Old Growth among Us:

A Characterization of Urban Old-Growth Forests in Halifax

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Abstract

Currently, there is little research in the field of urban old-growth forests. This study aims to address this issue, furthering our knowledge of urban old-growth in Nova Scotia. The research focuses on identifying similar forest characteristics between forests in Halifax urban core and in the hinterland of Nova Scotia. The field work and data analysis demonstrate that urban and hinterland forests have similar live tree and deadwood characteristics, providing a basis to classify these Halifax urban forests as old growth. This research can be further used to promote visitation to these accessible forest locations, and to manage the sites for old-forest characteristics.

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1.0 Introduction

Old-growth forests provide many environmental, social and economic benefits, both direct and indirect to our society. They are a unique habitat with a wide range of resident species, some of which only live in old-growth forest niches (Bart & Forsman, 1992). Further ecological benefits include sequestering carbon (Dwyer, McPherson, Schroeder, & Rowntree, 1992), providing genetic reservoirs (Mosseler, Major, & Rajora, 2003), and contributing to ecosystem integrity and health (Ordonez & Duinker, 2012). Although few, there are some areas of old-growth forests remaining in Nova Scotia such as Sporting Lake Island and Kejimkujik National Park (Simpson, 2014). Most of these unique ecosystems are deep in the hinterlands; however, there may be uncelebrated old-growth stands within the urban core of the city of Halifax.

This study focuses on identifying possible old-growth forests in Halifax urban core so as to increase their potential contributions to society. The information collected could aid the municipality with decision-making concerning the protection and management of these forests. It will also provide useful information to the public regarding forests in various communities, and, more generally, the role of a tree in creating a healthy ecosystem. This study characterizes urban old-growth forests to determine how similar they are to known old-growth forest stands in rural areas of Nova Scotia.

Old-growth forests are the late successional stage of forest development and are distinguished by old trees and spatial heterogeneity (Anonymous, 1989; Spies, 2004). Researchers use conventional measurements of such elements as live trees, dead trees (snags), canopy cover, and coarse woody debris (CWD) to characterize these forests. Old-growth forests contain distinctive trees that dominate during the late stages of natural forest succession, also known as climax species (Nova Scotia Department of Natural Resources, 2012). Most old-growth forests in North America are not considered virgin forests (i.e. free from disturbance of modern humans) (Fahey, 1998) due to our extensive history of agricultural and timber harvesting (Loo & Ives, 2003).

In Canada, old-growth forest stands are primarily found in some boreal forest regions and Canada's west coast; however, there are small patches of old growth remaining in the Maritime Provinces (Mosseler, Thompson, & Pendrel, 2003). Canada's National Forest Inventory (CanFI) contains information on the extent of its forests, providing an overview of different ecozones across the country (Canada's National Forest Inventory Project Office, 2014). The inventory does not identify old-growth forests specifically, but forest inventory attributes such as canopy closure and age by species can be used to determine areas of old-growth (Gillis, Gray, Clarke, & Power, 2003). In 2001, approximately 40% of Canada's primary forests were still intact; however only 7.4% are under protection (Singh, Shi, Foresman, & Fosnight, 2001), demonstrating that there is room to improve the conservation and management Canada's forests.

The Acadian Forest Region (AFR) encompasses the three Maritime Provinces of Canada and a small region of north eastern United States (Loo & Ives, 2003). The AFR has a long history of clear-cutting for agricultural and forestry purposes, eliminating most old-growth forests in the 19th and 20th centuries (Mosseler, Lynds, & Major 2003). The few areas of remaining old-growth are host to late-successional tree species that are shade-tolerant and regenerate naturally in the canopy gaps after small disturbances occur (Mosseler, Lynds & Major, 2003). There are six distinguishing species of the AFR; three are conifer species and three are non-conifer species, as shown in Table 1 (Stewart, Neily, Quigley, & Benjamin, 2003).

Table 1

Acadian Old-Growth Species (Stewart, et al., 2003)

Scientific Name	**Common Name**	**Conifer/Non-Conifer**
Picea rubens	Red Spruce	Conifer
Tsuga canadensis	Eastern Hemlock	Conifer
Pinus strobus	White Pine	Conifer
Acer saccharum	Sugar Maple	Non-Conifer
Betula alleghaniensis	Yellow Birch	Non-Conifer
Fagus grandifolia	American Beech	Non-Conifer

Urban forests encompass all the trees located within a designated municipality (HRM Urban Forest Planning Team, 2013). The city manages trees to promote their physiological, economic and biological values (Nowak & Dwyer, 2007). The Halifax urban core includes all communities that receive water and wastewater services, as shown in Figure 1 (HRM Urban Forest Planning Team, 2013). The HRM uses the Urban Forest Master Plan (UFMP) to manage the stands and individual trees on municipally owned land in the area. The city adopted the UFMP in September 2012 (with revisions in 2013) after unforeseen natural events, such as Hurricane Juan and a longhorn beetle infestation, destroyed thousands of trees in Halifax, emphasizing the need for a management plan (HRM Urban Forest Planning Team, 2013).

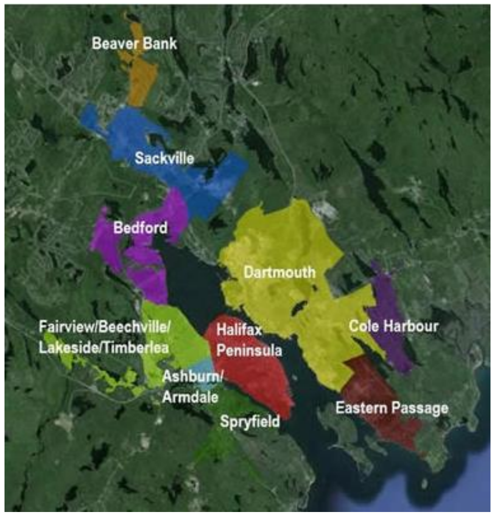

***Figure 1.* Halifax serviced core includes the highlighted communities (HRM Urban Forest Planning Team, 2013)**

The Nova Scotia Old Forest Policy (Nova Scotia Department of Natural Resources, 2012) defines the provincial government's view on the characteristics of an old-growth forest. These characteristics include stands where 30% or more of the total basal area is trees over 125 years old, 50% or more of the total basal area is associated with climax species, and crown closure is no less than 30%. The objectives of the policy are to identify and conserve old-growth forests within Nova Scotia, provide opportunities for the public to use the forests, and to provide direction about resource management decisions (Nova Scotia Department of Natural Resources, 2012). The policy promotes the use of a score sheet to determine the "old-growthness" of a forest based on characteristics such as the canopy cover, climax species composition and tree age. It is important to define old-growth stands so that they might be protected from timber harvesting (Tyrrell, 1992); however, policy-makers and forest managers continue to struggle to apply a unified definition to these forests (Spies, 2004; Hunter & White, 1997).

