Proceedings of the Nova Scotian Institute of Science (2010)
Volume 45, Part 2, pp. 26-54

POST-HURRICANE CONIFEROUS REGENERATION IN POINT PLEASANT PARK

JAMES W N STEENBERG* and PETER N DUINKER
School for Resource and Environmental Studies
Dalhousie University, Faculty of Management
6100 University Ave, Suite 5010
Halifax, NS, B3H 3J5

Point Pleasant Park in Halifax, Nova Scotia, sustained catastrophic forest disturbance from Hurricane Juan in September, 2003. This study assessed the adequacy of natural coniferous regeneration in the park in the fall/winter of 2006-2007 and compared the regeneration with pre- and post-disturbance park surveys. The park was stratified using existing trails, transects were spaced 10 m apart, and 20 m2 plots were laid every 10 m. There was a large observed variation of seedling density, with the highest densities being found in the northern and western section of the sample area, and the lowest being found in the south-east. Red spruce was the dominant regenerating species. Balsam fir showed a high variation in density. White pine was less dense and fairly uniformly distributed whereas eastern hemlock had a sparse and patchy distribution. White spruce and exotic species were sparse and tended to be found in areas with lower total regeneration. The comparison with the pre- and post-disturbance park surveys revealed regeneration similar in composition to existing and pre-disturbance forest cover. There are several park management techniques that could benefit park recovery such as the use of donor sites, the importation of favourable conifer species for fill-planting, the culling of some exotic species, and volunteer planting programs.
Keywords: Regeneration, succession, disturbance, Acadian Forest Region, park management, forest ecology, Atlantic Canada

INTRODUCTION

Overview

Urban ecosystems, such as forest parks, are of great importance to city dwellers for aesthetic, recreational, and educational purposes, clean air, and noise buffers. Because of the nature of urban activity, urban forest parks are subject to high levels of disturbance due to fragmentation, biomass removal, and invasive/exotic species (Nowak 1994, Dwyer et al 2003). Furthermore, urban forest parks are subject to the same natural disturbances experienced by native forest ecosystems such as fire and windthrow (Mosseler et al 2003). Natural disturbances in forest parks provide unique research opportunities such as assessing the extent and nature of damage a catastrophic wind disturbance can have, and the pattern of regeneration that will occur considering both the history of

* Corresponding author: jsteenbe@dal.ca.

intensive park management and the isolation from seed sources that are typical in native forests (Jotcham et al 1992, Neily et al 2004, Burley et al 2007).

Point Pleasant Park is situated in Halifax, Nova Scotia, at the south end of the city's peninsula. In September, 2003, the park was struck by Hurricane Juan and sustained extensive damage. There was public outcry from the citizens of Halifax to recover the forests of the park (PPPIDC 2005). The purpose of this study was to assess the regeneration of coniferous trees in the most disturbed forested areas of Point Pleasant Park to determine whether the park is recovering into a desirable state. The survey was completed in the fall/winter of 2006-2007 and measured regenerating tree-species composition, distribution, and density within the sample area, and as well made a description of the soil drainage and competition within each plot. A comparison between the species composition of the observed regeneration in this study and the forest composition before Hurricane Juan (Jotcham et al 1992, Neily et al 2004) provided data that were used to estimate whether the park was returning to a species composition similar to pre-hurricane conditions. The study results will be useful as baseline data to help discern which park management strategies can best achieve the goal of stable and expedited forest recovery.

OBJECTIVES

- To assess the adequacy of natural regeneration in heavily disturbed areas of the park.
- To compare the observed regeneration with the pre-disturbance forest conditions.
- To identify areas of high and low regenerative density for the possible use of donor sites as a park-recovery management tool.
- To identify which areas might require fill-planting or thinning.
- To assess the extent of park regeneration to exotic tree species.
- To provide baseline data on coniferous regeneration for park management and related decision-making.

Point Pleasant Park

Point Pleasant Park is comprised of 75 ha of forested land, recreational areas, and historical sites, and is situated at the southern tip of the Halifax peninsula. Point Pleasant was the original site chosen for the settlement that was to be Halifax in 1749, but the settlement was moved to present day downtown Halifax shortly after (Kitz &

Castle 1999, Kalkreuth & Duinker 2006). The site was then chosen for military defense of the harbour and city against the French and Americans and vegetation was continuously removed as the park was fortified. In 1866, Point Pleasant officially became a public park on a 999-year lease from the Crown to the City of Halifax. Large-scale vegetation removal ceased and the park vegetation grew into a plant community similar to those found in the Acadian Forest Region (AFR), the forest region in which the park is located (Farrar 1995, Kitz & Castle 1999, Burley et al 2007).

The Acadian Forest Region (AFR) covers the majority of the Maritime Provinces between 43°N and 48°N. It is bordered by the Boreal and Great Lakes-St Lawrence Forest Regions and shows characteristics of both (Rowe 1972, Loo & Ives 2003). The primary species associated with the AFR are red spruce, white pine, eastern hemlock, balsam fir, yellow birch, sugar maple, and red pine. Red spruce is the characteristic climax species associated with the region (Rowe 1972). Old-growth AFR stands are characterized by shade-tolerant, late-successional species such as red spruce and eastern hemlock, but are becoming rare due to agricultural and silvicultural land clearing (Loo & Ives 2003, Mosseler et al 2003, Stewart et al 2003). Most of the AFR is affected by human use and, in Nova Scotia, is dominated now by early-successional, even-aged stands with a relatively high frequency of white spruce, balsam fir, red maple, and white birch (Loo & Ives 2003, Mosseler et al 2003).

The Point Pleasant Park forest, and its place in the AFR, have been described by several authors (Rowe 1972, Simmons et al 1984, Jotcham et al 1992, Neily et al 2004). The park lies within the Atlantic Coastal Region (ACR) described by Simmons et al (1984), but previous surveys of the park found the forest composition to be most similar to the spruce-fir-pine-maple-birch association, which is an early successional complex of the ACR generally found in logged or burned areas (Jotcham et al 1992, PPC 1994, Neily et al 2004).

Point Pleasant Park shows characteristics of two forest sections within the AFR as characterized by Rowe (1972): the East Atlantic Shore section (A.5b) and the Atlantic Uplands section (A.11), (Rowe 1972, Neily et al 2004). Section A.5b is a strip that extends from Cape Breton to Mahone Bay and shows no dominance by red spruce (see Appendix A for species index). Low, dense stands of balsam fir, increased abundance of white spruce, as well as white pine along the shoreline, are all characteristic of section A.5b (Rowe 1972). Section A.11 covers over half of Nova Scotia and the primary species are red spruce, eastern hemlock, white pine, and red maple, with balsam fir present as young growth. The uplands are susceptible to wind and fire disturbances, and have been heavily affected by human development (Rowe 1972). A pre-hurricane ecological survey of Point Pleasant Park stated that a catastrophic disturbance such as a hurricane could cause severe tree mortality due to park's thin soil, steep topography, and presence of even-aged mature conifer stands (Jotcham et al 1991).

Approximately 63 ha (84%) of Point Pleasant Park were forested, and of that 63 ha, approximately 49.2 ha were coniferous stands (76-100% coniferous trees) and 3.8 ha were mixedwood stands (26-75% coniferous trees) (LeHave Forestry Consultants Ltd 1984). The dominant native coniferous species in the park were red spruce and white pine, with occurrences of balsam fir, eastern hemlock, white spruce, and red pine. Native non-coniferous species present included red maple, sugar maple, yellow birch, white birch, red oak, and white ash (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992, Neily et al 2004). Exotic tree species found in Point Pleasant Park include, among others, scots pine, austrian pine, douglas fir, norway spruce, and european beech (Jotcham et al 1992).

The majority of stands in Point Pleasant Park in the 1980s were over 75 years old and considered overmature in commercial forestry terms, or mature in parkland terms. Approximately 47% of the forest stands were even-aged and 43% were uneven-aged (LeHave Forestry Consultants Ltd 1984). The fact the Point Pleasant forests were largely coniferous and mostly mature made them highly susceptible to windthrow. Point Pleasant Park had a dense canopy of red spruce and white pine with slow growth rates throughout the park due to high within-stand competition (Le Have Forestry Consultants Ltd 1984, Jotcham et al 1992). The regeneration beneath the canopy layer was sparse and considered scattered (1-500 stems/ha) to understocked (500-1200 stems/ha), with rare, small patches of adequately stocked (1200-4200 stems/ha) and overstocked (>4200 stems/ha) regeneration (LeHave Forestry Consultants Ltd 1984).

