided between those that produced epicormic branching and those that did not (Table 5 and Figure 4). The heavily damaged trees (79%) died within 10 growing seasons after the ice storm (Table 6 and Figure 6).

Tree Regeneration in Unmanaged and Managed Stands

Pine regeneration was extremely sparse in all ice storm-damaged, unmanaged pine stands (Table 7). While still generally sparse, regeneration of hardwood species exceeded pine regeneration in all of these stands (Table 7). Cumulatively, seedlings of seven hardwood species were in these stands (Table 7). Red maple and red oak seedlings were found in each ice storm damaged, unmanaged stand (Table 7). American beech (*Fagus grandifolia*) and striped maple (*Acer pensylvanicum*) seedlings were found only in the red pine stand (Table 7).

Seven species regenerated in the two restoration cuts (Table 8). Of these, jack pine was the most abundant species, with 78% of the seedlings, averaging 9500 seedlings per ha (Table 8). Most of the remaining regeneration in the restoration cuts was comprised of red maple, white birch (*Betula papyrifera*) and gray birch (*Betula populifolia*).

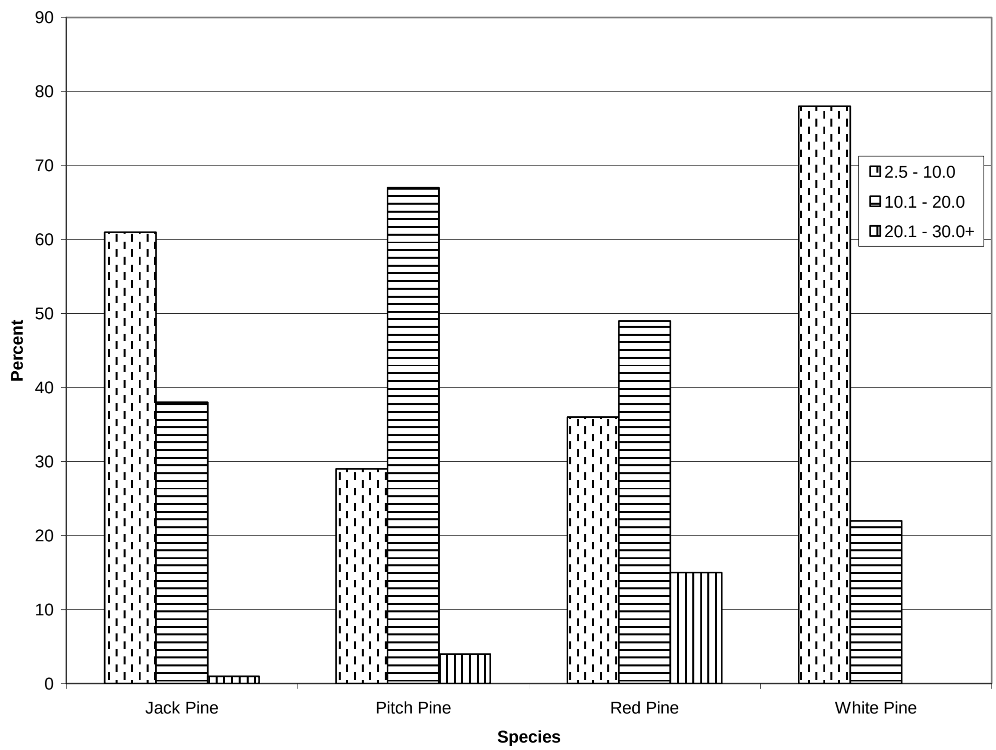

Figure 3. Size class distribution for each pine species in the uncut stands at Flat Rock. Prior to the ice storm, the majority of jack pine and white pine trees were in the smallest size class (less than 10 cm dbh) and most of the pitch pine and red pine trees were between 10 and 20 cm dbh.