This study assesses the degree to which selected urban forest stands in the Halifax urban core are similar to known old-growth stands in the Pockwock Lake region (35 km north west of downtown Halifax), and to four other old-growth forests, previously characterized by Stewart, Neily, Quigley, & Benjamin (2003). The literature review highlights background topics that are useful to understanding urban old-growth. The information summarized includes subjects such as old-growth forests in Canada, benefits of old-growth forests, urban forests, benefits of urban stands, and forest management practices. Little is known about urban old-growth forests, their locations, and their characteristics. The study attempts to address this knowledge gap in relation to forest stands within the Halifax urban core. The state of the selected stands was assessed between August and November 2014.

The research question investigated in this study is:

In the Halifax urban core, how similar are selected forest stands dominated by large old trees, to known old-growth forest stands in Nova Scotia?

The research question was addressed by assessing forest stands in the Halifax urban core and determining if they are characteristic of old-growth forests in Nova Scotia. Data about trees, snags and course woody debris were collected and analyzed from sites located near the Bedford Basin and Halifax Harbour. Calculations were made for each stand's basal area, old-growth dominated trees composition, coarse woody debris content, and canopy cover percent. The resulting information was then used to determine the degree of "old-growthness" of the stands and to recommend future management directions for old-growth conservation.

2.0 Literature Review

2.1 Literature Search Strategy

The search method used in this literature review was topic-based and the review is organized based on significant themes. Some key terms used in the search include: old-growth forests, urban forests, Acadian, Canada, Nova Scotia, benefits, and valuation. The databases used were Web of Science, Science Direct, Environmental Sciences and Pollution Management and Google Scholar. I also made use of a wide range of print-only literature

2.2 Old-Growth Forests

Old-growth forests are an integral ecosystem for the survival of many species; however, they continue to diminish due to timber harvesting and land-use change (Tyrell, 1992). Old-growth forests are characterized by stands of old trees, with a high diversity of species, habitat, structure, and landscape (Fahey, 1998). People view these forests as valuable because of their rarity (Hunter & White, 1997), social values (e.g. aesthetics and spiritual qualities) (Spies, 2004), and ecosystem services. Old-growth forests are the latest successional stage of most forest stand models such as Oliver and Larson's (1990) succession pattern that includes four stages: stand initiation, stem exclusion, under-story re-initiation, and old-growth. This late successional state of old-growth is often regarded as a shifting mosaic with continual disturbances and regeneration (Bormann & Likens, 1979; Oliver & Larson, 1990). Structural commonalities associated with old-growth forests include an abundance of old large trees, an uneven staged canopy, and a wide tree-age distribution. Other attributes include an abundance of decomposing downed wood, the presence of snags, and a variety of lichen species (Leverett & Davis, 1996). These characteristics are what make old-growth ecosystems unique in a forested landscape.

The definition of an old-growth forest can be rather general: a forest with old trees (Hunter & White, 1997). Old-growth stands differ greatly depending on the geographic region, disturbance regimes, and human influence. For this reason, some argue that a forest is only old-growth if it is a ‘virgin forest’, or untouched by humans (Fahey, 1998). However, this definition would not encompass most forests because of humans’ long history with the use of natural resources (Leverett & Davis, 1996). Even if a forested area had zero direct influence from people, air pollutants could still affect and alter the forest’s natural systems (Hunter & White, 1997). Values of old-growth can be explained both materially (economic and life-support values), and non-materially (sociocultural, ethical, aesthetic, and spiritual values) (Moyer, Owen, & Duinker, 2008). Understanding the values of old-growth helps to develop management plans aimed at conserving old-growth characteristics (Owens, Duinker, & Beckley, 2009).

The management of old-growth forests is a debated topic, ranging from passive (i.e. non-interventions) to active (i.e. tree cutting is permitted) management strategies (Hilbert & Wiensczyk, 2007). Some argue that foresters can harvest trees in an old-growth stand without compromising its structural and functional characteristics (Beese, Dunsworth, Zielke, & Bancroft, 2003; Burton, Kneeshaw & Coates, 1999). Others say that un-harvested old-growth stands support 1.5 times more biomass than a managed forest, and that harvesting trees results in impacts such as soil compaction, a reduction in downed CWD, and a shift in species composition (Carey & Johnson, 1995). Tyrell et al. (1998) identified two overarching levels for managing old-growth forests: the landscape and the stand. The landscape level of management is less used and focuses on minimizing stand fragmentation, monitoring disturbance regimes, and identifying habitat types (Hilbert & Wiensczyk, 2007). Stand-level initiatives manage specifically for old-growth characteristics such as uneven-aged tree populations and maintaining other late-successional forest attributes (Beese et al., 2003). For biodiversity conservation, foresters can implement a variety of management strategies at different spatial levels to address old-growth objectives (Lindenmayer & Franklin, 1997).

Before European settlement, old-growth forests were abundant from coast to coast across Canada. Currently, Canada's forests represent 9% of the world's forests, and 24% of the world's boreal forests (NRCAN, 2014). However, Canada has been singled out by the United Nations Environmental Programme (UNEP) for not preserving and sustainably managing its forests (Mosseler, Thompson & Pendrel, 2003). Harvesting and exporting timber continues to be one of Canada's highest sources of revenue (contributing $19.8 billion to GDP in 2013), but Canada has recently created initiatives to protect old-growth regions. Some of these projects include the coastal forest chronosequences project (Allen, Benton, Trofymow & Winder, 2014), and the Investments in Forest Industry Transformation program (NRCAN, 2014b). Most of Canada's old-growth forests are in British Columbia; however, the eastern provinces have residual old-growth stands that warrant provincial protection and specific management strategies.

The AFR is unique to the Maritime Provinces of Canada and north eastern United States. The ecologically diverse area is influenced from both warm, moist Gulf Stream currents and the cold Labrador Current (Loo & Ives, 2003). Along with these long-lived trees, the diversity of calicoid lichens and fungi species is another indicator of an old-growth Acadian forest in the Maritimes (Selva, 2003). The limited areas of old-growth remaining in the AFR are restricted to isolated patches located in places that are inaccessible for timber harvesting such as deep gorges, riparian zones or protected areas (Mosseler, Lynds, & Major 2003).

Centuries of clear-cutting and using the land for agriculture have left Nova Scotia with few old growth forests (Mosseler, Lynds, & Major 2003). In 2000, 91% of Nova Scotia forests consisted of even-aged stands that were less than 100 years old (NSDNR, 2000). Nova Scotia forests are around 150 years old when they attain structural features akin to old-growth forests (Mosseler, Lynds, & Major 2003). The NS Old Forest Policy has objectives to identify and conserve old stands, establish networks for these forests, and provide opportunities for the public to utilize Nova Soctia's old-growth forests (Nova Scotia Department of Natural Resources, 2012). This is a promising policy for Nova Scotia; however the effects of this policy have yet to be documented.