Park Soil

The soils of Point Pleasant Park are classified as brown shaley loam over slate and granite bedrock, and are mostly shallow (Jotcham et al 1992). Shallow loam soils are susceptible to erosion, as are areas with a slope gradient higher than 10%. Approximately 42% of Point Pleasant Park has a slope gradient of 10% or higher, so erosion is a concern (Keys 2004, Neily et al 2004). Due to high precipitation, drainage, and parent material, soils of the park the soils are very acidic (Jotcham et al 1992). Nutrient depletion of soils is also a concern due to the frequent historical removal of coarse woody debris (Kalkreuth & Duinker 2006). The level of soil disturbance due to the hurricane, as well as pre-hurricane soil conditions, can affect the post-hurricane regeneration. High levels of soil disturbance from uprooted trees can hinder advanced regeneration of existing vegetation and favour pioneer and exotic species (Roberts 2004, Burley et al 2007).

There was little evidence of soil compaction due to post-hurricane clean-up operations (Keys 2004). A comparison between disturbed and undisturbed soil samples revealed little soil disturbance from Hurricane Juan (Burley et al 2007). Thus there should be little to no impairment of park regeneration due to soil disturbance from Hurricane Juan or clean-up operations. There is also opportunity for soil improvement if some of the coarse woody debris from hurricane blowdown is left to decompose and improve soil conditions (Kalkreuth & Duinker 2006).

Disturbance History

Natural disturbances, coupled with the vegetation responses to the disturbances, characterize many plant communities (White 1979, Pickett & White 1985). A natural disturbance can be defined as a discrete event or phenomenon that disrupts ecosystem function and structure by changing the physical environment of said ecosystem. Parameters of disturbances, such as frequency, magnitude, and predictability, are extremely variable both in nature and in their effects on ecosystem structure (Picket & White 1985). Wind disturbance is prevalent in many terrestrial ecosystems, especially coastal boreal and temperate forests, such as the AFR (White 1979, Loo & Ives 2003, Mosseler et al 2003). Many factors can affect the resilience of a forest ecosystem to wind disturbance such as topography, substrate/soil quality, and the dominance of intolerant species (White 1979).

Hurricane Juan was a category-2 hurricane that made landfall in Nova Scotia on 29-September-2003 (EC 2004). The stands of Point Pleasant Park sustained significant damage due to the high winds. Up to 75,000 trees (approximately 80% of the trees) within the park were felled (EC 2004, Point Pleasant Park 2005). Point Pleasant Park previously was also subject to other disturbances such as fragmentation by trails, which can lead to the establishment of early-successional, shade-intolerant communities (Burley et al 2007), removal of coarse woody debris, and brown spruce longhorn beetle (*Tetropium fuscum*) outbreaks (Neily et al 2004, Kalkreuth & Duinker 2006). The disturbance history of the area has generated concern about the regenerative capabilities of the park.

The process of succession is dependent on factors such as the nature of the disturbance, characteristics of the disturbed site, species composition, and structure of the pre-disturbance community (Watt 1947, White 1991). Early succession is most often characterized by unstable population dynamics composed of shade-intolerant, short-lived species with high dispersal. As the forest community matures, it tends to become more stable and is comprised of shade-tolerant, long-lived species with lower dispersal (Connell & Slatyer 1977, Galipeau et al 1997, Mosseler et al 2003). These late-successional climax species tend to be replaced by the same species when small disturbances such as individual tree death occur (Pickett & White 1985, Mosseler et al 2003).

Many stands in the AFR are kept in a sub-climax state due to adverse environmental conditions (substrate and grade); these stands are comprised of mainly balsam fir, white spruce, black spruce, red maple, and tamarack. In the Galipeau et al (1997) study of an eastern boreal forest similar to the AFR, balsam fir and white spruce were important indicators of post-disturbance successional progress. White spruce was a better disperser and was present earlier and farther from preserved stands. Balsam fir invaded the disturbed areas by advancing fronts with lower dispersal, and was limited by the absence of shade. The species composition and abundance of seedlings in the disturbed areas of Point Pleasant Park will give an insight into the successional and regenerative progress/status of the park. Also, the data will indicate whether the species composition of the park is within the ecological boundaries of native and healthy AFR.

METHODS

Sample Design

The survey method used to assess coniferous regeneration in Point Pleasant Park was a stratified systematic plot-count sample method, and was completed in the fall/winter of 2006-2007. Broadleaf tree species were excluded from the sampling due to time constraints. The park was stratified into polygons defined by existing trails (Fig 1) and each stratum was given one of three levels of data collection priority based on visual inspection: 1) first-priority sampling, 2) second-priority sampling, and 3) no measurement. Strata showing the highest levels of disturbance were assigned the highest priority.

Transects were laid out at 10 m intervals and were oriented in the most efficient way based on the shape of each stratum. Plots were laid at 10 m intervals along each transect, giving a plot count of 100 plots/ha. Each plot was 20 m^2, giving a sample area of 2,000 m^2/ha with a total of 1,246 plots.

Plot Measurements

Each plot was assessed for individual tree species, individual tree heights, drainage, and competition:

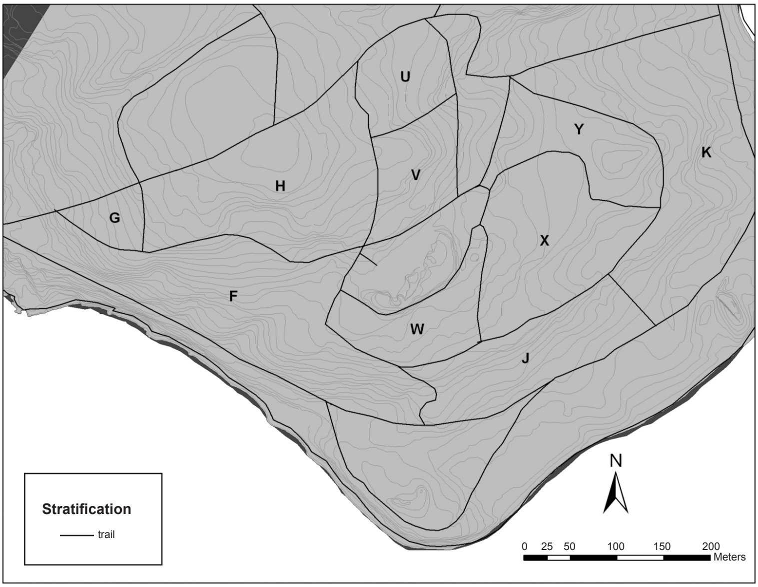

Fig 1 Stratification of the sample area within Point Pleasant Park.

1. Species. All coniferous trees taller than 10 cm and shorter than 200 cm within each plot were counted and identified using Farrar's (1995) guide to Canadian trees.
2. Height. All counted trees were categorized into three height categories: 10 cm – 30 cm, 31 cm – 100 cm, and 101 cm – 200 cm.
3. Drainage. Three categories of soil drainage were used to describe each plot: wet, fresh, and dry.
4. Competition. The main source of competition was assessed in each plot and assigned to one of four categories: low competition, grass, herbaceous growth, and woody shrubs.

Research Equipment

A compass was used to orient each transect using landmarks; landmarks were reassessed every few plots to ensure reliability. A hip chain would have been more accurate for laying transects but was not used due to time constraints and the unfavourable waste string left behind. Metal stakes and a 2.5 m plot-cord were used to layout each plot.

Data Analysis

Transect orientation and plot location, in each stratum, were mapped using ArcGIS Desktop V.9.1. ArcMap was used to map the density and distribution of each species and all species combined in the sample area. Density (stems/ha) and proportion of total regeneration (%) for each species and all species combined were tabulated for each stratum and the entire sample area.

The coniferous regeneration observed in this study was compared to two previous surveys conducted in Point Pleasant Park, using ArcGIS Desktop V.9.1. In the survey conducted by Jotcham et al (1992), aerial photographs were used to divide the forested area of Point Pleasant Park into 10 ecological areas. Using a 50 m x 50 m grid, 15 m x 15 m plots were established every 100 m and an inventory of all tree species taller than 1 m was taken. For the comparison in this study, the total stem counts of all coniferous species in these plots were converted to stems/ha and compared to stems/ha observed in this study in the same areas. The areas described by Jotcham et al (1992) were mapped using ArcMap and overlaid on the density distribution maps created for this study.

The Neily et al (2004) post-disturbance survey used 1:10,000 aerial photographs to classify Point Pleasant Park vegetation types using the Forest Ecosystem Classification (FEC) system as defined by Keys et al (2003). Using ArcMap, the described vegetation types were mapped and overlaid on the density distribution maps created for this study to conduct a descriptive comparison.

