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Effects of an Ice Storm on Fuel Loadings and Potential Fire Behavior in a Pine Barren of Northeastern New York

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ABSTRACT

Ecological effects of natural disturbances depend on the disturbance type, frequency, intensity and spatial scale. Of the major natural disturbances in the Northeast, ice storms are more frequent than fires or wind storms. Affecting nearly ten million hectares, the ice storm of January, 1998 was probably the most intense and widespread natural disturbance in the Northeast during the 20th Century. Some of the areas heavily impacted by this ice storm were sandstone pavement pine barrens of northeastern New York, among the rarest ecological communities in New York State. Jack pine (Pinus banksiana) is the dominant tree species in the barrens. Ice storm damage to pine trees resulted in estimates of woody debris averaging 18 tons/ac (40 tonnes/ha) at the eight sites sampled in this study. These unusually high fuel loadings increase the probability for catastrophic wildfire. Predictions of fire behavior and fire intensity in these ice storm-damaged stands were made using the TSTMDL subsystem of BEHAVE. Estimates of fire behavior in these ice storm-damaged stands include flame lengths between 10 and 17 ft (3 and 5 m) and fireline intensities between 900 and 2600 Btu/ft/sec (3175 and 9400 kW/m). Fires of these intensities would be very difficult to suppress and would cause adverse ecological effects, including destruction of seeds contained in the slash. Further research is necessary to customize fuel models used to predict fire behavior in northeastern forests affected by disturbances.

Keywords: fire behavior; fuels; disturbance ecology; ice storms; pine barren

INTRODUCTION

Ecological disturbances can have dramatic influences on the structure and composition of forest ecosystems (Kohm and Franklin, 1997). There are several different types of disturbances occuring with wide ranges of frequency, intensity, and spatial scale (Cairns et al., 1977; Pickett and White, 1985). Important ecological disturbances include fire (Wright and Bailey, 1982; Pyne et al., 1996), insect defoliation (Perry, 1994; Barbour et al., 1999), wind storms (Canham and Loucks, 1984, Foster, 1988; Barry et al., 1993; NYSDEC, 1996; Dunn, 2000), and ice storms (Lemon, P.C., 1961; Boerner et al., 1988; Barry et al., 1993; Irland, 2000; Smith, 2000; Hooper et al., 2001).

Although disturbances are stochastic events, they are not necessarily independent of each other. The probability of a fire occurrence, for example, often increases following other disturbances because of increased amounts of woody debris (fuel loading) on the forest floor (Pyne et al., 1996). For example, wildfires have occurred in forests after blow-downs (Henry and Swan, 1974; Lorimer, 1977) and also in forests after insect defoliation (Stocks and Alexander, 1980; Lotan and Perry, 1983). We are not aware of any scientific studies of wildfires directly linked to increased fuel loadings following an ice storm, but such occurrences have been documented in newspaper reports (Press Republican, 2000, 2001).

The greatest natural disturbance of the northeastern United States and southeastern Canada during the 20th Century may have been the ice storm of January, 1998. During the week of January 4, 1998 ice accretions ranged between diameters of 2.5 and 10 cm, affecting ten million hectares across New York, New England and southern Canada (Irland, 1998; NEFA, 1998; DeGaetano, 2000; Allen, 2001). High-intensity ice storm impact was reported for approximately two million hectares of forest (Irland, 1998). One of the consequences of this ice storm was increased amounts of coarse woody debris on the forest floor (Hooper et al., 2001)., known to increase the probability of wildfire, especially during lengthy periods of drought (Pyne et al., 1996).

With fewer than five known examples in New York State (Reschke, 1990; Edinger, et al., 2002), the sandstone pavement pine barrens used in this study are among the rarest ecological communities in New York. Periodic wildfires have maintained jack pine (*Pinus banksiana*) as the dominant species in the barrens (Adams and Franzi, 1994). The ice storm of 1998 severely affected these pine barrens in northeastern (Clinton County) New York. In several stands, more than half of the trees lost more than half of their crowns or were uprooted by the ice storm. Tree mortality ranged between 10 and 50 percent (Valentine, 2002; Yorks and Adams, 2003a). The extreme canopy damage and tree mortality caused by the 1998 ice storm greatly increased fuel loadings in the barrens. The objectives of this study were:

1. quantify ice-damage slash (fuel loading) in eight pine barrens stands;
2. estimate wildfire behavior and intensity using BEHAVE in these stands;
3. predict potential ecological impacts of wildfires in ice storm-damaged stands.

