Fifteen-year Forest Structure Changes in a Sandstone Pavement Barren

Thomas F. DellaRocco
Dr. Jacob N. Straub **(Faculty)**

Center for Earth and Environmental Science
SUNY Plattsburgh, Plattsburgh, NY 12901

ABSTRACT

The Altona Flatrock sandstone pavement barren is a rare fire-dependent ecological community geographically located at the narrow overlap of jack pine and pitch pine species ranges. We studied fifteen year post-ice storm plant community change at the Altona Flatrock pine barren in Clinton County, New York. Prior research predicted plant community changes in the barren due to fire exclusion. Our study is the first to examine long-term changes in plant species composition of this pine barren community. In the overstory, pitch pine basal area and density remained similar (i.e., < 20% Δ) between 1999 and 2014, while density and basal area of red maple increased 67% and 109%, respectively. Jack pine overstory mortality was 100% between 1999 and 2014 in our plots. Few jack pine saplings (12.5 stems/ha) and no pitch pine saplings were present in our plots. However, a great density of red maple saplings (1,950 stems/ha) existed. Ground cover was dominated by huckleberry, *Sphagnum* spp., and Schreber's big red stem moss. With an absence of fire and the subsequent decreases in jack and pitch pine, this post-ice storm pine barren is developing into a boreal heath barren dominated by huckleberry in the understory with an overstory comprised mostly of red maple. In the absence of fire, or a suitable management alternative, this rare ecological community type may become extirpated from this Region. Further research could focus on successfully regenerating fire dependent pines to provide a more complete understanding of the ecological requirements and traits in this sandstone pavement barrens ecosystem in Clinton County.

Keywords: pine barren; succession; ice storm; fire; jack pine; pitch pine

INTRODUCTION

The Altona Flatrock pine barren in Clinton County, New York was heavily influenced by a large ice storm in 1998 (Irland 1998). An assessment of overstory tree composition at this site in 1999 revealed it was dominated by an admixture of jack pine (*Pinus banksiana*), pitch pine (*P. rigida*), with few red maple (*Acer rubrum*). This pine barren is geographically located at the northern terminus of pitch pine and southern terminus of jack pine (Burns and Honkala 1990, Meilleur et al. 1997). Both species depend on fire for reproduction (Yorks and Adams 2003). Fire heats the seratonous cones of these trees and in turn spread the winged seeds on the bare, scarified post burn soil for successful seed germination. This particular sandstone pavement pine barren is fire-dependent and considered a rare ecosystem by the New York Natural Heritage Program (Edinger et al. 2002). The last stand-replacing fire to affect this pine barren occurred in 1957 and it burned over 1,200 ha. In this type of ecosystem, fire acts as an ecological mechanism to set the successional state back to a less developed state (Noble and Slatyer 1980).

The objective of this study was to quantitatively assess successional development of this pine barren fifteen years after the ice storm. Specifically, we aimed to test for differences in density, basal area, frequency, and importance value of the overstory tree community. This assessment allowed us to describe succession in the pine barren after a major disturbance and with the absence of fire. Without fire in this pine barren we predict it will trend toward an alternate community type.

METHODS

Site Description

For a full site description see Krill et al. (2004).

Data Collection

In 1993, > 45 permanent forest plots were established at the Altona Flatrock pine barren (Appendix A). These plots were $100m^2$ and situated along transects that ran perpendicular to existing trails. These study plots were sampled in 1999 after an ice storm affected the region. Damage from this ice-storm was extensive and pervasive (Krill et al. 2004). Plots were delineated with cairns and painted wood stakes and geographical coordinates were recorded. Individual trees were given unique numbered tags. In 1999 data was collected on species and DBH for all overstory trees. We re-sampled a subset (n = 8), from two different stands, of these original plots because it was logistically impossible to sample all plots. We sampled four plots from the “pitch pine dominated” stand and four plots from the “jack pine/pitch pine dominated” stand.