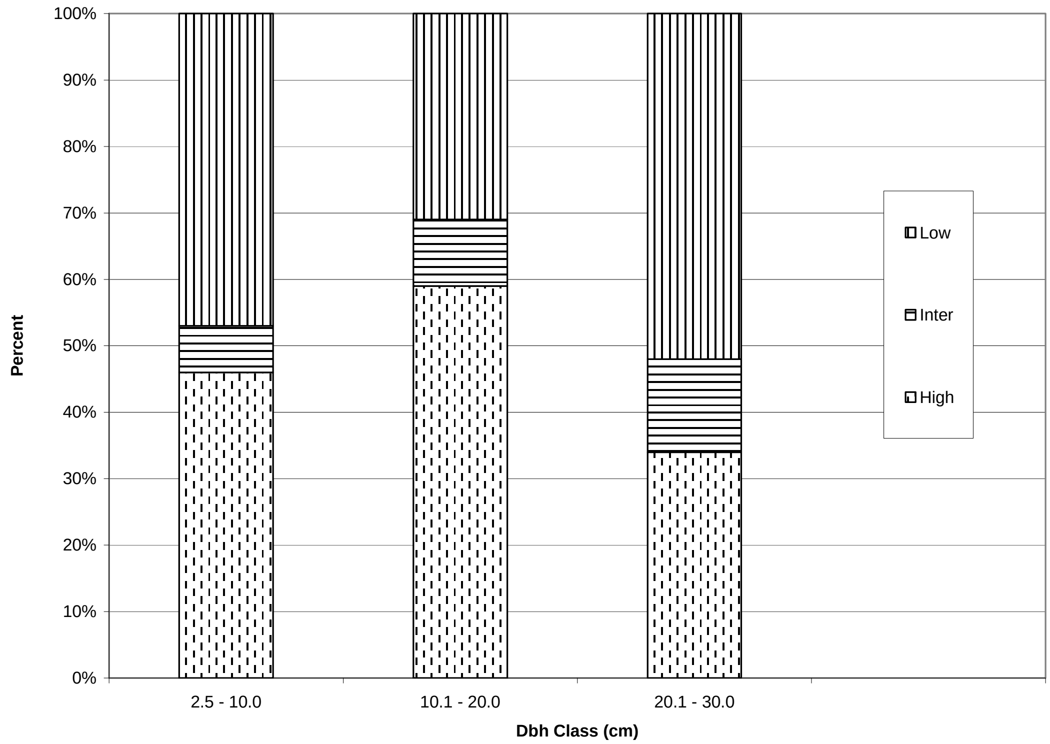

Figure 4. Damage category proportions for each size class in the uncut stands at Flat Rock. Across all size classes, between 30 and 60% of the trees showed high amounts of ice storm damage (greater than 75% crown loss, stem broken below crown, uprooted tree). Severe tree damage was especially high for trees between 10 and 20 cm dbh.