RESULTS

Point Pleasant Park Regeneration

A density distribution map was created for each of the seven species categories used in analysis: all species combined, red spruce, white pine, balsam fir, eastern hemlock, white spruce, and exotic species (Table 1). There was a large observed variation of seedling density in the sample area, with the highest densities found in the northern and western section of the sample area and the lowest in the south-eastern area. The highest density was in stratum G at 5407 stems/ha, and the lowest density was in stratum J at 917 stems/ha (Table 2, Fig 2). The dense regeneration patch found in the north-eastern section of stratum X (4639 stems/ha) and the south-western section of stratum Y (4200 stems/ha) was adjacent to a surviving immature red spruce stand that lies in the centre of stratum X, where there was no data collection. Other gaps in data collection in the study area included the Martello Tower fortification on the northern edge of stratum H, the heather patch in the centre of stratum W, and the Cambridge Battery fortification (Fig 1).

The map of the red spruce density distribution (Fig 3) illustrates how regeneration in the sample area was comprised mainly of red

Table 1 Species index

Abbreviation	Common Name	Scientific Name
AP	Austrian pine	*Pinus nigra*
BF	Balsam fir	*Abies balsamea*
BS	Black spruce	*Picea mariana*
DF	Douglas fir	*Pseudotsuga menziesii*
EH	Eastern hemlock	*Tsuga canadensis*
WC	Eastern white cedar	*Thuja occidentalis*
EB	European beech	*Fagus sylvatica*
NS	Norway spruce	*Picea abies*
RM	Red maple	*Acer rubrum*
RO	Red oak	*Quercus rubra*
RP	Red pine	*Pinus resinosa*
RS	Red spruce	*Picea rubens*
SP	Scots pine	*Pinus sylvestris*
SM	Sugar maple	*Acer saccharum*
TA	Tamarack	*Larix laricina*
WA	White ash	*Fraxinus americana*
WB	White birch	*Betula papyrifera*
WP	White pine	*Pinus strobus*
WS	White spruce	*Picea glauca*
YB	Yellow birch	*Betula alleghaniensis*

spruce, with the exception of strata G and H where balsam fir was the dominant regenerating species, at 74 and 49% of the total regeneration, respectively. Red spruce was the only species with a regeneration frequency greater than 50% for the entire sample area (Fig 9). White spruce tended to be found in areas with lower total regeneration (Fig 8). The highest observed density of white spruce was in stratum J, at 96 stems/ha, which also had the lowest total regeneration, at 917 stems/ha. White spruce was not found in stratum G.

Balsam fir showed a high variation in density across the sample area (Fig 4), ranging from 146 stems/ha (3% of total) in stratum Y to 3981 stems/ha (74% of total) in stratum G. Aside from strata G and H, and several isolated dense plots, balsam fir was sparsely distributed. Despite lower densities in some parts, balsam fir, like red spruce, is found in every stratum.

White pine was less dense and fairly uniformly distributed throughout the sample area (Fig 5), comprising 2-12% of the observed regeneration in all strata. White pine density was lower along the southeastern side of the sample area, in strata K, J, W and the southern portion of X. White pine was the third and final species to be found in every stratum.

Eastern hemlock was rare, with a density of just 33 stems/ha for the entire sample area. Strata G and V were the only areas where

Table 2 Summary data for each stratum and the entire sample area

Stratum	Species	Stems	Stems/ha	% of Total
G (0.41 ha)	RS	56	1037	19
	WP	15	278	5
	BF	215	3981	73
	EH	6	111	2
	WS	-	-	-
	Exotic	-	-	-
	Total	292	5407	100
H (3.05 ha)	RS	863	2358	45
	WP	69	188	4
	BF	964	2584	49
	EH	6	16	0
	WS	19	52	1
	Exotic	18	49	1
	Total	1921	5249	100
F (3.74 ha)	RS	524	1065	50
	WP	82	167	8
	BF	316	642	30
	EH	29	59	3
	WS	24	49	2
	Exotic	66	134	6
	Total	1041	2116	100
V (1.00 ha)	RS	423	2747	74
	WP	62	403	11
	BF	41	266	7
	EH	33	214	6
	WS	3	19	0
	Exotic	9	58	2
	Total	571	3708	100
U (0.93 ha)	RS	144	1162	53
	WP	31	250	11
	BF	84	677	31
	EH	3	24	1
	WS	1	8	0
	Exotic	9	73	3
	Total	272	2194	100
K (3.84 ha)	RS	402	705	58
	WP	63	111	9
	BF	138	242	20
	EH	3	5	0
	WS	49	86	7
	Exotic	37	65	5
	Total	692	1214	100

Table 2 *Cont'd*

Stratum	Species	Stems	Stems/ha	% of Total
W (1.12 ha)	RS	76	679	64
	WP	2	18	2
	BF	34	304	29
	EH	1	9	1
	WS	6	54	5
	Exotic	-	-	-
	Total	119	1063	100
X (2.30 ha)	RS	790	3798	82
	WP	22	106	2
	BF	131	630	14
	EH	1	5	0
	WS	18	87	2
Exotic	5	24		1
	Total	967	4649	100
Y (1.37 ha)	RS	771	3743	89
	WP	54	262	6
	BF	30	146	3
	EH	-	-	-
	WS	7	34	1
	Exotic	3	15	0
	Total	865	4199	100
J (1.75 ha)	RS	127	583	64
	WP	9	41	5
	BF	38	174	19
	EH	1	5	1
	WS	21	96	11
	Exotic	4	18	2
	Total	200	917	100
Total (19.51 ha)	RS	4176	1676	60
	WP	409	164	6
	BF	1973	792	28
	EH	83	33	1
	WS	148	59	2
	Exotic	151	61	2
	Total	6940	2785	100

hemlock density exceeded 100 stems/ha, with 111 and 214 stems/ha, respectively. Hemlock had a patchy distribution and tended to be found in areas with denser total regeneration in the northwestern part of the sample area (Fig 6). No hemlock was found in stratum Y.

Like white spruce, the exotic species found in Point Pleasant Park, with scots pine as the majority, and some austrian pine, douglas fir, and norway spruce, showed density distribution patterns different from the rest of the sampled species (Fig 7). They were found not to exceed a 20% regeneration frequency in the sample area and

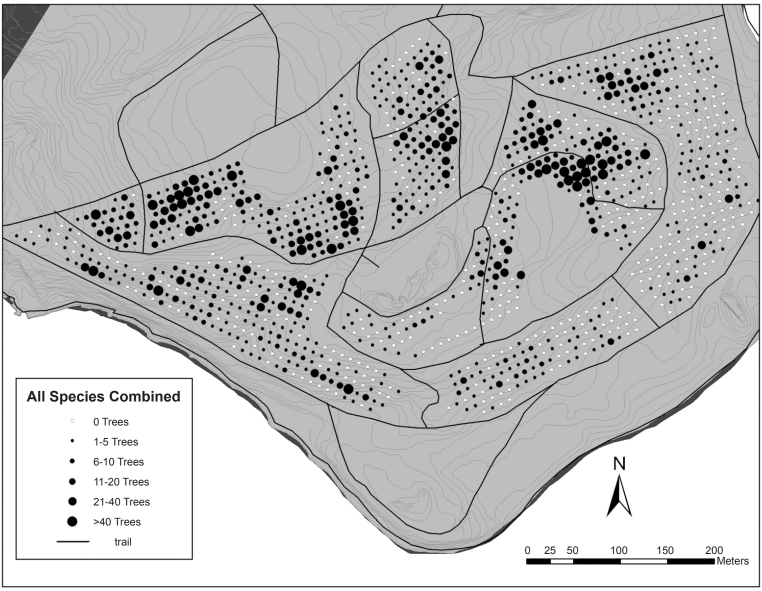

Fig 2 The density distribution of all species in the sample area of Point Pleasant Park.