Old-growth forests provide extensive benefits to the surrounding environment and to humans. They are structurally diverse, which creates niches for an array of species, some of which live only in these habitats (Hagen, Vincent & Welle, 1992). Old-growth stands are also considered a reservoir for genetic diversity. Mosseler, Major & Rajora (2003) found that as a tree population ages, the gene pool and reproductive fitness of the community increases. This attribute could become an asset as climates change and species are forced to adapt to new conditions. Old-growth forests also act as a carbon sink, removing carbon dioxide from the atmosphere and storing it in live woody tissues, organic matter and soil. Aging forests continue to provide a positive net carbon balance, contrary to the view that they are carbon neutral (Luyssaert, et. al, 2008; Gunn, Ducey, & Whitman, 2014). Old stands can also provide abundant ecosystem services, such as water and air purification (May & Davis, 1998), erosion prevention, and popular ecotourism locations. These positive attributes of old forests can be greatly diminished by human disturbances to their natural growing regimes.

2.3 Urban Stands

Extensive documentation shows that urban forests enhance overall human well-being with meaning and emotion (Herzog & Strevey, 2008; Chiesura, 2004). Halifax contains many urban parks, some of which have been minimally influenced by humans in the last century. People benefit greatly from Halifax's forested parks, which increase the aesthetic appeal of the neighbourhoods where they occur, encourage outdoor activities, and lower noise levels (Dwyer, et al., 1992). Halifax residents have shown that they value the urban forest because it adds diversity and variety to the urban setting, provides natural ambient sounds, and creates historical connections with large trees (Peckham, Duinker, & Ordonez, 2013).

City trees provide values that aid in the natural functioning of the urban forest ecosystems. The services provided by urban trees can mitigate urbanization effects and the degradation of ecosystems (Roy, Bryne & Pickering 2012). Some additional ecological benefits include providing habitat for wildlife and slowing down the rate of soil erosion (Dwyer, et al., 1992). Trees are also a major contributor to the carbon sequestration process. The amount of CO_2 that trees trap is directly related to the tree's biomass, which is dependent upon species age, composition, and growing conditions (McPherson, 1998). Therefore, carbon sequestration by trees can help offset carbon emissions and decrease atmospheric greenhouse gases (Pasher, McGovers, Khoury, & Duffe, 2014). In the last few decades, cities have altered their urban forest plans to include more environmental initiatives rather than strictly aesthetics (Seamans, 2013), thus benefiting the natural ecosystem.

Urban forests have also demonstrated their economic benefits to municipalities. A study completed for Allan Park, Toronto, demonstrated that the trees in the park provided 26 326 USD in annual benefits and had a benefit-to-cost ratio of 4:1 (Millward & Sabir, 2011). Urban forests also decrease the heat-island effect, which constitutes a localized increase in temperature when materials with a low specific capacity (i.e. concrete and asphalt) are abundant, thus storing the heat during the day and releasing it at night. Vegetation can redistribute the thermal energy through evapotranspiration, therefore moderating the city's temperature (Gallo et al., 1993). This cooling of the ambient atmosphere decreases the use of air conditioners, and consequently lowers building maintenance costs (Brack, 2002). The study of urban trees continues to display their economic benefits, encouraging cities to place emphasis on integrating forests into municipal development plans.

2.4 Urban Old-Growth

Comprehensive research has been done on old-growth and urban forests, both internationally and within Nova Scotia. However, little information exists that assesses old-growth forests in an urban setting. Loeb (2012), published a book entitled *Old Growth Urban Forests*, which encourages readers to recognize urban old-growth forest stands, even when human activity influences the forest's structure and composition. A few cities across the world have noted the presence of local urban old-growth including Singapore (Shapiro, Ni, & Ang, 2008), Atlanta, Georgia (Wilson, 2007), and Overton, Tennessee (Baker, 1998). More research is needed to define urban old-growth characteristics and how human influence changes the structure of old-growth stands within the city. In this study, I will contribute to the urban old-growth literature with examples in Halifax.

3.0 Methods

3.1 Study Area

The study sites are all located in Halifax. The city occupies 5 577 km^2 of land, and had a population of 408 700 in 2013 (Statistics Canada, 2014). The area is situated on the Atlantic coast of Canada, and contains both rocky and sandy shorelines. The average summer temperature is approximately 17.2 °C, and average winters are around -2.2 °C (Government of Canada, 2010). Rainfall ranges between 75.1mm/month and 143.6mm/month, depending on the time of year (Government of Canada, 2010).

Eight study sites (Table 2 and Figure 2) were chosen for measurement. All sites are within larger forest ecosystems owned by the municipality (see HRM Urban Forest Planning Team, 2013). The Halifax UFMP set a study area that is smaller than the total territory of HRM (HRM Urban Forest Planning Team, 2013). Six study sites were located within the UFMP serviced core, and two in the hinterlands. Candidate stands were first chosen based on communications with John Simmons, John Charles, and Peter Duinker (pers. Comm, September 2014). The two hinterland sites were confirmed as old-growth stands by Berry Geddes, forester with Halifax Water, and Peter Duinker (pers. Comm, September 2014). Reconnaissance visits to all suggested sites were then completed to establish whether the site was appropriate for the study based on size and abundance of large trees.

Table 2

Name, location and characteristics of the eight study sites.

Name	Location	Dominant Tree Species	Ownership/Management	Size (hectares)
Point Pleasant Park	44°37’31”N 63°34’26”W	Red maple	HRM	77
Sir Sandford Fleming Park	44°37’49”N 63°36’10”W	Red spruce, eastern hemlock, red maple	HRM	39
Hemlock Ravine Park	44°41’28”N 63°40’14”W	Eastern hemlock, red spruce	HRM	72
Admiral’s Cove Park	44°43’23”N 63°39’10”W	Red spruce, eastern hemlock	HRM	90
Shubie Park	44°42’09”N 63°33’24”W	Eastern hemlock	HRM	16
Birch Cove Park	44°40’47”N 63°33’40”W	Red maple	HRM	4
Pockwock East	44°46’51”N 63°51’17”W	Red spruce, yellow birch	Crown land, managed by Halifax Water and NS DNR	4858 (provincially Protected Watershed Area (PWA))
Pockwock West	44°46’38”N 63°51’59”W	Red spruce	Crown land, managed by Halifax Water and NS DNR	4858 (PWA)

Figure 2. **Six study site locations within the Halifax urban core.**

Three 20m x 20m plots were located within the stands using non-random, purposive sampling. The largest, most mature trees were located and the plots were developed around these trees. The bias associated with this sampling method is understood and necessary to determine plot sites with the highest densities of large trees. Random sampling would not be appropriate in this situation. For the objective to be accomplished, the best examples of old-growth were purposively chosen as plot locations, at all eight sites.

3.2 Data Collection

Sampling techniques were derived from the Nova Scotia Department of Natural Resource Forest Inventory Permanent Sampling Plot (PSP) Measurement Methods and Specifications (NSDNR, 2003), and the Ecological Monitoring and Assessment Network (EMAN) Terrestrial Ecosystem Protocols (Environment Canada, 2003). In each plot, all living trees taller than 1.4 m were identified (by species) and diameter at breast height (DBH) measurements were taken.