In the fall of 2014, plots were located with compass bearings and interplot distances, and then remarked with surveyors tape and flags. We sampled all plants, lichen, and detritus within plots in three strata; overstory, understory and groundcover. We counted and measured DBH for all overstory trees that were ≥ 2.5 cm within each plot. We also recorded stand, plot number, tree tag number, species, height, canopy fullness, canopy dieback and live status. If we encountered a tree, which did not have a tree tag it was given a new tag and number. A tree with multiple trunks was considered one individual if the trunk deviation occurred above breast height. If multiple trunks occurred below breast height then we considered these multiple individuals. Dead tree species were determined by referencing the tree tag and referring to original records. Tree height was determined with an electronic inclinometer and recorded to the nearest 1m. Tree DBH was determined using a D-tape measure. Recovery class, canopy fullness and die back were determined using a visual assessment.

Within each large plot we identified and used calipers to measure, the DBH of all trees < 2.5 cm DBH (i.e., saplings). For the understory we recorded stand, plot number, species, and height. To record height we used a meter stick and rounded the height to the nearest 0.5 m.

In each corner of the larger plots we established $1m^2$ ground cover plots. Within these plots we identified all plants not included in the overstory and understory categories and estimated each species' percent cover. We also recorded the amount of detritus (i.e. leaf debris, sticks, and logs) as an absolute percent cover.

Data Analysis and Summary

Basic summaries of data and all statistical tests were carried out using Microsoft Excel. A paired T-test was used to compare tree density (tree/ha) and dominance (m^2/ha) between 1999 and 2014. We considered densities or dominance statistically significant if the P-value was < 0.05. Relative importance was calculated as the sum of Relative Density + Relative Dominance + Relative Frequency for jack pine, pitch pine, and red maple separately in 1999 and 2014.

RESULTS

One softwood (pitch pine) and two hardwoods (red maple and red oak) comprised 100% of all live overstory trees sampled in 2014. Among plots, standing total live tree density ranged from 600 trees/ha to 2,300 trees/ha while snag density ranged from 100 trees/ha to 800 trees/ha. Average DBH was 16.0 cm (SE = 0.93), and 5.4 cm (SE = 0.37) for pitch pine and red maple, respectively while average height was 6.4 m (SE = 0.43) and 5.3 m (SE = 0.19) for pitch pine and red maple, respectively. We recorded no living jack pines and jack pine snags averaged 262.5 trees/ha. Average canopy fullness and dieback was 56.2% and 24.8% for red maple trees, respectively. Average canopy fullness and dieback was 48.3% and 21.5% for pitch pine trees, respectively.

Table 1. Live tree and snag, density, dominance (m^2/ha), frequency of live tree occurrence, and importance value. This data was sampled from eight 10m X 10m plots at Altona Flatrock Pine Barren, autumn, 2014.

	Live trees/ha*		Dead trees/ha*		Dominance*		Frequency		Relative Importance	
Species	1999	2014	1999	2014	1999	2014	1999	2014	1999	2014
Red Maple	**463**	**775**	25	13	**1.1**	**2.3**	0.63	0.88	105.6	158.0
Jack Pine	138	0	325	25	1.8	0.0	0.50	0.00	73.0	0.0
Pitch Pine	725	600	413	88	11.0	13.8	0.88	1.00	221.4	230.0
All Trees	1325	1375	763	125	14.0	16.1	1.00	1.00		

• The star (*) following the title signifies a paired T-test was carried out on these columns.
The bold values indicate there was a significant difference ($p<0.05$) between 1999 and 2014.

Live total tree density and basal area was similar between 1999 and 2014 while density of dead trees decreased (Table 1). Live red maple density (t= 3.96, P= 0.005), dominance (t = 3.01, P= 0.020), frequency of occurrence, and relative importance increased from 1999 to 2014 (Table 1) while snag density was similar between years. Jack pine snag density remained similar between 1999 and 2014 (t = -2.14, P=0.070). Live jack pine frequency and relative importance decreased between 1999 and 2014, while density (t = -1.45, P=0.190) and basal area (t = 1.96 P= 0.091) were similar between 1999 and 2014. Live pitch pine density (t = -1.45, P= 0.190) and snag density (t = -0.737, P= 0.485) experienced no change from 1999 to 2014. However, dominance (t = 1.96, P=0.091), frequency, and relative importance all increased. Relative importance increased by 33% and 4% for red maple and pitch pine, respectively but because no jack pines survived to 2014, relative importance was zero (Table 1).