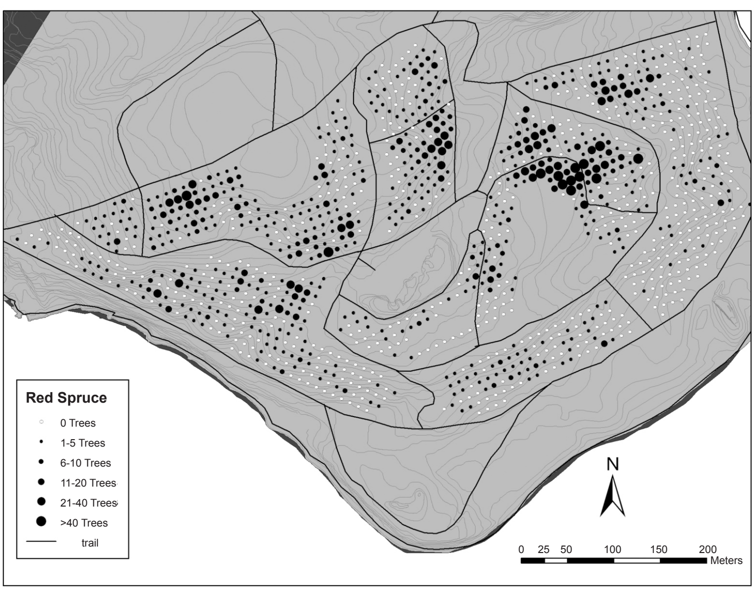

Fig 3 The density distribution of red spruce in the sample area of Point Pleasant Park.

tended to be found in more disturbed areas such as strata K and J. Exotic species were found only in low density; never more than 5 individuals per plot and only once exceeding 100 stems/ha, in stratum F. There was also a large patch of exotic species found in the disturbed centre of stratum F. In addition, stratum F had the highest density and proportion of total regeneration of exotics, with134 stems/ha and 6%, respectively. No exotic species were found in strata G and W.

Height Distribution

The distribution of regenerating trees among the three height categories varied among the species sampled (Fig 10). Approximately 50% of all white pine, balsam fir, and exotic species counted were 10-30 cm in height. Approximately 10% of all species were 101-200 cm tall except for white spruce and eastern hemlock, where approximately 30% of the trees were 101-200 cm tall. Red spruce, white spruce, and eastern hemlock differed from white pine, balsam fir, and the exotic species in that the majority of trees counted were in the 31-100 cm category. Approximately 50% of the total observed regeneration was 31-100 cm tall.

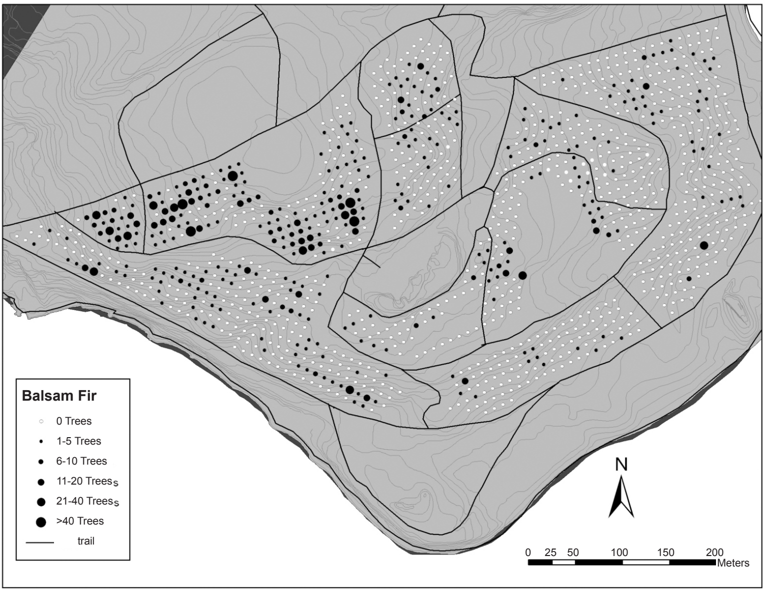

Fig 4 The density distribution of balsam fir in the sample area of Point Pleasant Park.

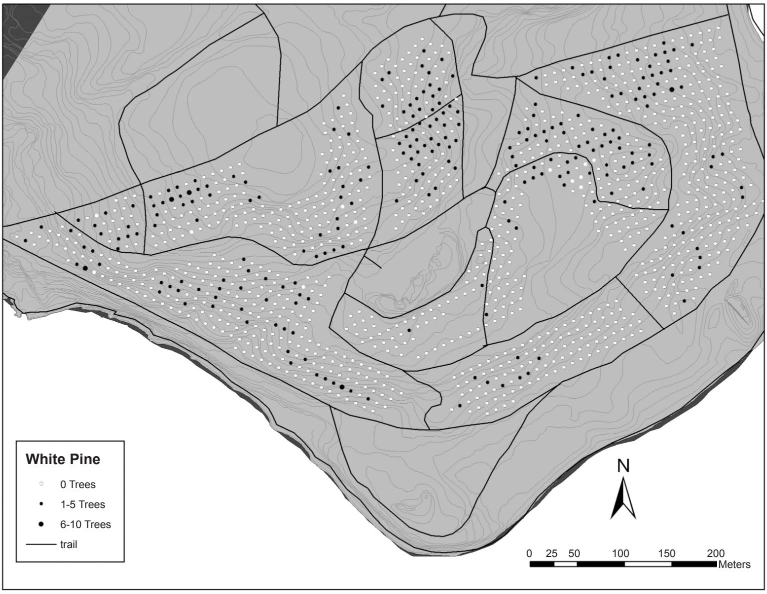

Fig 5 The density distribution of white pine in the sample area of Point Pleasant Park.

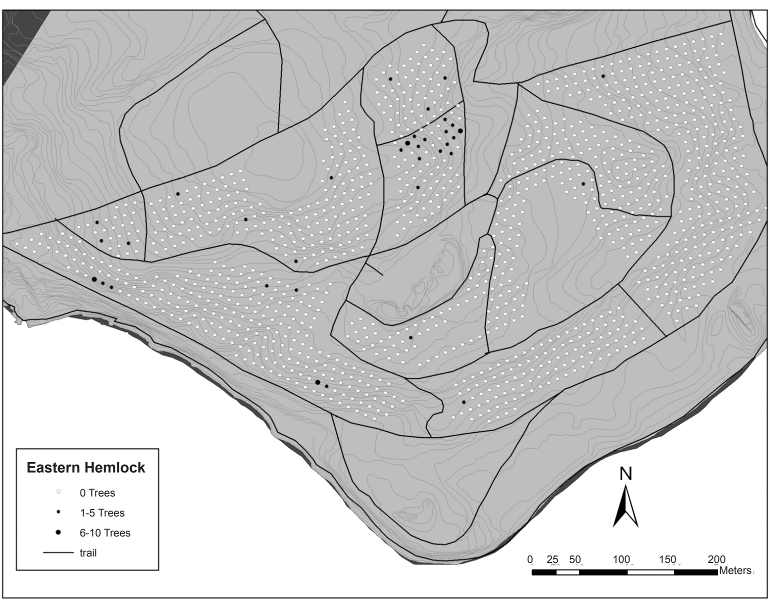

Fig 6 The density distribution of eastern hemlock in the sample area of Point Pleasant Park.

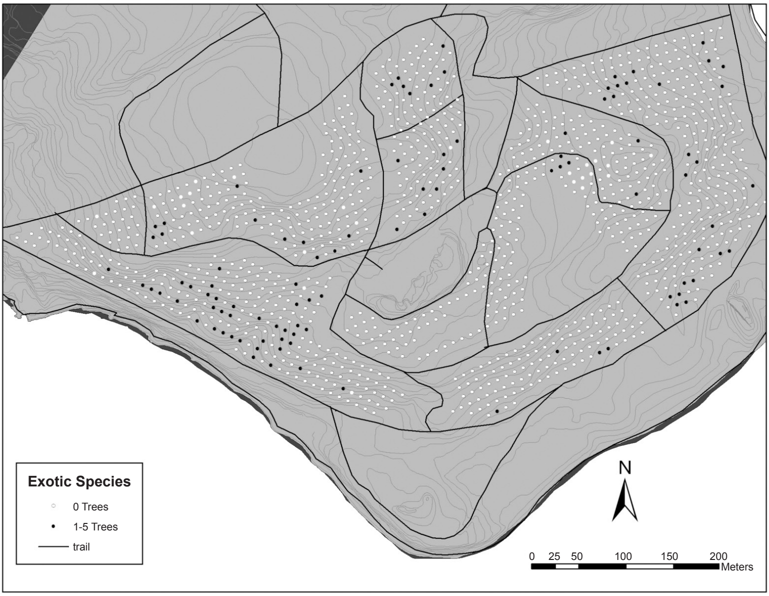

Fig 7 The density distribution of exotic species in the sample area of Point Pleasant Park.