Snags were then located within each plot and protocols from EMAN were used (EMAN, 2003). Snags were differentiated if they had a lean greater than 45°, a DHB greater than 7cm, and a height greater than 1.4m. Every snag was recorded by species (when possible), DBH (cm), height (m), decay class (refer to Table 3), and crown class (broken or intact).

Table 3

Decay classification system using the EMAN protocol (Environment Canada, 2003, adapted from Sollins 1982).

Class	Description
1	Freshly dead, bark intact, branches intact (including small), needle leaf retention, bole sound, bole raised off ground on branches.
2	Beginnings of decay but rot not established in wood that was sound at time of death. Bark mostly intact, branch stubs, bole not raised on branches, bole mostly sound.
3	Rot becoming established. Bark loose and mostly flaked off, bole beginning to rot but maintaining structural strength – round, straight, not sinking into ground. Or, mummified snag. Dry, hard, barkless rampike. Typical 1 or 2 decades following stand-initiating disturbance such as fire or budworm.
4	Advanced decay. Bark mostly absent, bole mostly decayed with some sound wood present. Colonized with vegetation. Lacking structural strength - bole oval and bending to shape of ground. Last stage for snags which will be rotted, wobbly, and could easily be pushed over.
5	Rotted though, becoming hummus. Sunken into mound on the ground, but retaining a woody characteristic, not yet part of the forest floor.

Downed CWD was measured using a line-intersect method modified from McRae, Alexander, & Stocks (1979) and Van Wagner (1968) (see Figure 3). Guidelines for the line-intersect method can be found in the NSDNR Forest Inventory PSP Measurement Methods and Specifications (NSDNR, 2002), and the NSDNR protocol for Measurement of Woody Debris (NSDNR, 2003). An equilateral triangle with 18m sides was measured out within each plot, with one line-transect from the triangle along the plot boundary. Every piece of downed CWD that crossed the triangle was measure once. Decay class (refer to Table 3), diameter at point of intersect, and length were recorded. Species was not noted.

Downed CWD was assessed using the following criteria (adapted from NSDNR, 2003 and modified by McRae et al. (1979) and Van Wagner (1968)):

1. Downed, dead woody material (twigs, stems, branches, and bolewood) from trees and shrubs. Dead branches attached to bole of standing trees not assessed because not considered to be downed material. Stumps are not counted.
2. Material lying above the duff layer, leaning ≤ 15°, with a diameter >7.0cm at point of intersection.
3. Fully decayed pieces that are completely colonized by forest floor vegetation and ‘flattened’ to the forest floor are not counted. Distinction between decay class 5 and fully decayed wood is notably the protrusion of the log above the forest floor and the presence of an internal woody structure.
4. Pieces with their central axis crossed by the transect line. Any piece whose centre line corresponds exactly to the transect line is not counted.
5. Curved or angular pieces crossed by the transect line more than once are included only at first intersection.

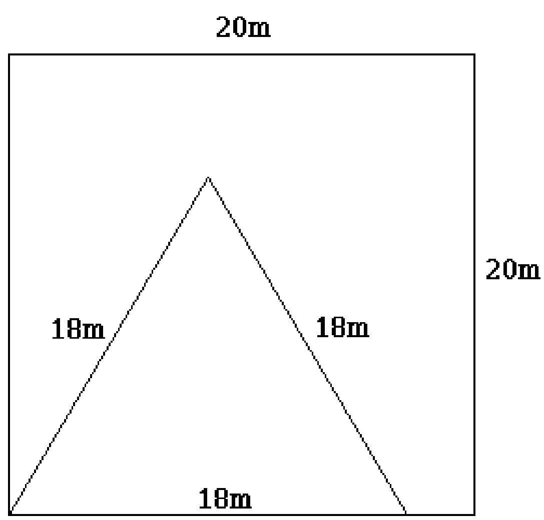

Figure 3. **Line-intersect method used to measure downed CWD (NSDNR, 2003).**

Canopy cover was measured within each plot and averaged. Canopy cover is often measured using a densiometer, but this tool was not available for the study, so a photo interpretation method of percent cover was used (Avery & Burkhart, 2002). To determine percent canopy cover, one photograph was taken 2m in to the plot from each of its corners. This was repeated for each plot, resulting in 12 photographs for each site. The photographs were overlaid with grid lines and percentage canopy cover was manually calculated.

There were a few limitations and delimitations to the study. Trees were not aged due logistical issues. There were also time constraints (deciduous trees lose their leaves in late October), and weather restrictions on data-collection opportunities. Some delimitations identified were the site and plot locations, the time of year for data collection, and the measurements taken.

3.3 Data Analysis

Using the sampled data from each site, the information was manipulated to determine the following characteristics: number of trees exceeding 40cm DBH (Nova Scotia Department of Natural Resources, 2012), diameter distributions, live tree basal area (m^2/ha), snag volume (m^3/ha), snag basal area (m^2/ha), total down CWD volume (m^3/ha), and total CWD volume (m^3/ha).

Basal area calculation:

$BA(m^2) = pi*(DBH)^2/40000$

Where, *BA* = basal area

DBH = diameter at breast height in cm

The volume of snags and downed CWD per hectare was calculated using Van Wagner's equation (1968):

$V = \pi^2 * \Sigma (d^2/8L)$

Where, *V* = volume of wood per unit area (m^3/ha);

d = diameter of downed CWD at intersection (cm), and;

L = length of sample line (m)

To determine the basal area and volume per hectare, numbers were divided by 0.12 (the three plots totaled to 1200m^2). The data were analyzed using a visual comparison method. Graphs and tables were compared and conclusions were based on visual differences in characteristics. Inferential statistics were not used because of the low number of test sites and therefore the low validity of the study (Zar, 1974).

4.0 Results

4.1 Live Trees Summary

The total basal area (m^2/ha) of the eight stands was mostly dominated by red maple, red spruce and eastern hemlock (Figure 4).

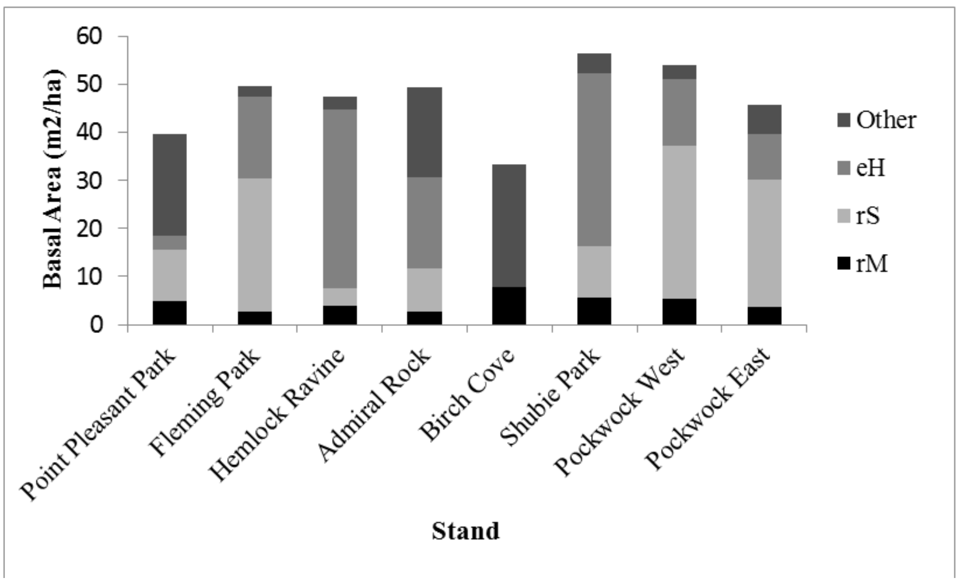

***Figure 4*. Species composition for dominant species in each of the eight measured sites (eH = eastern hemlock, rS = red spruce, rM = red maple).**