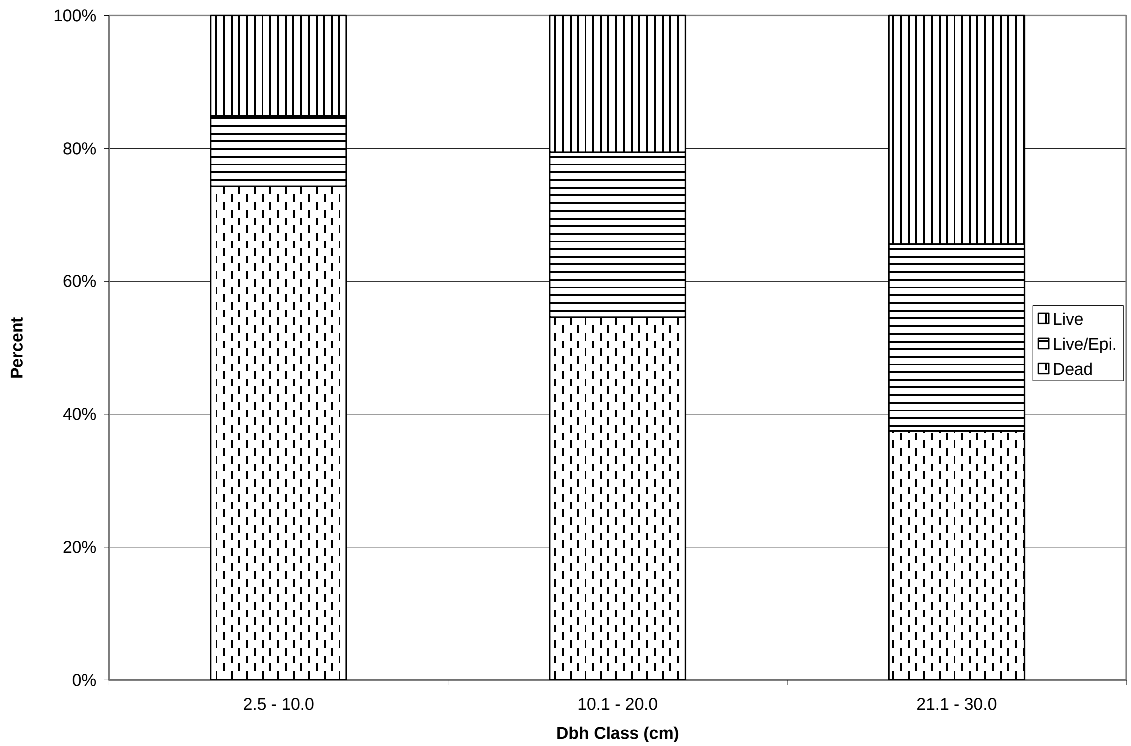

Figure 5. Recovery category proportions for each size class in the uncut stands at Flat Rock. The majority of trees in the smallest and mid-range size classes were killed by the ice storm. Epicormic branching helped many of the large trees recover from ice storm damage.

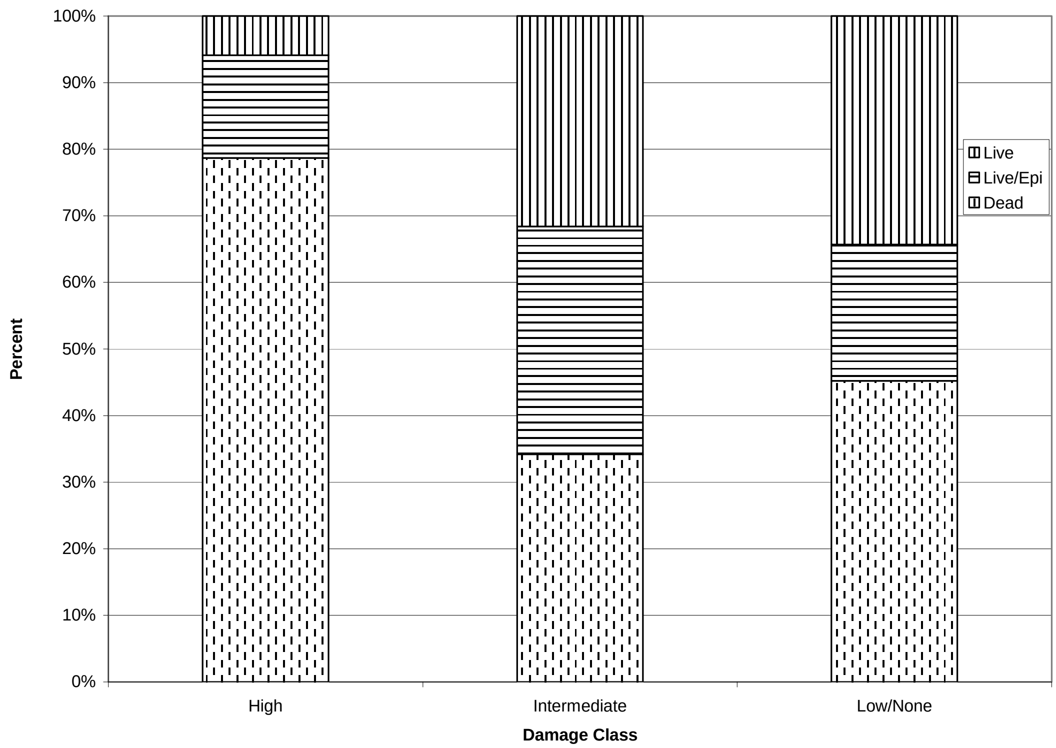

Figure 6. Tree recovery category proportions within each ice-damage class at Flat Rock. Nearly 80% of the trees with high levels of ice storm damage did not recover from these injuries (greater than 75% crown loss, stem broken below the crown, uprooted trees). Epicormic branching, especially in pitch pine, was the primary method for recovery from ice storm damage.