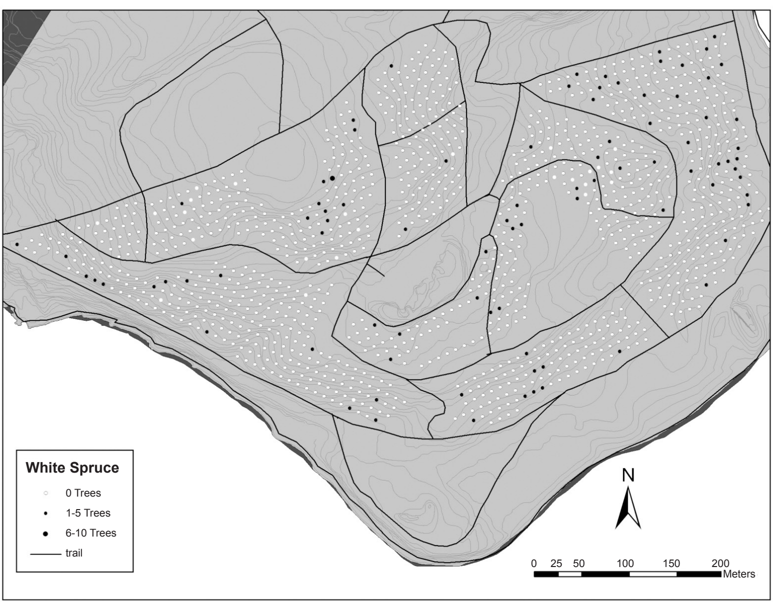

Fig 8 The density distribution of white spruce in the sample area ofPoint Pleasant Park.

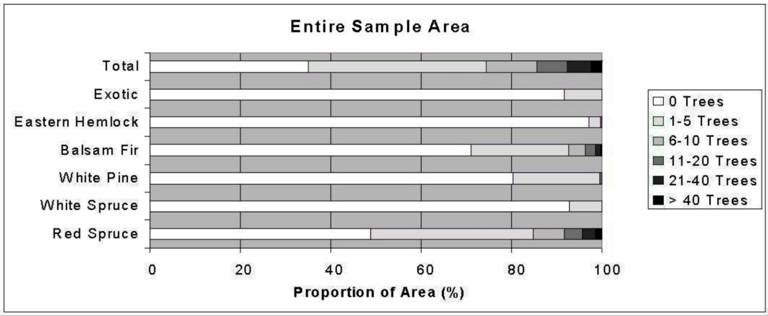

Fig 9 Regeneration frequency histogram illustrating the proportion of area covered by each density category in the entire sample area.

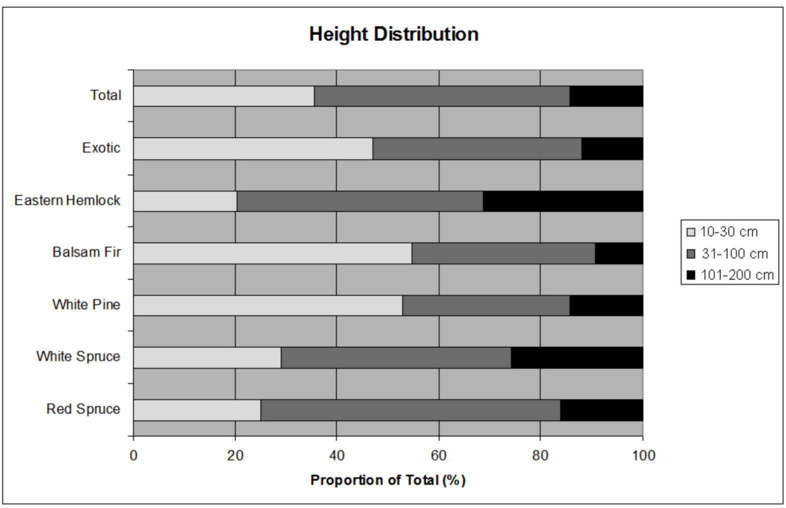

Fig 10 Height distribution of regenerating species in the sample area of Point Pleasant Park.

Pre-Disturbance Survey Comparison

The stand division of Jotcham et al (1992) was used for a comparison with the regeneration observed in this study (Fig 11). Their area 2 covers the majority of the sample area, consisting of all of stratum G, H, U, V, K, X, Y, and the majority of stratum F. Red spruce was the dominant species in area 2 in the pre-disturbance survey and this survey (Table 3). There was a large increase in balsam fir density in areas 2, 5 and 8 from pre-disturbance conditions, especially area 2 where balsam fir increased from 115 stems/ha to 860 stems/ha. However, there was certainly a skew in the data towards larger increases from pre-disturbance conditions, especially

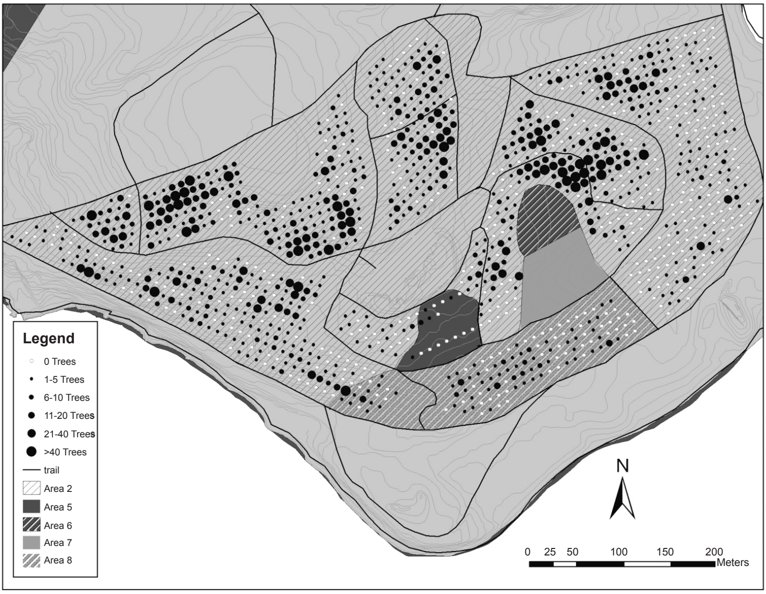

Fig 11 Overlay of observed regeneration and the Jotcham et al. (1992) park survey classification.

in balsam fir, because stems under 1 m in height were not counted in the Jotcham et al (1992) survey.

White pine showed small increases in density from pre-disturbance conditions in all three areas. A large increase in eastern hemlock from pre-disturbance conditions was also seen, especially in areas 5 and 8 where it was not observed before the hurricane, though it remained at very low densities (the highest being 38 stems/ha in area 2). Exotic species in area 8 decreased from 80 stems/ha before Hurricane Juan to 29 stems/ha after Hurricane Juan and remained absent in area 5 in the post-disturbance survey. In area 2, exotic regeneration was nearly twice as dense as during pre-disturbance conditions. White spruce decreased in density from pre-disturbance conditions in areas 2 and 8, more so in area 8 where it was surpassed by red spruce as the dominant species. There was an increase in white spruce from pre-disturbance conditions in area 5 (34 stems/ha) but it was not present before the hurricane.

Areas 6 and 7 were also found within the sample area of this study, but no data were collected in them as they were occupied by dense white birch and red spruce thickets, respectively.

Post-Disturbance Survey Comparison

Neily et al (2004) identified nine vegetation types, five of which overlapped the sample area of this study: VT9, VT10 (unit 1), VT10

Table 3 Comparison of the observed regeneration and the regeneration in the overlapping areas defined by the Jotcham et al. (1992) Point Pleasant Park survey

Area	Species	Stems/ha (1992)	% of Total	Stems/ha (2006)	% of Total
2 (17.36 ha)	RS	894	74	1850	61
	WP	107	9	175	6
	BF	115	10	860	28
	EH	4	0	38	1
	WS	58	5	56	2
	Exotic	36	3	67	2
	Total	1215	100	3046	100
5 (0.56 ha)	RP	267	100	-	-
	RS	-	-	431	66
	WP	-	-	17	3
	BF	-	-	155	24
	EH	-	-	17	3
	WS	-	-	34	5
	Exotic	-	-	-	-
	Total	267	100	367	100
8 (1.59 ha)	RS	204	18	593	48
	WP	44	4	111	9
	BF	107	9	400	33
	EH	-	-	4	0
	WS	702	62	89	7
	Exotic	80	7	29	2
	Total	1138	100	1229	100

(unit 2), VT11 (unit 1), and VT11 (unit2) (Table 4, Fig 12). VT9 *Red spruce-Hemlock, Starflower* covered all of stratum G, and the eastern ends of strata F and H. The dominant regenerating species was balsam fir (2367 stems/ha, 67% of total). Red spruce represented the second most-abundant species, and eastern hemlock was more dense than in other vegetation types (139 stems/ha). The only other area with higher densities of eastern hemlock than VT9 was stratum V, located in VT10 (unit 1).