Red maple had an uneven-aged stand structure in 1999 and 2014, where most trees were <6 cm DBH. Red maple increased in abundance between 1999 and 2014 in every DBH class except 4-6 cm while remaining consistent in DBH classes 12-14 cm and 14-16 cm (Figure 1). Red maple increased gains through recruitment and survival of older age classes. The recruitment of red maples was most evident by the number of trees in the DBH class of 2-4 cm; this class had 237.5 trees/ha in 1999 and 450 trees/ha in 2014.

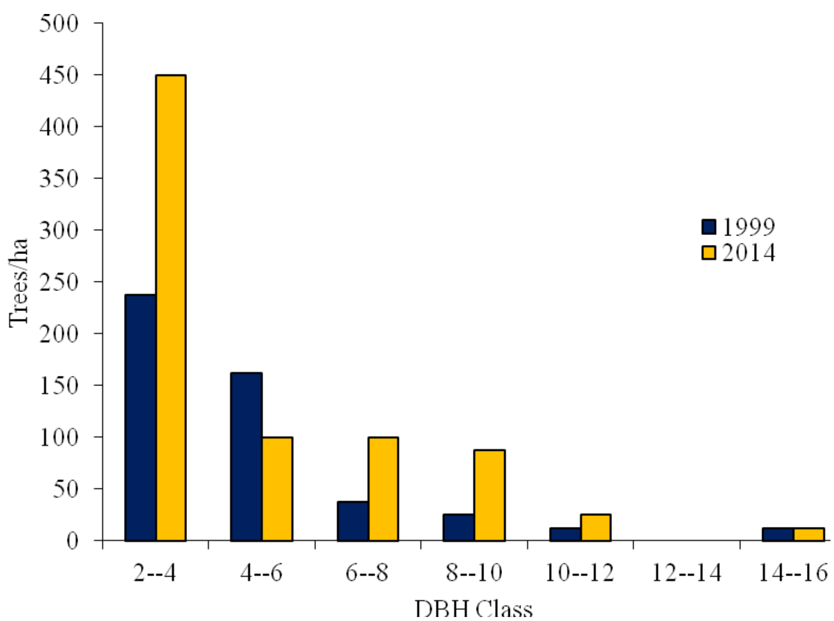

Figure 1. Live tree density (tree/ha) by diameter (cm) at breast height class for red maple (*Acer rubrum*) sampled from eight 10m X 10m plots at Altona Flatrock pine barren, autumn, 2014 (red bars) and those sampled in autumn 1999 (green bars).

Pitch pine had an even-aged stand structure in 1999 and 2014. Pitch pine abundance decreased from 1999 to 2014 in every DBH class except 20-22 cm, 22-24 cm, 26-28 cm and 32-34 cm where abundance increased (Figure 2). In DBH class 28-30 cm pitch pine abundance was zero in both years. All jack pines alive in 1999 were dead in 2014.