METHODS

Site Description

The sandstone pavement pine barrens of Clinton County, New York were created approximately 12,000 ybp when a catastrophic flood drained glacial lake Iroquois. The floodwaters scoured surface material and exposed bedrock on discontinuous locations within a perimeter of about 32 square kilometers (Franzi and Adams, 1999). The composition and structure of plant communities in these barrens have been created and maintained by periodic wildfires. The predominant tree species in the barrens is jack pine (*Pinus banksiana*), with small areas dominated by pitch pine (*P. rigida*) or red pine (*P. resinosa*). The predominant shrubs are huckleberry (*Gaylussacia baccata*) and blueberry (*Vaccinium angustifolium*). Lichens (e.g., *Cladina rangiferina* and *Cladonia uncialis*) and mosses (e.g., *Polytrichum juniperinum* and *Pleurozium schreberi)* are abundant groundcover plants.

Three pine barrens in Clinton County were used as study sites. The William H. Miner Agricultural Research Institute in Chazy, New York owns the largest pine barren, approximately 2500 acres (1000 ha), locally known as “Flat Rock”. The Gadway jack pine barren preserve is about 500 acres (200 ha) in size and is owned by the Adirondack Nature Conservancy. The jack pine stand in the Stafford Rock barren is owned by Mr. Harold Rabideau.

Field Sampling

During the summers of 2000 and 2001, fuel loadings were sampled in eight different pine stands. The stands selected included one *Pinus rigida* stand at Flat Rock, one *Pinus resinosa* stand at Flat Rock, one *Pinus banksiana & Pinus rigida* stand at Flat Rock and five *Pinus banksiana* stands. The number of transects at each site is listed in Table 1.

Table 1. Site abbreviations, locations and dominant tree species.

Site Abbrevation	Dominant Species	Location	Sample Points
JP1	*P. banksiana*	Flat Rock	5
JP2	*P. banksiana*	Flat Rock	10
JP3	*P. banksiana*	Flat Rock	5
JP4	*P. banksiana*	Gadway	12
JP5	*P. banksiana*	Stafford	5
JPPP	*P. banksiana - P. rigida*	Flat Rock	5
PP	*Pinus rigida*	Flat Rock	10
RP	*P. resinosa*	Flat Rock	5

The fuels sampled in each of the eight stands were broken branches and tree stems resulting from the January 1998 ice storm. At each sample point, 20-m transect lines were established in each of the cardinal directions to assess slash fuels along a total distance of 80 m at each sample point. The number of intercepts of slash fuels were recorded by diameter class along each transect line as follows: 1 - 2.5 cm; 2.6 - 5.5 cm; 5.6 - 10.5 cm; 10.6 - 15.5 cm and 15.6^{+} cm, from ground level to 2 m above ground. The average number of fuel particles in each size class was calculated for each site.

Data Analysis

The computer program BEHAVE 4.1 (Albini, 1976; Burgan and Rothermel, 1984; Andrews, 1986; Burgan, 1987) was used to model fire behavior in the eight sampled stands. The BEHAVE system is a series of programs used to determine fire behavior under various conditions, such as different fuels, weather and topography. Test Model (TSTMDL) was used to modify fuel model number 4 of the 13 Stylized Northern Forest Fire Laboratory (NFFL) Fuel Models. Fuel model number 4 is designed for chaparral ecosystems, but it is also appropriate for modeling fire behavior in jack pine stands (Anderson, 1982). The TSTMDL program allows for the customization of stylized fuel models. TSTMDL was used to predict fire behavior under a given set of environmental conditions, but with different fuel loadings. Approximations of the stylized fuel size classes used in BEHAVE (Andrews, 1982) were made in the following manner: 10 – hr time lag fuels, 1 to 2.5 cm; 100 – hr time lag fuels, 2.6 to 10.5 cm; and 1000 – hr time lag fuels, 10.6 to 15.6+ cm).

Many environmental factors must be considered when selecting an acceptable fire behavior prediction model (Hely et al., 2001). Customized fuel loadings (high fuel loadings caused by ice storm damage) for fuel model 4 are more appropriate for predicting fire behavior in the pine barrens than using stylized models for logging slash (model numbers 11, 12 or 13), in part, because these models do not include estimates for live woody fuels. The stylized fuel loadings for model 4 are: 1-hr, 11.23 tonnes/ha; 10-hr, 8.99 tonnes/ha; 100-hr, 4.48 tonnes/ha; and live woody fuels, 11.23 tonnes/ha.