VT10 (unit 1) *Red spruce-White pine*, *Bracken* covered most of the study area, and was similar to area 2 in the Jotcham et al (1992) survey. VT10 (unit 1) followed the most common regeneration pattern in the park: red spruce was dominant, with smaller components of balsam fir, white pine, eastern hemlock, white spruce, and exotic species. VT10 (unit 2) *Red spruce-White pine, Bracken, with Old Field Patches* covered all of stratum W and the portion of stratum X on the eastern edge of the surviving immature red spruce stand. This vegetation type had little regeneration, with a dominance of

Table 4 Comparison of the observed regeneration and the regeneration in the overlapping vegetation types defined by the Neily et al. (2004) Point Pleasant Park survey

Vegetation Type	Species	Stems/ha	% of Total
VT9	RS	665	19
WP	228	6	
BF	2367	67	
EH	139	4	
WS	76	2	
Exotic	44	1	
Total	**3519**	**100**	
VT10 (unit 1)	RS	2421	65
WP	220	6	
BF	909	24	
EH	41	1	
WS	53	1	
Exotic	76	2	
Total	**3721**	**100**	
VT10 (unit 2)	RS	802	64
WP	35	3	
BF	317	25	
EH	5	0	
WS	94	8	
Exotic	-	-	
Total	**1252**	**100**	
VT11 (unit 1)	RS	452	54
WP	57	7	
BF	217	26	
EH	-	-	
WS	62	7	
Exotic	45	5	
Total	**833**	**100**	
VT11 (unit 2)	RS	2423	44
WP	77	1	
BF	3038	55	
EH	-	-	
WS	-	-	
Exotic	-	-	
Total	**5538**	**100**	

red spruce and balsam fir. Most of the regeneration was adjacent to the residual spruce stand in stratum X.

VT11 (unit 1) *Red spruce-Balsam fir, Schreber's moss* (Mature) overlapped the more disturbed, eastern portion of the sample area and overlapped the majority of stratum K, the northern half of stratum J, and the southern portions of strata X and Y. VT11 (unit 1) had the lowest regeneration density of all the vegetation units,

Fig 12 Overlay of observed regeneration and the Neily et al. (1992) park survey classification.

at 833 stems/ha, and was dominated by red spruce and balsam fir. White spruce density in this vegetation type was 62 stems/ha and constituted 7% of the total regeneration. VT11 (unit 2) Red spruce-Balsam fir, Schreber's moss (Immature) consisted mainly of the surviving red spruce stand, and overlapped only a few plots with high densities of red spruce and balsam fir regeneration.

DISCUSSION

Successional Response of Point Pleasant Park

Concern has been expressed about the regenerative capabilities of the park, based on existing vegetation surveys. It is possible that due to the isolation of Point Pleasant Park from other possible seed sources, and high fragmentation of the park due to trails, the post-disturbance regeneration could consist largely of shade-intolerant, short-lived, pioneer tree species (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992, Neily et al 2004). While this pattern of succession after stand-replacing disturbances is typical in native Acadian forest, as well as most other forest types (White 1979, Loo & Yves 2003, Mosseler et al 2003), it is a concern in Point Pleasant Park for two reasons. First, the park may stay in a sub-climax community dominated by short-lived species, such as white spruce and balsam fir, due to poor soil conditions and high disturbance levels (Mosseler et al 2003, Neily et al 2004, Burley et al 2007). Second, Point Pleasant Park is a recreational area, and the aesthetic value of the park forests is of high importance. Prompt regeneration into red spruce-white pine-eastern hemlock forest, typical of native Acadian old growth, could be an important park management goal (Neily et al 2004, Keys 2005). Due to the possibility of exposed mineral soil and fragmentation by trails, there is also a concern that exotic species may regenerate rapidly in the park (Moola & Vasseur 2004, Keys 2005).

Red spruce was the dominant overstorey species in Point Pleasant Park prior to hurricane Juan, and was likewise found to comprise 60% of the regeneration in the sample area. Strata G and H were the only areas where red spruce did not comprise at least 50% of the observed regeneration. It is likely that Hurricane Juan did not remove enough pre-hurricane vegetation, the main source of seed dispersal in disturbed areas, to significantly alter the forest composition of Point Pleasant Park (Castelli et al 1999, Burley et al 2007). The immature spruce stand found in the centre of stratum X is one such source for seed dispersal and is most likely the seed source for the dense red spruce regeneration seen to the north-east of the stand. Red spruce is a long-lived species (250-450 years) and is a shade-tolerant, climax species in native Acadian Forests (Mosseler et al 2003), so it is a favourable species for regeneration.

White pine was the other dominant, pre-disturbance canopy species, but was not found to be regenerating in nearly the same density as red spruce. Despite the low observed pre-disturbance regeneration of white pine (LeHave Forestry Consultants Ltd 1984), it was predicted that white pine would be dominant in regeneration because of both the residual white pine scattered throughout the disturbed area and the affinity of white pine seedlings for exposed mineral soil caused by uprooted trees and scarification from clean-up operations (Neily et al 2004). In comparison to other observed species, white pine was relatively evenly distributed through both heavily disturbed areas and less disturbed areas, but the expected dense white pine regeneration was not observed; strata U and V were the only areas where white pine accounted for more than 10% of the observed regeneration.

There are several possible explanations for the lack of dense white pine regeneration. It has been observed that white pine has cyclic propagule dispersals, with good seed crops occurring every three to five years (Burns & Honkala 1990). Also, although white pine was a dominant canopy species and constituted much of the forest basal area before the hurricane, it was much less dense than red spruce, and therefore had fewer individuals for seed dispersal. For example, in area 2 in the Jotcham et al (1992) survey, red spruce and white pine constituted 46 and 35% of the basal area, respectively, yet white pine only had a total of 104 stems, compared to 760 red spruce stems. A final hypothesis is that there was a lack of exposed mineral soil that is well suited for white pine regeneration, due in part to the high amount of ground covered by coarse woody debris and litter. Burley et al (2007) found no significant difference in soil quality between disturbed and undisturbed plots. Like red spruce, white pine is a longer lived, climax species in native Acadian forest (Loo & Yves 2003, Mosseler et al 2003) and a main constituent of the ACR, where Point Pleasant Park is located (Simmons et al 1984), so its regeneration should be closely monitored by park managers.

Eastern hemlock was found in rather low densities throughout the park; the only areas where hemlock constituted more than 1% of the observed regeneration were strata G, F, and V (stratum V had the highest densities at 214 stems/ha). Eastern hemlock is a climax, shade-tolerant species, typical of AFR old growth that would certainly be a favourable species for regeneration in Point Pleasant Park. Although eastern hemlock had the lowest regeneration of all species in the sample area, it was never a large component of the park before Hurricane Juan (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992) and was in fact observed at higher densities than in pre-disturbance surveys.

Balsam fir and white spruce are two pioneer species that each have properties indicative of the level of disturbance in an area (Galipeau et al 1997, Mosseler et al 2003). White spruce is a good disperser and tends to be the first coniferous colonizer in the most disturbed areas whereas balsam fir is not as good a disperser and tends to be found in more shaded areas, with some intact canopy and existing balsam fir regeneration (Galipeau et al 1997). The largest concentrations of balsam fir were found in strata G and H, where it was the dominant regenerating species. These areas were adjacent to less-disturbed areas in the northern portion of the park and had some intact canopy (mainly in stratum G). The more-disturbed, eastern strata, such as J, K, and W with lower total regeneration, had higher relative white spruce densities. The higher white spruce regeneration in these areas may be indicative of higher disturbance levels and slower successional progress. However, the areas were still dominated by red spruce regeneration and did have a white spruce component before Hurricane Juan (Jotcham et al 1992).

In the survey conducted by LeHave Forestry Consultants Ltd (1984), most of the regeneration in Point Pleasant Park was scattered (1-500 stems/ha) or understocked (500-1200 stems/ha). The coniferous regeneration observed in the entire sample area of this study was adequately stocked (1200-4200 stems/ha), but was overstocked in strata G, H, X, and Y and understocked in strata J and W.