Figure 7. Ten-year old jack pine seedlings in an experimental restoration cutting in the Flat Rock pine barren.

Table 3. Number of sample trees in the uncut stands, by species and dbh class, 1998 and 2007 assessments.

	Species				
Dbh class (cm)	Jack pine	Pitch pine	Red pine	White pine	Total
2.5 - 10.0	96	32	26	25	179
10.1 - 20.0	59	112	36	7	214
20.1 - 30.0+	2	19	11	0	32
Total	157	163	73	32	425

Table 4. Number of sample trees in the uncut stand, by damage category (1998), species and dbh size class.

Severe Damage

Dbh class (cm)	Jack Pine	Pitch Pine	Red Pine	White Pine	Total
2.5 - 10.0	56	18	8	1	83
10.1 - 20.0	31	73	23	1	128
20.1 - 30.0+	1	5	4	0	10
Total	88	96	35	2	221

Intermediate Damage

Dbh class (cm)	Jack Pine	Pitch Pine	Red Pine	White Pine	Total
2.5 - 10.0	11	0	0	1	12
10.1 - 20.0	5	15	1	1	22
20.1 - 30.0+	0	4	0	0	4
Total	16	19	1	2	38

Damage Low/None

Dbh class (cm)	Jack Pine	Pitch Pine	Red Pine	White Pine	Total
2.5 - 10.0	29	14	18	23	84
10.1 - 20.0	23	24	12	5	64
20.1 - 30.0+	1	10	7	0	18
Total	53	48	37	28	166

Table 5. Number of sample trees in the uncut stand, by recovery category (2007), species and dbh size class.

Dead Tree

Dbh class (cm)	Jack Pine	Pitch Pine	Red Pine	White Pine	Total
2.5-10.0	89	10	22	12	133
10.1-20.0	40	48	28	1	117
21.1-30.0+	2	4	6	0	12
Total	131	62	56	13	262

Live tree with epicormic branches

Dbh class (cm)	Jack Pine	Pitch Pine	Red Pine	White Pine	Total
2.5-10.0	0	18	0	0	18
10.1-20.0	0	53	0	0	53
21.1-30.0+	0	9	0	0	9
Total	None	80	None	None	80

Live tree without epicormic branches

Dbh class (cm)	Jack Pine	Pitch Pine	Red Pine	White Pine	Total
2.5-10.0	7	4	4	13	28
10.1-20.0	19	11	8	6	44
21.1-30.0+	0	6	5	0	11
Total	26	21	17	19	83

Table 6. Number of trees in each recovery category (2007), by damage class (1998).

Damage class	Recovery Category: Dead tree	Live tree with epicormic branches	Live tree without epicormic branches	Total
High	174	34	13	221
Intermediate	13	13	12	38
Low/None	75	34	57	166
Total	262	81	82	425

Table 7. Tree regeneration in four unmanaged, ice storm-damaged stands, Altona Flat Rock.

Species	Jack Pine (JP)	Pitch Pine (PP)	Jack Pine-Pitch Pine (JPPP)	Red Pine (RP)
		stems per hectare		
Jack Pine	40	0	0	0
Pitch Pine	0	0	20	0
Red Pine	0	0	0	0
White Pine	40	40	0	460
Subtotal Pines	80	40	20	460
Red Maple	60	400	2680	1680
Striped Maple	0	0	0	2360
Red Oak	220	150	60	580
American Beech	0	0	0	1400
Big-tooth Aspen	0	0	0	160
White Birch	0	0	0	20
Gray Birch	0	10	0	0
Subtotal Hardwoods	280	560	2740	6200
Total	360	600	2760	6660

Table 8. Tree regeneration (stems per ha) in two restoration cut sites at Altona Flat Rock.