The jack pine stand at the Gadway barrens (JP 4) showed the least amount of ice storm damage resulting in the lowest slash loading on the forest floor. Therefore, JP4 was used as the baseline reference and then customized values were applied to fuel model 4 for each of the other seven stands.

For example, 97 intercepts for the 10-hr size class were counted in JP1 stand and 30 were counted at JP4 (baseline stand, corresponding to 8.99 tonnes/ha of 10-hr fuels). Therefore, the 10-hr fuel loading for JP1 was estimated by the following:

$$\frac{8.99}{30} = \frac{X}{97}$$

X = 29.0 tonnes per ha for JP1

Values for environmental parameters were selected to approximate summertime conditions for the pine barrens. The fuel moistures used in TSTMDL suggest moderate levels of precipitation and a low to medium fire potential. Fuel moistures are within the range of medium to high values for fuel model 4. The environmental parameters and respective values used in TSTMDL were: 1-hr fuel moisture (12%); 10-hr fuel moisture (13%); 100-hr fuel moisture (14%); live herbaceous fuel moisture (120%); live woody fuel moisture (120%); wind speed (9 mph) and slope (0%).

Output from BEHAVE programs include predictions of the rate of heat release at the soil surface (reaction intensity) and rate of heat release at the leading edge of the fire (fireline intensity). These are ecologically meaningful estimates of fire behavior that can be used to document effects of fire on ecosystem components.

RESULTS

The 10-hr fuel loadings ranged from 9.0 tonnes/ha) at JP 4, the baseline reference level, to 29.4 tonnes/ha (RP); (Table 2). Estimated 100-hr fuel loadings ranged from 4.5 tonnes/ha at JP 4, the baseline reference, to 17.9 tonnes/ha (RP); (Table 2). The total dead fuel loadings for the eight sites sampled in this study averaged 40.7 tonnes/ha.

Table 2. Fuel loadings used for TSTMDL fire behavior predictions.

Site	Live Woody[a]	1 - hr[a]	10 - hr[b]	100 - hr[b]	Total Dead Fuel
			tonnes per hectare		
PP	11.2	11.2	10.5	11.6	33.3
JP4	11.2	11.2	9.0	4.5	24.7
JP3	11.2	11.2	11.7	5.2	28.1
JP2	11.2	11.2	17.4	6.7	35.3
JP5	11.2	11.2	20.1	9.0	40.3
JPPP	11.2	11.2	23.1	17.2	51.5
JP1	11.2	11.2	29.1	14.2	54.5
RP	11.2	11.2	29.4	17.9	58.5

[a] Adapted from stylized fuel model # 4 (Anderson, 1982).

[b] Estimation based on transect sampling of slash.

The predicted fire behavior characteristics for each of the eight sites are shown in Table 3. These fires would be fast-moving, with rates of spread ranging between 14m/min to 20 m/min. The average rate of spread for each of the eight sites was 15.6 m/min. Predicted flame lengths ranged from 3 m to 5 m. The average flame length for the eight sites was 3.9 m.

Predicted reaction and fireline intensities for the eight sites are shown in Table 3. Predicted reaction intensities ranged from 1008 kW/m^2 to 2259 kW/m^2 (Table 3). The average predicted reaction intensity was 1498 kW/m^2. Predicted fireline intensities ranged from 3175 kW/m to 9416 kW/m (Table 3). The average predicted fireline intensity was 6145 kW/m.

Table 3. Fire behavior predictions (SI units) for eight pine barren sites.

Site	Rate of Spread (m/min)	Heat per Unit Area (kJ/m^2)	Reaction Intensity (kW/m^2)	Fireline Intensity (kW/m)	Flame Length (m)
PP	14	14004	1048	3175	3
JP4	17	13348	1008	3808	3
JP3	16	13998	1049	3705	3
JP2	20	21895	1616	7239	5
JP5	20	24708	1809	8075	5
JPPP	17	27796	2008	7941	5
JP1	18	31344	2237	9416	5
RP	17	31750	2259	8974	5
Average	15.6	20604.9	1498.3	6144.8	3.9

DISCUSSION

Natural disturbances can have profound effects on the structure of forest ecosystems, including increases in woody debris on the forest floor (Franklin, et al., 2000). For example, the January, 1998 ice storm increased woody debris in an old-growth hardwood forest in Quebec, Canada by 19 tonnes/ha (Hooper et al., 2001). Estimated slash loadings in the Clinton County, New York pine barrens caused by the January, 1998 ice storm are higher than those reported by Hooper et al. (2001).