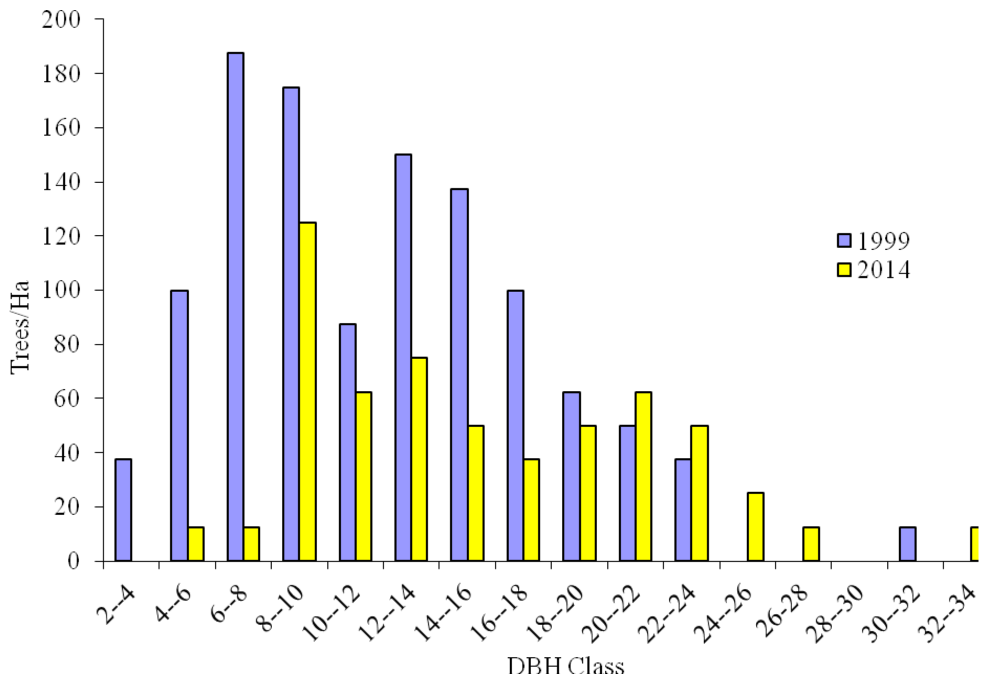

Figure 2. Live tree density (tree/ha) by diameter (cm) at breast height class for pitch pine (*Pinus rigida*) sampled from eight 10m X 10m plots at Altona Flatrock pine barren, autumn, 2014 (yellow bars) and those sampled in autumn 1999 (light blue bars).

No pitch pine saplings were recorded in any plot. Jack pine regeneration was very low (12.5 saplings/ha). In contrast, red maple saplings averaged 1,950 /ha. The average height of jack pine saplings was 1.0 m while the average height of red maple saplings was 1.8 m.

Groundcover species richness was twenty-one and was mostly huckleberry (*Gaylussacia baccata*) and *Sphagnum* spp.. Huckleberry comprised the greatest absolute percent cover (63.2%) of plants in the groundcover (Figure 3). *Sphagnum* spp. comprised an average of 56.7% of our sampled plots. Schreber's big red stem moss (*Pleurozium schreberi*) comprised the third greatest absolute percent cover (30%). The three functional groups, which dominated the groundcover were bryophytes and lichen (153%), woody plants (145%) and herbaceous plants (15%).

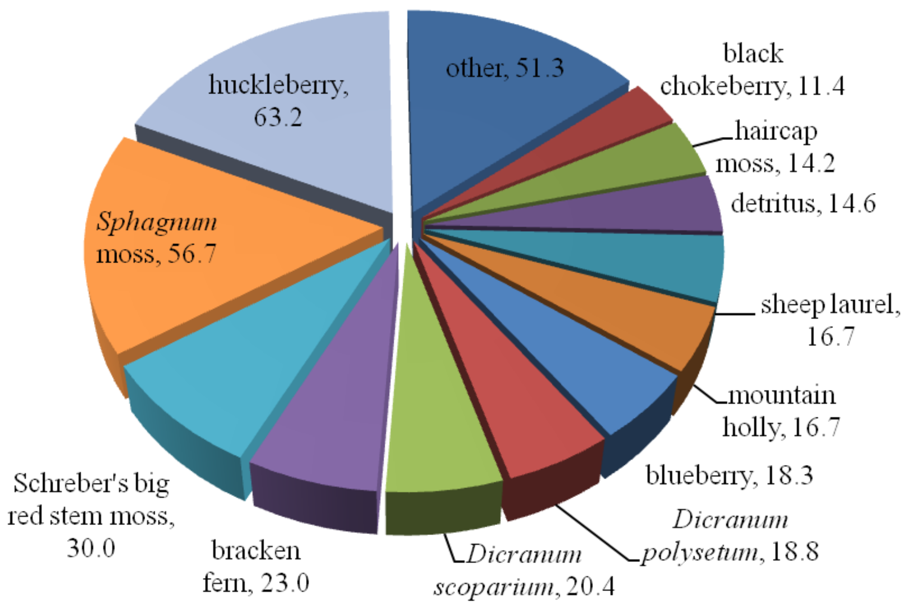

Figure 3. Absolute percent cover by species for ground cover sampled from 1m X 1m plots at Altona Flatrock pine barren, autumn, 2014.