Restoration Cut	Jack Pine	White Pine	Red Maple	Birch[1]	Red Oak	Aspen[2]	Total
				Species			
Site #1	7280	27	1067	1173	0	0	9547
Site #2	11813	213	1573	1173	53	107	14932
Average	9547	120	1320	1173	27	54	12240

[1] White and Gray Birch

[2] Big-tooth Aspen

DISCUSSION

Effects of other ice storms on forest vegetation have been documented (e.g., Lemon, 1961; Bruederle and Stearns, 1985; Seischab *et al*., 1993), but none of these caused such severe and widespread damage as the "great ice storm of 1998" (Irland, 1998; Dupigny-Giroux, 2000; Smith, 2000; Allen, 2001; Hooper *et al*., 2001). Questions about restoration of the Flat Rock pine barren following the 1998 ice storm were similar to those faced by managers of the Moquah pine barren in the Chequamegon National Forest after an ice storm at that location in 1991 (Vora, 1993).

Fifty percent of the sample trees in this study were in the 10.1 to 20.0 cm dbh size class. Most of these mid-sized trees were jack pine, pitch pine or red pine, most (55%) were severely damaged by the ice storm in 1998, and most of these trees had died by 2007. The majority of the surviving trees in this size class were pitch pine. The ability to grow new branches from epicormic buds was of major importance for the survival of pitch pine trees that had been severely damaged by the ice storm. Jack pine and red pine trees do not have epicormic buds from which new branches can grow following crown damage.

Overall, more than 60% of the trees in this study had died during the decade following the ice storm. Typically, gaps in the forest canopy created by overstory tree mortality represent opportunities for the establishment of tree regeneration (Nyland, 1996). In the sandstone pavement barren, however, pine regeneration was absent or sparse, 10 years after the ice storm. A scarcity of pine regeneration in the barren was also reported in the first few years following the ice storm (Yorks and Adams, 2003; 2005).

In the ice-damaged barren, regeneration of several hardwood species, especially red maple and red oak, was more abundant than pine seedlings. Red maple and red oak seedlings were a mixture of regeneration established prior to the ice storm (advance regeneration) and seedlings established after the canopy openings were created by the ice storm (Yorks and Adams, 2003; 2005; Krill *et al*., 2004). However, mortality rates of hardwood seedlings are usually high (Berglund, 1976; Grimes, 1979; Gurevitch *et al*., 2006). In a droughty and nutrient-deficient site, low survival rates for hardwood seedlings should be expected. Therefore, it is unlikely that red maple and red oak will dominate this ice-damaged barren in the future.

In general, the post-ice storm regeneration pattern in the pine barren is not an example of disturbance-accelerated plant community succession (e.g., Abrams and Scott, 1989). The exception may be the red pine stand, where red pine seedlings were absent and the combined abundance of six hardwood species was over 6,600 stems per ha, including red maple, striped maple, red oak and American beech. The high tree mortality and inadequate pine regeneration across most of this rare ecological community suggests that without management intervention, the barren would gradually be converted from a pine barren to a heath barren, dominated by black huckleberry and late low blueberry (Yorks and Adams, 2003; 2005).

Assessment of the post-ice storm damage conditions across the pine barren revealed two immediate concerns for the management of this rare ecological community:

1. The broken trees and branches increased fuel loadings and raised the risk of wildfires;
2. A large portion of the jack pine seed bank was contained in serotinous cones attached to the broken branches.

Fuel loadings across the ice storm-damaged barren were measured during the summer of 2000 and estimates ranged between 24.7 and 58.5 metric tons per ha (Sargis and Adams 2004). These fuel loadings were extraordinarily high, much higher than stylized fuel models for eastern jack pine forests (Albini, 1976; Anderson, 1982) or prescribed burns in jack pine logging slash (Stocks and Walker, 1972; McRae, 1979). There was no doubt that these high fuel loadings throughout the pine barren, coupled with a summer drought, would present unacceptable wildfire risk for the land owner.