The estimated slash loadings in the pine barrens of Clinton County, New York ice storm-damaged stands are higher than values reported for five undamaged jack pine stands in Ontario (Stocks et al., 1990), which ranged between 6.5 and 22.5 tonnes/ha. Slash loadings in this study are close to the low end of the values for jack pine logging slash weights reported by Stocks and Walker (1972) that ranged between 34 and 117 tonnes/ha.

Woody debris is an important fuel component for wildland fires and contributes directly to fireline intensity and reaction intensity (Albini, 1976). Fireline intensity (the product of fuel weight, heat content and rate of spread) is the best fire behavior descriptor for correlations with above-ground fire effects (Andrews and Rothermel, 1982). Fires with fireline intensities greater than 1700 kW/m can easily develop into wildfires that require extreme suppression efforts to control (Sando, 1978; Andrews and Rothermel, 1982). Fireline intensity values reported for wildfires include: over 10,000 kW/m (Van Wagner, 1965; DeCoste et al., 1968; Ohmann and Grigal, 1979); over 20,000 kW/m (Van Wagner 1977); over 30,000 kW/m (Walker and Stocks, 1972; Simard et al., 1983); over 40,000 kW/m) (McArthur and Cheney, 1966); and over 50,000 kW/m (Anderson, 1968; Stocks and Alexander, 1980).

Fuel loadings in the ice storm-damaged pine barrens in this study could easily produce fireline intensities typical of wildfires that would be very difficult to control. Stocks and Walker (1972) reported fire behavior characteristics for 24 prescribed burns in jack pine slash. Two fires had fireline intensities less than 1730 kW/m, three fires had intensities between 1730 and 3460 kW/m, and 19 had intensities greater than 3460 kW/m (Stocks and Walker, 1972). Figure 1 illustrates the relationship between flame spread rates, heat per unit area and fireline intensity. Potential fireline intensities of post-ice storm Clinton County, New York pine barren fires would be very high, with flame lengths between 3 to 5 m, largely due to high fuel loadings.

Fuel loadings also directly influence a fire's reaction intensity, which is heat per unit area divided by the residence time of a burning fuel particle. Reaction intensity is the best fire descriptor for evaluating fire effects at or near ground level (Andrews and Rothermel, 1982). Due to canopy breakage caused by the ice storm, a large proportion of the serotinous jack pine cones were attached to pieces of slash at the forest floor. With serotinous cones that open when heated, jack pine is a fire-adapted species exhibiting canopy storage of seeds (Burns and Honkala, 1990). However, predicted reaction intensities for the post-ice storm barrens suggest that fires would likely combust cones, rather than simply open them. Jack pine seeds are often destroyed by burning slash piles (McRae, 1979).