DISCUSSION

Our results corroborate previous predictions that the Altona Flatrock pine barren is undergoing a rapid plant community shift, at least in the areas we sampled. Specifically we documented: 1) 100% jack pine overstory mortality over the last fifteen years, 2) red maple increase in density and dominance, 3) pitch pine growth and natural stand progression, 4) scant evidence of regeneration for either jack or pitch pine.

The ice storm of 1998 killed more jack pine than other tree species in the Altona Flatrock pine barren, a finding consistent with other research (Ryan and Smith 2005). One reason for mortality of jack pine is the infrequency of this species to produce epicormic branches after crown and stem damage (Krill et al. 2004). Epicormic branching is a plant strategy that allows needles or leaves to develop, usually from the main stem, and photosynthesize when the main canopy has received damage or has perished. Therefore, this ice storm may have accelerated the state-shift of this community type by promoting faster growing species like red maples, while killing jack pines. Pitch pine did not experience mortality to the extent of jack pine because of their tendency to produce epicormic branches and continue to photosynthesize.

Red maple had considerably more recruitment into the overstory than other tree species. The lack of recruitment of pitch pine and sparse recruitment of jack pine alludes to a possible environmental driver effecting reproduction of these species in the pine barren. We suspect a factor inhibiting recruitment is direct competition from shrubs like huckleberry. The thick mat of bryophytes and lichen present an additional hindrance to recruitment because bryophytes and lichen are a poor medium for pine seeds to germinate (Yorks and Adams 2003). The lack of fire as a disturbance in this ecosystem is another environmental driver likely effecting the recruitment of pitch pine and jack pine because both species are fire dependent. These species produce seratonous cones, which require fire as a mechanism to open and release the seeds. In addition, fire clears the understory and scarifies the soil to produce the growing conditions necessary for jack pine and pitch pine regeneration. We did encounter some oak saplings, which indicated oaks may have a long term advantage over red maple, jack pine and pitch pine if the practice of fire suppression continues. Red oak is predicted to increase in density and dominance in northern New York, while red maple is predicted to decrease (Iverson et al. 1999). A moderate increase in climate may completely push jack pine out of the region and promote pitch pine however more work is need to substantiate this claim.

Our data suggest the Altona Flatrock pine barren is shifting to a alternative community type. Possible alternate community types include a boreal heath barren or a stand dominated by hardwood species like red maple (Edinger et al. 2002). However, given the depth and quality of soil, tree density will likely remain low, regardless of the lack of fire. This change in overstory trees is significant because the jack pine and pitch pine dominated pine barren, which has historically existed at the location is a rare ecosystem in New York state and globally (Edinger et al. 2002). In addition, pine barrens provide 'habitat islands' for many animals that require shrubland or the gestlalt of a young forest (Bried et al. 2014). With extensive and growing areas of mature forest, pine barrens may contribute disproportionately to early successional habitat availability and regional biodiversity conservation (Bried et al. 2011). Further, this pine barren is at the northern limit of pitch pine and southern limit of jack pine, making this pine barren a unique opportunity to study inter- and intra-specific competition of these two tree congeners (Meilleur et al. 1997, Burns and Honkala 1990).

Groundcover was dominated by a diversity of woody shrubs, bryophytes and lichen. The bryophyte and lichen community was so dense it blocked light from the soil substrate which makes it difficult for any woody or herbaceous seeds to germinate (Yorks and Adams 2003). Woody shrubs like huckleberry, were often over a meter in height in some areas, shaded any jack pine or pitch pine seedlings and made them unlikely to develop to saplings. This dense groundcover is a direct effect of a lack of fire, which would otherwise burn away groundcover, eliminating competition for the jack pine and pitch pine seedlings, while proving fertile substrate, leaving the ground scarified and bare or sparse. Scarified soil conditions are needed for the germination and growth of jack pine.