The stands were all mixed wood forests, except for Birch Cove Park, which was broadleaf dominated. Therefore, Birch Cove had many species in the “other” category such as red oak and sugar maple. Point Pleasant Park also had many species, other than the dominating three, such as white pine and red oak.

The six species that dominate Acadian old-growth forests are red spruce, eastern hemlock, white pine, American beech, sugar maple and yellow birch. The stands measured ranged from 68 (Point Pleasant Park) to 93 (Admiral Cove) in percent cover of the old-growth six basal area (Figure 5). The two hinterland old-growth stands (Pockwock West and Pockwock East) had 87% and 91% respectively, demonstrating a similarity between the hinterland old-growth stands and the urban stands.

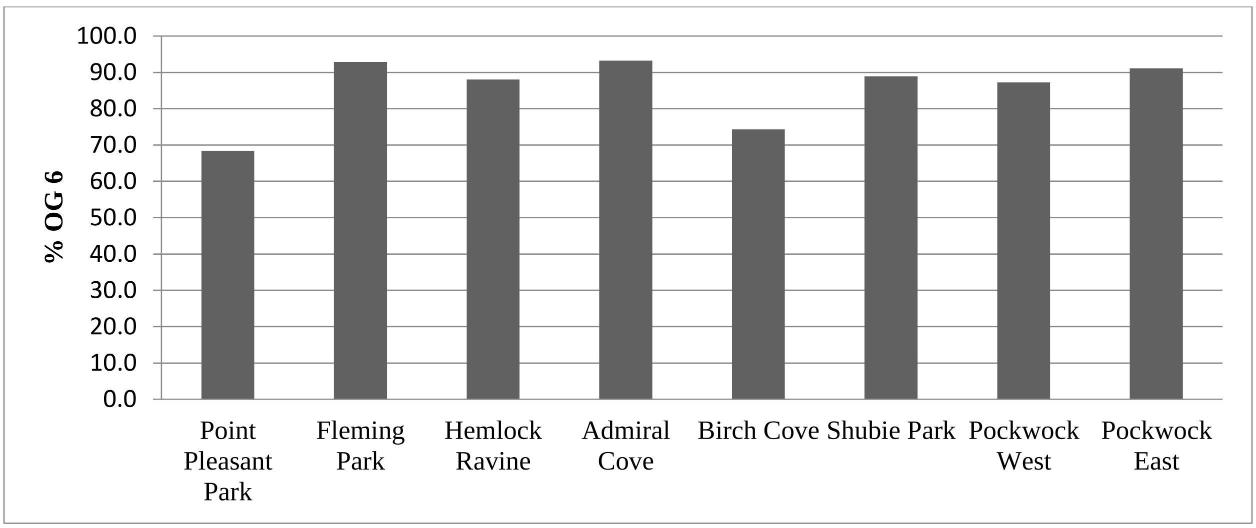

***Figure 5*. Percent composition (basal area m^2/ha) of the "old-growth six" species in each of the eight measured stands.**

In characterising the stands' diameter distributions tree with DBH less than 10 cm were excluded from the analysis as they are considered to be regeneration. In Figure 6, the y-axis indicates the number of stems measured, and the scaling for each historgram was adjusted for maximum ability to discern within stand patterns. The number of trees was almost three fold greater in Pockwock West, Shubie Park, Fleming Park and Hemlock Ravine than in other stands.