Exotic Species

Urban forest ecosystems are often isolated from adjacent seed sources that exist in native forests. Also, they are subject to seed dispersal from many exotic tree species found in the urban environment, which may inhibit the growth of native species (Nowak 1994, Dwyer et al 2003, Moola & Vasseur 2004). It has been found that stand-replacing events, such as hurricanes, can lead to greater invasion of exotic species in the AFR, which are often shade-intolerant pioneer species that favour disturbed conditions (Mosseler et al 2003, Moola & Vasseur 2004). There is also concern that forest fragmentation due to trails and the existing presence of exotic species in Point Pleasant Park could lead to the continued invasion of exotics, as trails can act as vectors for invasive species into native plant communities (Neily et al 2004, Keys 2005, Burley et al 2007).

The exotic coniferous species found in this study included douglas fir, scots pine, austrian pine, and possibly norway spruce. Exotic species were present at a higher density and frequency in areas with lower total regeneration, but had lower density in some areas in comparison to pre-disturbance conditions (Jotcham et al 1992). Burley et al (2007) found no significant relationship between disturbed areas and the distribution of exotic species and also found them to be present mainly in areas with better soil conditions. Native species appear to be able to out-compete exotics in the acidic, shallow soils found in Point Pleasant Park (Jotcham et al 1992, Burley et al 2007). Exotic conifers found in the sample area were all present before Hurricane Juan (LeHave Forestry Consutlants Ltd 1984, Jotcham et al 1992) and are unlikely to inhibit existing advanced regeneration in the park. However, they may impede regeneration in more disturbed areas of the sample area with less dense regeneration, especially in the centre of stratum F where exotics, mainly scots pine, constituted much of the observed regeneration.

Pre-Disturbance Survey Comparison

Natural succession in forests is highly variable and a great deal of the post-disturbance vegetation composition relies on chance (White 1991). Larger, stand-replacing gaps tend to favour the succession of shade-intolerant, short-lived pioneer species, while smaller gaps tend to be replaced by existing canopy species (White 1991, Goldblum 1997, Mosseler et al 2003). When high amounts of existing vegetation remain intact after a disturbance, the species composition of succession should resemble that of the pre-disturbance state

(Roberts 2004). It has been shown that succession following a large stand-replacing wind disturbance may also be strongly influenced by undisturbed, understorey vegetation, as well as the level of soil disturbance, more specifically, exposed mineral soil (Carlton & Bazzaz 1998, Castelli et al 1999, Burley et al 2007).

It is highly advantageous when post-disturbance regeneration studies have existing pre-disturbance vegetation surveys of the sample area to use in comparison and evaluate to what extent pre-disturbance forest structure dictates succession. Due to the management history of Point Pleasant Park, there are several vegetation surveys available for comparison (LeHave Forestry Consultants Ltd 1984, Jotcham et al 1992, Neily et al 2004).

It is possible that following a large wind disturbance event, succession will consist of a reorganization of existing canopy species, with relatively little regeneration of pioneer species, regardless of gap size (Castelli et al 1999). Mature to overmature forests, such as the majority of stands in Point Pleasant Park, will also likely have depleted pioneer seed banks. Succession following large-scale wind disturbances is dictated by seed sources from neighbouring vegetation, surviving vegetation within the disturbed area, and seed banks within the soil (Frelich 2002, Burley et al 2007). Spruce seeds have a short lifespan within the seed bank (Burley et al 2007) so the dominance of red spruce regeneration within most of the sample area must be due to neighbouring spruce within the park and surviving vegetation in the disturbed area. Area 2 is described by LeHave Forestry Consultants Ltd (1984) as having a thick red spruce understorey beneath the dominant/co-dominant white pine/red spruce overstorey. The comparison between disturbed and intact plots carried out by Burley et al (2007) found no significant difference in understorey composition. The presence of both the red spruce understorey and the immature surviving red spruce stand located in stratum X is most likely the major seed source for the park and could explain the dominance of advanced red spruce regeneration observed in this study.

In pre-disturbance conditions, there was a considerable white spruce constituent in the southeast corner of the park, especially area 8 where 61% of the observed coniferous species were white spruce (Jotcham et al 1992). The majority of area 8 is in stratum J; and while stratum J was found to have the highest concentration of white spruce in the park at 96 stems/ha (11% of the total), red spruce is still the dominant regenerating conifer. In area 8, white spruce decreased from 702 stems/ha in the pre-disturbance conditions to 89 stems/ha in this study.

Area 5 showed a drastic change in species composition since Hurricane Juan. The only coniferous species found in the area before the hurricane was red pine, which was not found during this survey. Considering the level and age of coniferous regeneration in the area, it is possible that there was an error in the Jotcham et al (1992) survey. European beech was the other dominant pre-disturbance species, but was not included in this survey. Red spruce and balsam fir were the main post-disturbance species, though total regeneration in area 5 was low, at 367 stems/ha.

It is difficult to discern the full pattern of succession in Point Pleasant Park given that only coniferous species were sampled. Burley et al. (2007) found substantial broadleaf regeneration in the park, mainly red maple and white birch. However, the observed regeneration in the park remains dominated by red spruce, as it was before Hurricane Juan. There is a substantial increase in balsam fir from pre-disturbance conditions, but the Jotcham et al (1992) survey did not tally stems below 1 m in height. The majority of observed balsam fir was 10-30 cm in height; this may explain some of the observed increases in density from pre-disturbance conditions.

Post-Disturbance Survey Comparison

The VT9 *Red spruce-Hemlock, Starflower* vegetation type is dominated by red spruce, with a hemlock-white pine component, and is a climax community. There is also a smaller white birch, red maple, and balsam fir component (Neily et al 2004). Much of the canopy remained intact in this area following the hurricane, which was likely the seed source for the hemlock found in this area. Balsam fir is highly shade-tolerant, and is typically a pioneer species found in disturbed areas (Galipeau et al 1997, Mosseler et al 2003). The dominance of balsam fir regeneration in this area was not unusual, though balsam fir is not as favourable as red spruce for regeneration because it is shorter lived and not a dominant climax canopy species (Jotcham et al 1992, Loo & Yves 2003, Mosseler et al 2003). This finding also indicated a presence of balsam fir regeneration in the understorey prior to the hurricane, as balsam fir has limited dispersal capabilities.

VT10 *Red spruce-White pine, Bracken* is also a climax community dominated by red spruce, with white pine, red maple, and balsam fir. Unit 2 contained disturbed field patches that were occasionally reverting to white-spruce-dominated patches before Hurricane Juan (Neily et al 2004). Both units of the VT10 vegetation type showed a similar regeneration pattern that is consistent with the majority of the sample area, with approximately 60% red spruce, 20% balsam fir, and a lesser occurrence of white pine, eastern hemlock, and exotic species. However, the regeneration density in unit 2 was considerably lower than in unit 1, at 1252 stems/ha versus 3721 stems/ha. This may be due to the presence of disturbed field patches that characterize unit 2, and the presence of european beech and the heather patch. White spruce was more prevalent in unit 2 than unit 1, which is indicative of the higher disturbance levels expected in unit 2 (Galipeau et al 1997, Mosseler et al 2003, Neily et al 2004).

VT11 *Red spruce-Balsam fir, Schreber's moss* is the only mid-successional community described by Neily et al (2004), and is dominated by red spruce and balsam fir, with several early successional non-coniferous species. Unit 1 was a mature stand, and sustained almost complete canopy removal from Hurricane Juan. Unit 1 was found to have a low regeneration density of 833 stems/ha, though the area remained dominated by red spruce and balsam fir. The higher densities of white spruce and exotic species than the other overlapping vegetation types could be indicative of high levels of disturbance (Mosseler et al 2003, Moola & Vasseur 2004). Unit 2 was mainly occupied by the surviving immature red spruce stand. The few plots that did lie in this unit are directly adjacent to the stand and skew the data toward dense regeneration (5538 stems/ha). Neily et al (2004) argued that the VT11 vegetation type has the potential to mature into a red spruce-white pine-eastern hemlock climax community. Considerable attention should be given to this location when deciding park management goals due to both low observed regeneration and Acadian old-growth potential.

Park Management Recommendations

Stand-initiating disturbances such as hurricanes can alter forest communities in such a way that they take hundreds of years to return to a state similar to pre-hurricane conditions (Boose et al 2001, Mosseler at al. 2003). Park managers and visitors alike hope to see relatively quick regeneration to a forest structure similar to native Acadian old growth, as it was prior to Hurricane Juan (Keys 2005, PPPIDC 2005).

Several management techniques may be possible in achieve this goal, given the findings of this regeneration survey. The first is the use of overly dense plots as donor sites for seedling transplantation to understocked areas. Slow tree growth rates have been observed in Point Pleasant Park before Hurricane Juan and thinning was previously suggested (LeHave Forestry Consultants Ltd 1984), as individual tree growth is a function of density. It is encouraging that red spruce regeneration was prevalent throughout the park, so it is important to ensure adequate growth of the species. Areas in the park that were considered overstocked, such as strata G, H, X, and Y, could act as donor sites of red spruce for strata that were understocked, such as strata J, K, and W. This transplantation would also thin the overstocked red spruce regeneration to promote faster and healthier individual tree growth.