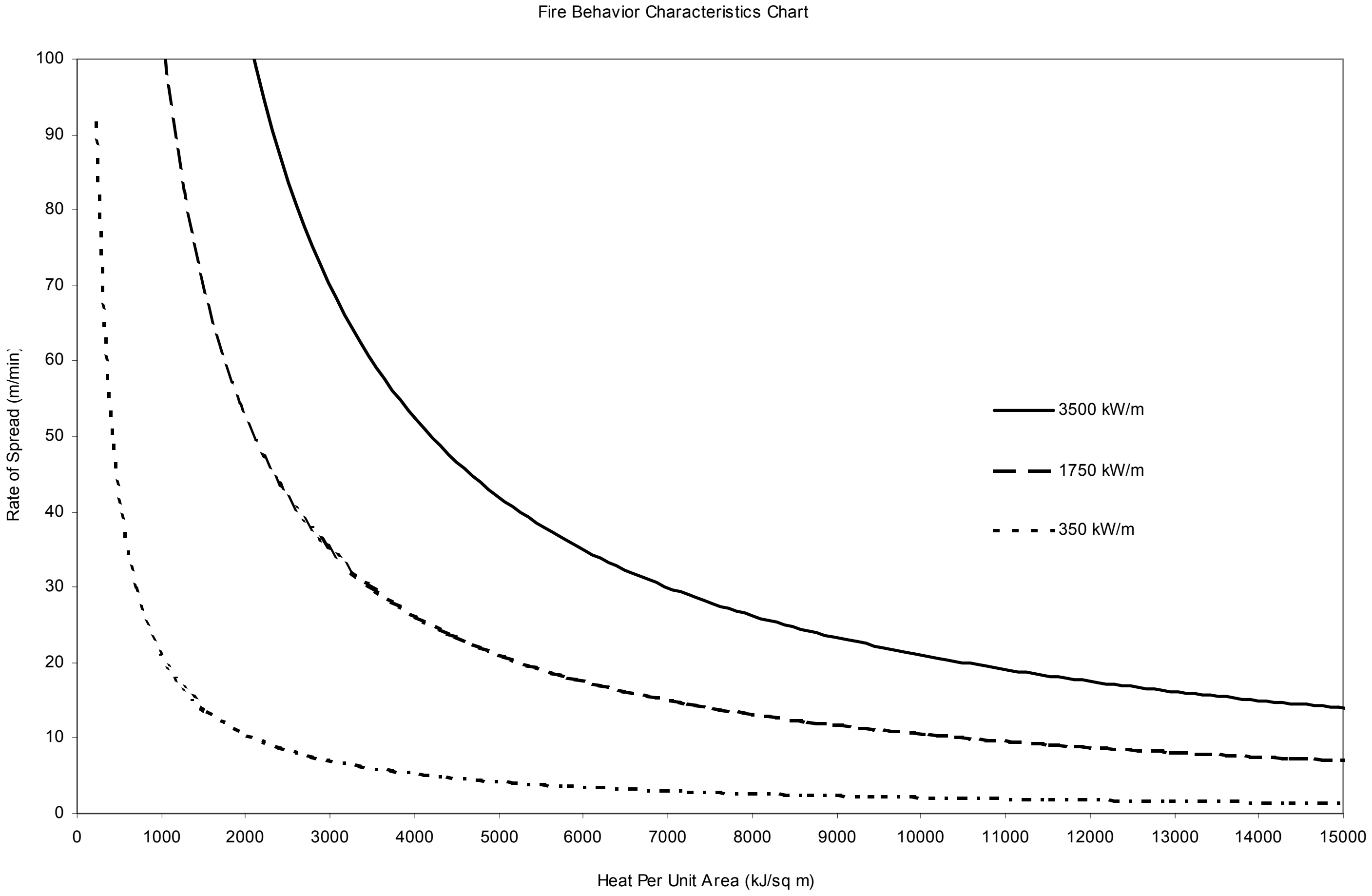

Figure 1. Relationship between fire spread rate, heat per unit area and fireline intensity.

The ice storm of January, 1998 presented some challenging management issues for these rare ecological communities. The impact of the ice storm on stand structure in the pine barrens was extremely severe. Tree mortality from ice storm damage in these barrens ranged between 10 and 50 percent (McCaffery, 1999; Valentine, 2001; Yorks and Adams, 2003a). Without fire, the release of jack pine seed from serotinous cones would be inadequate to regenerate a new stand. With fire, seeds in the slash would likely be destroyed by the intense heat from fires that would also be very difficult to manage. During the summers of 1998 to 2001, fuel reduction operations were implemented in sections of the barrens to reduce the risk of high-intensity wildfires. As an additional benefit, it was hoped that soil scarification plus crushing of slash and competing shrub vegetation by skidder tires and feller-bunchers would stimulate jack pine regeneration. This mechanical treatment of ice storm-impacted stands successfully initiated jack pine seedlings while regeneration in adjacent, untreated stands remains sparse (Yorks and Adams 2003b). Given the exceptionally high risk for using prescribed fire in these ice storm-impacted pine barrens, mechanical treatments remain the best management options for ecosystem restoration.

Conclusions

1. The ice storm of January, 1998 resulted in the accumulation of extremely large amounts of slash at the forest floor in the pine barrens of Clinton County, New York;
2. These large fuel loadings have potential to produce high-intensity wildfires that would be very difficult to control;
3. Mechanical treatment, rather than prescribed fire, is the preferred option for restoration projects in these ice storm-damaged pine barrens.

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