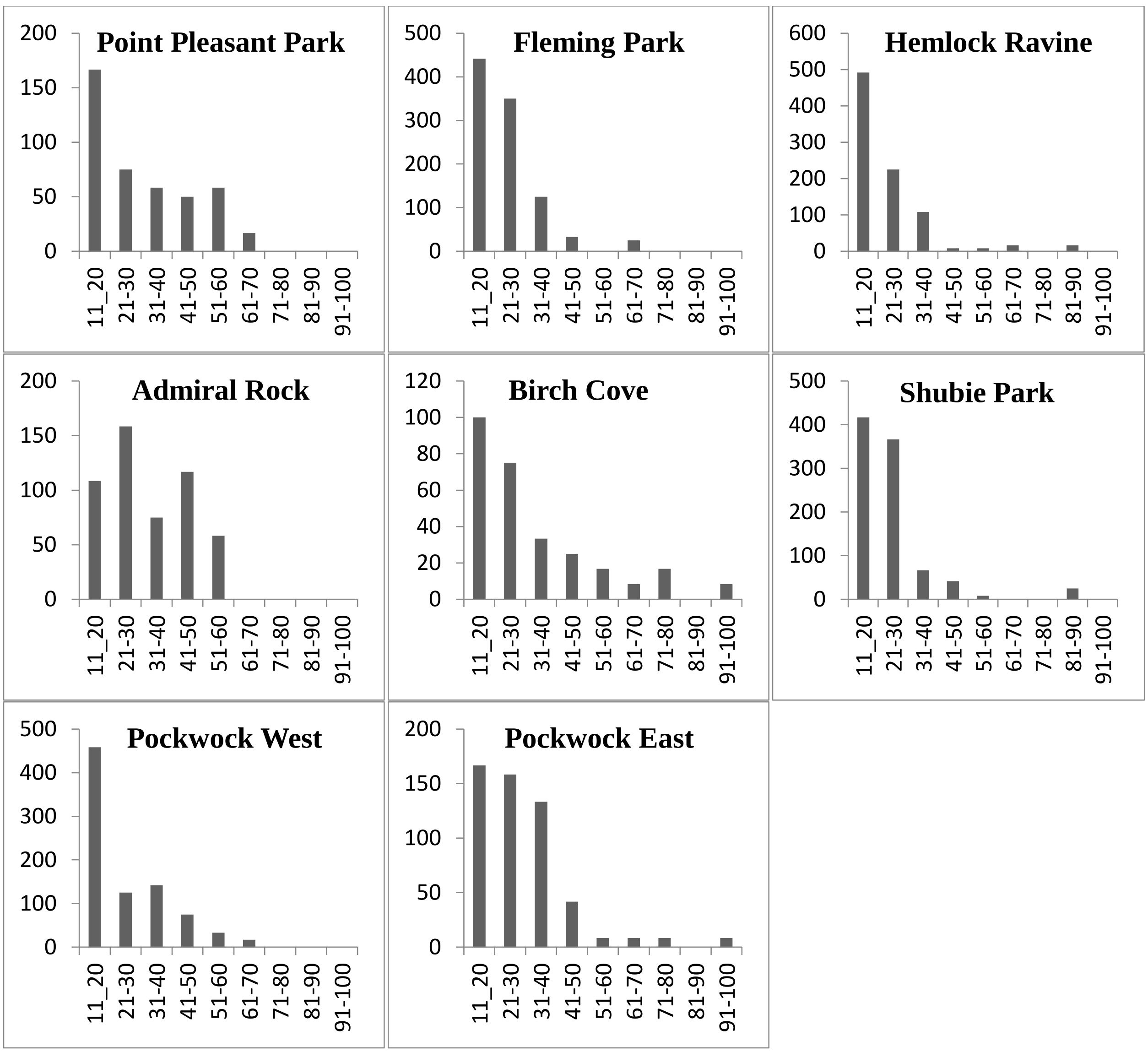

***Figure 6*. Diameter Distributions in classes of 10cm for all eight sites in Halifax**.

To set this study's results into a more fulsome context of old-growth stands across Nova Scotia, we retrieved data on four old-growth stands (Grand Anse, North River, Panuke Lake and Sporting Lake) from Stewart, Neily, Quiglet & Benjamin (2003) (Table 4). In making the comparisons between my data and those of Stewart et al. (2003), only trees with DBH > 40 cm were used because of their importance in the Old Forest Policy (Nova Scotia Department of Natural Resources, 2012). The six urban forest sites all fall within the ranges of the hinterland old-growth stem density and basal area. Density of trees >40 cm diameter ranged from 58 to 195 stems, and basal area was between 12.6 and 43.3 m^2/ha. Birch Cove and Point Pleasant Park were outliers in terms of total density because of the abundance of regeneration and small trees.

Table 4

Density (#stems/ha) and basal area (m^2/ha) of all live trees and live trees >40 cm diameter.

	All Trees		Trees >40cm	
	Density (#/ha)	Basal Area (m^2/ha)	Density (#/ha)	Basal Area (m^2/ha)
Point Pleasant Park	2583	36.5	133	27.5
Fleming Park	1392	49.6	58	12.6
Hemlock Ravine	1367	47.3	58	18.8
Admiral Rock	1725	49.4	175	32.2
Birch Cove	3392	33.3	75	22.9
Shubie Park	1500	56.4	75	26.4
Pockwock West	1292	54.0	133	23.2
Pockwock East	1192	45.5	83	21.0
Grand Anse	1476	40.3	106	22.0
North River	1072	34.5	79	17.5
Panuke Lake	1195	59.7	195	43.4
Sporting Lake	1054	57.0	148	35.3

4.2 Deadwood

All sites contained at least 11 snags/ha, and Admiral Cove contained the highest density of snags with 183/ha (Figures 7-9). Snag volume ranged from 4 m^3/ha to 86 m^3/ha, and snag basal area ranged from 0.7 m^2/ha to 10.3 m^2/ha.

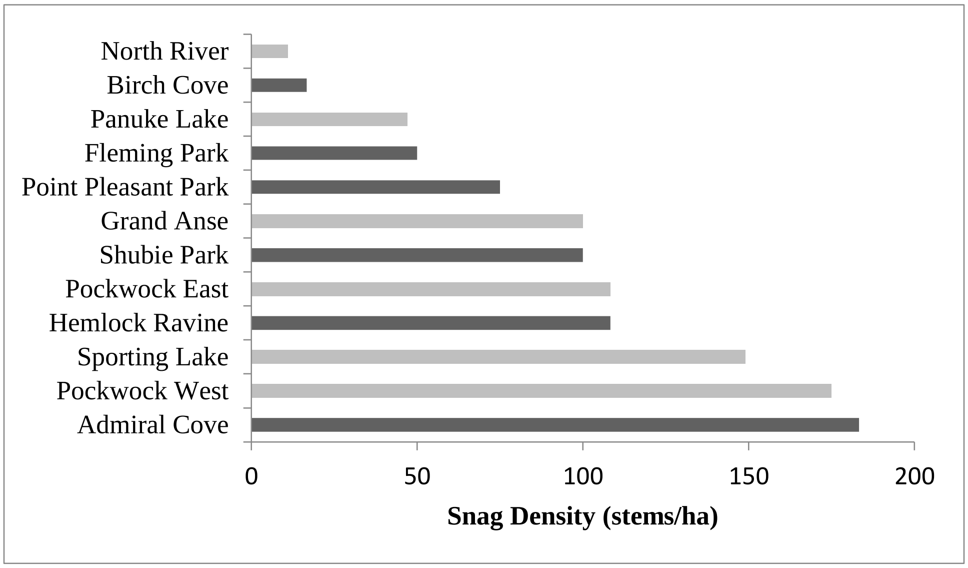

***Figure 7*. Snag densities for all Halifax sites and four Nova Scotia hinterland sites (Stewart et al., 2003). Dark bars indicate urban Halifax forests and light bars indicate hinterland old-growth stands.**

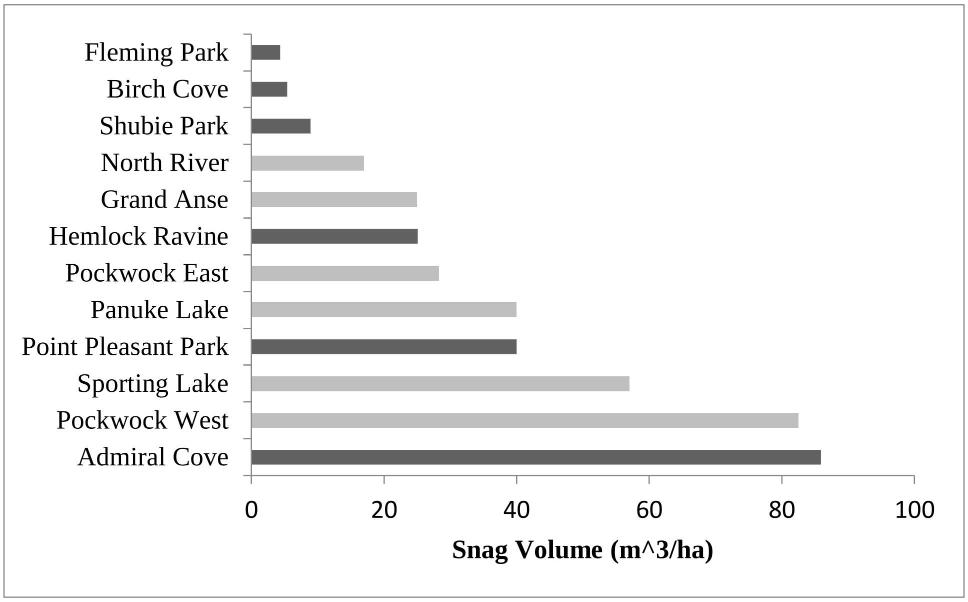

***Figure 8*. Snag volume for all Halifax sites and four Nova Scotia sites (Stewart et al., 2003). Dark bars indicate urban Halifax forests and light bars indicate hinterland old-growth stands**.