The rate of jack pine reproduction at the Altona Flatrock pine barren is extremely low when compared to other sites, which experience disturbances like fire. For example, at a different site four years after a seed tree cutting and proscribed burning 12,196 jack pine saplings/ha were recorded (Yorks and Adams 2003). In addition, at other sites twenty year old stands have been recorded to have 2,470 jack pine trees/ha (Burns and Honkala 1990). We sampled no pitch pine seedling in our plots. This same observation was made on an unburned site in Pennsylvania (Ruffner 1997). However, on a burned site at this location in Pennsylvania seedling density averaged 116 pitch pine seedling/ha. Other studies have found a large number (5,500 seedlings/ha) of pitch pine seedlings following a "high intensity" fire (Major et al. 1998). In an Ohio mature oak-hickory stand no red maple trees were sampled (Burns and Honkala 1990). Six years after a clear cutting at this site, 2,200 red maple seedlings/ha were sampled. Similarly, we found 1,950 red maple saplings/ha.

Because we sampled only eight plots, our inferences do not extend to the entire Altona Flatrock pine barren ecosystem. There are portions of the Altona Flatrock that have experienced restoration cuts and these areas have dense stands of jack and some pitch pine (Krill et al. 2004). Jack pine has not experienced 100% mortality on the entire Altona Flatrock. We found no statistical difference in jack pine density and basal area. However, there was a significant biological difference in jack pine density and basal area. This was likely a result of the small sample size used in this study. It is also possible that jack pine populations are decreasing because of intraspecific competition or old age. The pitch pine trees may be affected by similar drivers.

Altona Flatrock has a history of fire suppression and limited active management practice (Yorks and Adams 2003). As early as 2003 active management practices including restoration cutting and prescribed burning of the pine barren was recommended. Since that time and because of a lack of management and natural fire, the pitch pine and jack pine populations in parts of the Altona Flatrock pine barren have diminished. The pine barren ecosystem is fire-dependent so succession normally occurs in a cycle, which is driven by fire (Noble and Slatyer 1980). The lack of fire in this pine barren has put this ecosystem on a linear successional trajectory. This linear succession has lead the pine barren to trend towards an alternative community type of increased red maple or towards a boreal heath barren (Edinger et al. 2002).

An experimental restoration cutting was implemented in 2000 (Krill et al. 2004). This resulted in the recruitment of jack pine and pitch pine seedlings. This restoration cutting scarified the soil and simulated the effect of a wild fire, which is necessary for jack pine regeneration (Yorks and Adams 2003). Pitch pine regeneration is also aided by fire and soil scarification.

There are >45 study plots at the Altona Flatrock pine barren. If more of these were sampled then a holistic perspective of successional trends occurring could be understood. Another reason these other plots should be studied is because other locations in this pine barren are dominated by different species. A better understanding of the reproductive ecology of tree species would lead to a better understanding of why we only sampled one jack pine and no pitch pine saplings. Studying the effects of the current ground cover on seedling recruitment would supplement our understanding of the succession occurring in this pine barren. Future studies similar to the comparative study we carried out may also lead to an enhanced understanding of the growth, survival and succession occurring at the Altona Flatrock pine barren and similar ecosystems.

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Appendices

Appendix 1: Latitude and longitude for permanent forest plots established in 1998 and used for this study. The plots represent the northeast corner of 10m X 10m plots.

Pitch Pine

#1	N 44°50.146'	W 73°34.272'
#2	N 44°50.140'	W 73°34.309'
#3	N 44°50.127'	W 73°34.350'
#4	N 44°50.125'	W 73°34.385'

Jack Pine-Pitch Pine

#1	N 44°49.984'	W 73°34.521'
#2	N 44°49.989'	W 73°34.486'
#3	N 44°49.965'	W 73°34.477'
#5	N 44°50.048'	W 73°34.513'

Appendix 2: List of all species sampled at the Altona Flatrock pine barren in 2014 by scientific and common name. This list is divided into the three categories sampled including overstory, understory, and groundcover.

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