With its serotinous cones and canopy storage of seeds, jack pine typically regenerates following fire and the origin of even-aged stands can be traced to the most recent fire occurrence (Wein and MacLean, 1983; Burns and Honkala 1990). Although wild fires occurred at Flat Rock during the 20th century (Adams and Franzi, 1994; Gooley, 2005), prescribed burning had not been used in the barren because of the "anti-fire" sentiments held by the majority of property owners in the region. Following the ice storm of 1998, prescribed burning was not an option because fuel loadings at Flat Rock were too high to safely conduct a prescribed fire (Sargis and Adams, 2004). The restoration cutting was an experiment to see if jack pine stands could be regenerated using this mechanical treatment in lieu of fire.

In the second year following the restoration cuttings, jack pine seedling densities averaged 34,800 stems per ha (Yorks and Adams, 2003). These stem densities were higher than those reported for comparable jack pine seedling ages in other studies (Caveney and Rudolph, 1970; Beland *et al*., 1999). Jack pine regeneration following these restoration cuttings was considered adequate for stand replacement (Lynham, pers. commun.). By 2007, the average number of jack pine seedlings in the restoration cut areas averaged 9,500 stems per ha. High mortality rates should be expected for jack pine seedlings (Yarranton and Yarranton, 1974; Kenkel, *et al*., 1997). While jack pine seedling mortality rates were high during the first decade following the restoration cuttings, the seedlings in 2007 were approximately two meters tall and well-established (Figure 7).

The ice storm and subsequent restoration cuttings dramatically changed the structure of the pine barren. Ecosystem structure is an important aspect of wildlife habitat, including birds of the forest (DeGraaf and Rudis, 1987; DeGraaf *et al*., 1992; Bolen and Robinson, 2003). Habitat selection by birds in the Altona Flat Rock pine barren was well-documented in the early 1990's, prior to the ice storm (Gifford, 1994). Perhaps because of the abundance of dead and dying trees in the post-ice storm barren, two previously unreported species of woodpeckers, the three-toed woodpecker (*Picoides tridactylus*), and the black-backed woodpecker (*Picoides arcticus*) have been recently observed (Glidden, pers. observation).

Kirtland's warbler (*Dendroica kirtlandii*) is an endangered species that, until recently, was known to nest primarily in young jack pine stands located in Michigan's northern Lower Peninsula, with a few nesting records for the Upper Peninsula and elsewhere (Mayfield, 1990; Ewert, 2000; Corace, 2001). Transient Kirtland's warblers have not been observed in the jack pine barrens of Clinton County, New York (Mitchell and Krueger, 1997). The population of Kirtland's warbler appears to be increasing; in 2006, approximately 1,500 singing males were counted in Michigan and for the first time, Kirtland's warblers have been found nesting outside of Michigan (Thompson, 2008). In 2007, a pair of Kirtland's warblers was observed nesting in Wisconsin and another nesting pair was observed in Ontario (Thompson, 2008). The structure of the jack pine stands that were established by restoration cuttings a decade ago in the Flat Rock pine barren may provide suitable breeding habitat for Kirtland's warbler in northern New York. Local birders will be watching for Kirtland's warblers during the 2008 breeding season.

The ice storm of 1998 caused significant crown damage and mortality of jack pine, pitch pine and red pine trees in the rare sandstone pavement barren of Clinton County, New York. The capability of pitch pine to grow new branches from epicormic buds increased tree survival. Regeneration of jack pine in the post-ice storm barren was at risk because the seeds remained inside unopened serotinous cones attached to broken branches. Pine regeneration was extremely sparse in the ice-damaged stands and red maple was the most opportunistic species. Experimental restoration cuttings created an adequate seedbed and induced jack pine seed release from the resinous cones. The restoration cuttings successfully regenerated a new even-aged stand of jack pine without using fire.

ACKNOWLEDGEMENTS

The authors would like to thank the Forest Ecology and Management students of 1998 for initiating this long-term study. We are grateful for support from the owner of the Altona Flat Rock pine barren, The William H. Miner Agricultural Research Institute of Chazy, New York.

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