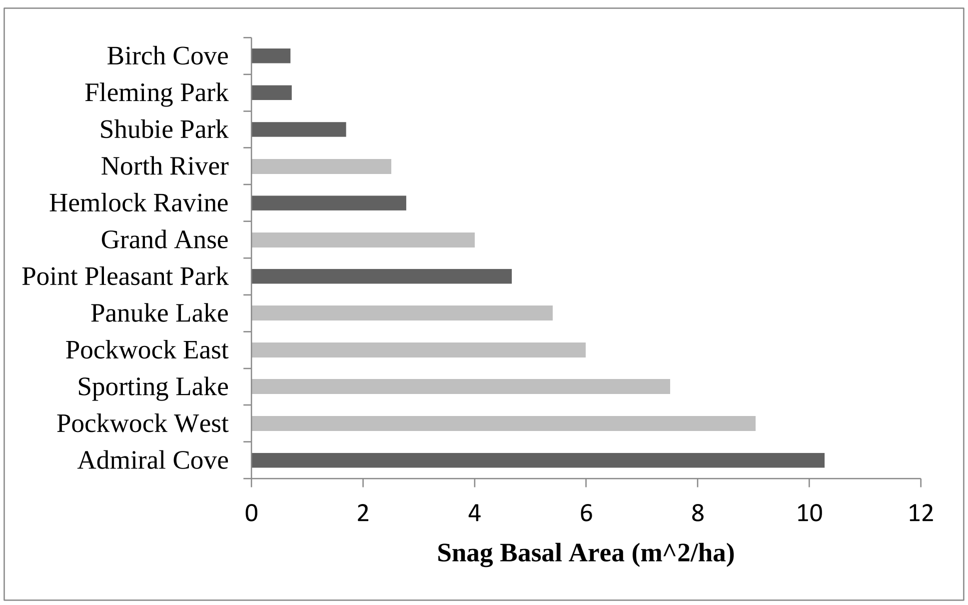

***Figure 9*. Snag Basal area for all Halifax sites and four Nova Scotia sites (Stewart et al., 2003). Dark bars indicate urban Halifax forests and light bars indicate hinterland old-growth stands.**

Downed wood volume ranged from 2 m^3/ha in Birch Cove to 195 m^3/ha at the Pockwock East site (Table 5). Birch Cove had few pieces of downed wood because it is a managed broadleaf-dominated forest and deadwood has been cleaned up. The total deadwood includes snag volumes and downed wood volumes. Again Birch Cove had the least total deadwood, 5 m^3/ha, and Pockwock East had the most total deadwood with 191 m^3/ha.

Table 5

Downed wood volume (m^3/ha) and total deadwood volume (m^3/ha).

	Downed Wood Volume (m^3/ha)	Total Deadwood (m^3/ha)
Point Pleasant Park	134	152
Fleming Park	44	35
Hemlock Ravine	47	62
Admiral Rock	169	216
Birch Cove	2	5
Shubie Park	47	47
Pockwock West	114	173
Pockwock East	195	191
Grand Anse	58	84
North River	45	62
Panuke Lake	71	110
Sporting Lake	91	148

5.0 Discussion

5.1 Dominating Species

Overall, three species dominated the eight measured stands: eastern hemlock, red spruce and red maple. Hemlock Ravine, and Shubie Park were composed mainly of eastern hemlock. Fleming Park, Hemlock East and Hemlock West were dominated by red spruce. Admiral Rock was made up of equal parts eastern hemlock and red spruce. Point Pleasant Park and Birch Cove were the only two that included major components of other species. Point Pleasant Park is one of the more managed forests with comprehensive forest plans and intentional plantings of many different tree species. For example, in 2007 HRM workers planted 15 000 seedlings, including nine different species of trees (Halifax Regional Municipality, 2011). Even if these trees were not planted in our exact site location, their seeds may have transported unintentionally and regenerated at our study area. Birch Cove includes many other species because it is a broadleaf forest, and is host to species such as sugar maple, red oak and service berry.

When comparing the species composition distributions to those in the Stewart et al. (2003) there are similar results. The two conifer stands (Panuke Lake and Sporting Lake) had only eastern hemlock and red spruce trees, and mostly eastern hemlock and red spruce trees, respectively. Sporting Lake also had 20% white pine trees. These results are very similar to those concluded from the conifer stands in this study. The non-conifer stands, Grand Anse and North River, were dominated by sugar maple and white pine. This is dissimilar to the results from Birch Cove, which was composed of mainly red maple and a variety of other species. Many of the species in Birch Cove are not considered old-growth Acadian trees, unlike Grand Anse and North River. However, it was the only stand of non-conifers we could identify in the study.

The percent composition of Acadian old-growth trees was consistent throughout all the stands. The range, in basal area, was between 68% and 93%. Point Pleasant Park and Birch Cove had the least percentage of old-growth trees, while the other six sites were all approximately 87% of the old-growth six. Dominance of the six Acadian old-growth trees is a main characteristic of these forests in Nova Scotia (Loo & Ives, 2003), and the eight urban sites all demonstrate a dominance of these species. When comparing these percentages to those of Stewart et al.(2003), they were similar. North River and Panuke Lake were composed entirely of Acadian old-growth species. Grand Anse and Sporting Lake were approximately 90% old-growth species. However, Stewart et al. (2003) study reported only live trees with diameters >10cm and rounded to the closest 10% for species composition. Without these two factors, the percentages may be even closer to those of the urban forests.

5.2 Diameter Distributions

The regeneration of trees in the class 0-10cm was noticeable in three sites. Birch Cove, Point Pleasant Park, and Admiral Cove stood out as having large densities of regenerating trees (0-10cm DBH), ranging from 1000 to over 3000 stems per hectare. The regeneration in Birch Cove was mainly red maple, service berry, and choke cherry. However, no large service berry or choke cherry trees were documented, demonstrating that these species are generally small trees and should not be considered as old-growth regeneration in this area. Point Pleasant Park had similar species in the 0-10 cm DBH category, which also included witch hazel and white ash. Admiral Cove's regenerating species were mostly eastern hemlock and red spruce. The regeneration at this site was growing in large patches under wide gaps in the canopy. These areas may have been affected by Hurricane Juan or, they may have been subject to some more recent tree removal by the city.

In the diameter classes greater than 10cm, all sites showed similar diameter distributions. The graphs were positively skewed with decreasing number of trees in larger diameter classes. This is expected of naturalized forests with uneven stand structure (Stewart et al., 2003). The trees above 40cm DBH were mainly eastern hemlock and red spruce, with the exception of a few red maple and red oak. These trees are expected to dominate in old-growth Acadian forests and are also assumed to be the oldest in the stands. Point Pleasant Park and Admiral Cove had the most amount of trees in the larger diameter class, closely followed by Pockwock West. Although the age of a large tree does not correlate directly with its diameter (Stewart et al., 2003), the ecosystem functions of large trees will be similar. The values associated with large trees are wide-ranging and include carbon storage, habitat and air purification (Hagen, Vincent & Welle, 1992; Luyssaert et al., 2008), demonstrating the importance of large trees in these forests.