The import of favourable conifer species, such as white pine and eastern hemlock, from nurseries for fill-planting in the park, especially the most disturbed areas of the sample area, such as strata K, J, and W, would further aid park regrowth into a healthy red spruce-white pine-eastern hemlock climax community. Planting initiatives have been successful in the park in the past, and in fact a small number of the observed seedlings may have been planted prior to Hurricane Juan. Many of the areas with the lowest observed regeneration, such as VT11, are believed to have the potential to return to a red spruce-white pine-eastern hemlock climax community, despite the high disturbance levels (Neily et al 2004). Non-coniferous regeneration, especially red maple and white birch, though not included in this study, should not be overlooked. The planting of native deep-rooted non-coniferous species, especially around the shore perimeter, would help to create a wind barrier and shift the park forests to mixedwood stands that are more resistant to catastrophic wind disturbance. Non-coniferous root systems are also good nutrient sources for the park soil (PPC 1994).

Another possible management strategy is the culling of exotic species, as they can be invasive in disturbed urban ecosystems and prevent native growth (Dwyer et al 2003, Moola & Vasseur 2004). Exotic species were found to have higher densities in areas with lower total regeneration and occupied a patch in the centre of stratum F. The planting of native species in understocked areas could eliminate the chance of exotic conifer invasion, and park visitors may also find this to be a more attractive management technique than culling. It is also important to note that the exotic species observed in this study were all found prior to Hurricane Juan and were not considered a major invasive threat to the pre-disturbance community (Jotcham et al 1992). The eventual phasing out of exotic species in Point Pleasant Park would help to return the park to a more natural state, but it is unlikely that the exotic conifer species in the park pose a threat to native regeneration.

Follow-up regeneration studies will be necessary to ensure that the regeneration observed in this study continues to be adequate in the following years. Moreover, it will be necessary to monitor the efficacy of any thinning/planting that may take place. This dataset may also be useful for other future studies such the effects of edges, fragmentation, and increased off-trail traffic on park regeneration.

Natural regeneration appears to be adequate in the majority of the sample area. A combination of passive management and monitoring in the majority of the park, and red spruce transplantation and fill planting in the southeastern edge of the park could lead to the eventual regrowth of Point Pleasant Park into a stable climax community similar to native Acadian old-growth forest. Point Pleasant Park has the benefit of having a high level of community concern because of proximity to the urban core of Halifax, high recreational value, and a long and colourful history of the area. Taking advantage of this concern to establish a volunteer community program in the park, such as a transplant/replant program, would be a low-cost tactic to enhance park recovery, public involvement, and public approval.

Acknowledgements Thank you to Tarah Wright, Blair Pardy, Jeremy Lundholm, Johanna Kalkreuth, and the GIS centres at Dalhousie University and the University of Guelph.

REFERENCES

Avery TA, Burkhart H (2001) Forest Measurements. McGraw Hill, New York, NY.

Bertram H, Miller CI, Beers TW (1982) Forest mensuration. John Wiley & Sons, New York, NY.

Boose ER, Chamberlin KE, Foster DR (2001) Landscape and regional impacts of hurricanes in New England. *Ecological Monographs* 71:27-48.

Burley S, Robinson SL, Lundholm JT (2007) Post-hurricane vegetation recovery in an urban forest. Saint-Mary's University, Halifax. Unpublished manuscript.

Burns RM, Honkala BH (1990) Silvics of North America: 1. conifers; 2. hardwoods. US Department of Agriculture, Washington DC.

Carlton GC, Bazzaz FA (1998) Resource congruence and forest following and experimental hurricane blowdown. *Ecology* 79:1305-1319.

Connell JH, Slatyer RO (1977) Mechanisms of succession in natural . communities and their role in community stability and organization. *American Naturalist* 11:1119-1144.

Dwyer JF, Nowak DJ, Noble MH (2003) Sustaining urban forests. *Journal of Arboriculture* 29:49-55.

EC (Environment Canada) (2004) Hurricane Juan: September 28 & 29, 2003. Environment Canada, Gatineau, PQ. Unpublished report.

Farrar JL (1995) Trees in Canada. Fitzhenry & Whiteside Ltd, Markham, ON.

Frelich LE (1995) Old forest in the Lake States today and before European settlement. *Natural Areas Journal* 15:157-167.

Frelich LE (2002) Forest dynamics and disturbance regimes. Cambridge University Press, Cambridge, UK.

Galipeau C, Kneeshaw D, Bergeron Y (1997) White spruce and balsam fir colonization of a site in the southeastern boreal forest as observed 68 years after fire. *Canadian Journal of Forest Research-Revue Canadienne de Recherche Forestiere* 27:139-147.

Goldblum D (1997) The effect of treefall gaps on understory vegetation in New York State. *Journal of Vegetation Science* 8:125-137.

Jotcham JR, Strong KW, Marvin TK (1992) An ecological survey of Point Pleasant Park. Maricoba Incorporate & Maritime Testing Limited, NS.

Kalkreuth JM, Duinker PN (2006) Characterizing post-hurricane coarse woody debris and overstorey in Point Pleasant Park, Halifax, NS. School

for Resource and Environmental Studies, Halifax, NS. Unpublished manuscript.
Keys K, Neily P, Quigley E, Stewart B (2003) Forest ecosystem classification of Nova Scotia's model forest. Natural Resources Canada - Nova Forest Alliance, Stewiacke, NS.
Keys K (2004) Ground disturbance survey for Point Pleasant Park: post-hurricane Juan clean-up. Nova Scotia Department of Natural Resources, Truro, NS.
Keys K (2005) Point Pleasant Park forest ecosystems and soils. Nova Scotia Department of Natural Resources Truro, NS.
Kitz J, Castle G (1999) Point Pleasant Park: An Illustrated History. Point Pleasant Publishing, Halifax, NS.
LaHave Forestry Consultants Ltd (1984) A forest management strategy for Point Pleasant Park. LaHave Forestry Consultants Ltd, Bridgewater, NS.
Loo J, Ives N (2003) The Acadian forest: historical condition and human impacts. *Forestry Chronicle* 79(3):462-474.
Moola FM, Vasseur L (2004) Recovery of late-seral vascular plants in a chronosequence of post-clearcut forest stands in coastal Nova Scotia, Canada. *Plant Ecology* 172(2):183-197.
Mosseler A, Lynds JA, Major JE (2003) Old-growth forests of the Acadian Forest Region. *Environmental Reviews* 11(51):47-77.
Neily P, Keys K, Quigley E (2004) Ecosystems of Point Pleasant Park. Nova Scotia Department of Natural Resources, Truro, NS.
Nowak DJ (1994) Understanding the structure of urban forests. *Journal of Forestry* 92:36–41.
PPC (Park Planning Committee) (1994) Point Pleasant Park management plan. Halifax Regional Municipality, Halifax, NS.
Pickett STA, White PS (1985) The Ecology of natural disturbance and patch dynamics. Academic Press Inc, Orlando, FA.
Point Pleasant Park (2005) About the park: the challenge. Point Pleasant Park, Halifax NS.
PPPIDC (Point Pleasant Park International Design Competition) (2005) Stage one competition brief: regenerate, restore, renew. Halifax Regional Municipality & Southwest Properties Ltd, Halifax, NS.
Roberts MR (2004) Response of the herbaceous layer to natural disturbance in North American forests. *Canadian Journal of Botany* 82(9):1273–1283.
Rowe JS (1972) Forest regions of Canada (CFS Publication No. 1300). Department of the Environment, Ottawa, ON.
Stewart BJ, Neily PD, Quigley EJ, Duke AP, Benjamin LK (2003) Selected Nova Scotia old-growth forests: age, ecology, structure, scoring. *Forestry Chronicle* 79(3):632-644.
Simmons M, Davis D, Griffiths L, Muecke A (1984) Natural History of Nova Scotia. Nova Scotia Department of Lands and Forests, Truro, NS.
Watt AS (1947) Pattern and process in the plant community. *Journal of Ecology* 35(1-2):1-22.
White AS (1991) The importance of different forms of regeneration to secondary succession in a Maine hardwood forest. *Bulletin of the Torrey Botanical Club* 118(3):303-311.
White PS (1979) Pattern, process, and natural disturbance in vegetation. *Botanical Review* 45:229-299.