The diameter distribution patterns of the eight measured sites are also similar to the four sites from Stewart et al. (2003). All four of their sites fit an exponential regression model, with a positive skew, with levels of regeneration between 500 and 900 stems/ha. Except for the three urban sites with high levels of regeneration, this was also the range for all sites measured. There appeared to be few significant differences in diameter distribution classes greater than 10 cm between conifer and non-conifer stands.

5.3 Density and Basal Area

The total density (number of stems per hectare) in all sites (eight Halifax and four hinterland Nova Scotia) ranged from 1054 to 3392. Birch Cove and Point Pleasant Park were outliers, with densities above 2500. The remaining urban sites were all similar and within the ranges of the hinerland old-growth forest densities. The density of trees with a DBH greater than 40 ranged from 58 to 195. Birch Cove have one of the lowest densities, with only 75 stems/ha. This may explain why the forest has an abundance of regeneration. Moreover, the dominant species grow more slowly in diameter than do conifers, so the trees are likely to be smaller at the same age as conifers. The known old-growth sites on average did show a greater number of trees with diameters greater than 40 cm, with the exception of Admiral Rock and Point Pleasant Park.

The total basal areas (m^2/ha) for all sites ranged from 33.3 to 59.7. The sites with the lowest basal areas were Birch Cove and North River, both of which are broadleaf dominated forests. This finding suggests that non-conifer forests have smaller total basal areas than conifer forests in Nova Scotia. The sites with the highest total basal areas were Panuke Lake, Sporting Lake, Shubie Park and Pockwock West respectively. Higher basal areas in the known old-growth forests may indicate that the urban forests are not as mature. However, the range of basal areas (not including the two broadleaf stands) was only approximately 20 m^2/ha, suggesting that the variance is due more to the differences in species composition between stands.

Basal area of trees with diameters greater than 40cm were between 12.6 m^2/ha and 43.4 m^2/ha. Panuke Lake had both the highest density of trees and highest basal area. These numbers indicate that Panuke Lake has a high percentage of large trees when comparing it to total density of all trees. In Comparison, Birch Cove had the highest density of trees, a low density of trees >40cm, and a low basal area, indicating that it may be less characteristic of an old-growth forest. With the exception of a few high outliers in the basal areas of trees >40cm, all sites showed similar characteristics, possibly demonstrating their similarities as old-growth forests.

5.4 Deadwood

A high abundance of large pieces of deadwood is a characteristic of old-growth forests (McGee, Leopold & Nyland, 1999). However, the urban sites may have altered amounts of deadwood because of the city's management strategies. Many of the forests measured had large pieces of downwood from trees that had been cut down for safety or aesthetic purposes. Although this is not a natural process, the downed coarse woody debris has similar ecological functions as naturally occurring CWD. The volume of downed CWD was highest in Pockwock, Admiral Cove, and Sporting Lake.

Forest managers may also influence snag abundance by removing snags that are deemed unsafe or visually unpleasant. Snag densities were higher in the known old-growth forests, with the exception of the two non-conifer stands (North River and Grand Anse). Admiral Cove had the highest snag volume and basal area, with the presence of many large white pine and red spruce snags. Higher snag volumes have been correlated with old-growth forests (Hale, Pastor & Rusterholz, 1999), and this study appears to demonstrate the same association between old-growth stands and snag volume.

6.0 Conclusions

Urban forests within Halifax share many similar characteristics with old-growth hinterland forests in Nova Scotia. They have comparable diameter distributions, species compositions, and stem densities. The stands also have similar abundances of snags and total downed wood. These characteristics demonstrate that from a physical perspective, these forest stands within the city should be considered old-growth forests. There is a varying range of "old-growthness" within the city, depending on which characteristics are highlighted. For example, Point Pleasant Park has a high tree density and high total basal area of trees over 40 cm DBH, yet Fleming Park has the highest percentage of old-growth-six species composition.

I would argue that in terms of comparable characteristics to hinterland old-growth forests, Admiral Rock is the most similar. It has the highest old growth six species composition, the most amount of deadwood, and a relatively even diameter class distribution. Admiral Rock is a 90 ha park located at the north end of the Bedford Basin, containing large, old red spruce and eastern hemlock trees. Even though it is surrounded by high-traffic roads, the park is surprisingly quiet and undisturbed.

6.1 Study Deliverables

The purpose of this study was partly to address the question of similarities between rural and hinterland old-growth forests but also to highlight these stands as unique ecosystems. The research should help promote visitations to the parks so that people can readily experience local old-growth forests within the city. If people were aware of these complex ecosystems, and the abundance of benefits that they provide to our cities, they may be more inclined to visit these old-growth forests. The old-growth forest stands in Halifax can provide educational experiences, and generally increase the well-being of visiting residents.

Local residents can gain hands-on educational experience from visiting these parks. The forests should be considered heritage areas, because of the parks' high abundances of Acadian old growth trees. People can visually learn about how Nova Scotia looked before human settlement, and how we have shaped our current landscape. Some notable large trees include the eastern hemlocks in Shubie Park and Fleming Park, and the red oaks in Birch Cove. These trees have (presumably) been growing for well over a hundred year, demonstrating their resilience to our changing landscape and climate.

Since the characteristics of the selected urban forest sites are similar to hinterland old-growth, they should be managed to enhance these characteristics. Forest managers should promote the regeneration and growth of Acadian tree species. The municipality can do this by actively removing non-native invasive species or by planting new trees of old-growth-six species. No large old-trees should be removed, regardless of their species. They are current habitat to many woodland animals and will die naturally over time. The urban foresters should also leave all downed deadwood and snags, unless they are potentially dangerous to visitors. Decaying deadwood is an important feature of old-growth forests for carbon cycling, nutrients and habitat purposes (Burrascano, Lombardi & Marchetti, 2008). Lastly, these forests should be properly distinguished with informative signage, demonstrating the rarity of these stands and their unique benefits to the environment and the Halifax community. This signage could also be in the form of small QR codes throughout the parks, which the user will scan, taking them to an educational webpage with information about the old-growth forest.

6.2 Future Research

This study provides a comprehensive overview of the structural similarities between urban old-growth and hinterland old-growth. The research could be expanded upon using diverse new investigations. One new study should include coring the large trees located at the six urban sites. This is one aspect of the study that limits our ability to properly classify Halifax urban forests as old-growth forest stands according to the *Nova Scotia Old Forest Policy* (Nova Scotia Department of Natural Resources, 2012). A second study may include public research and involve survey questions to local residents such as **a)** how much do they known about Acadian old-growth forests, **b)** would they like to know more, and **c)** their willingness to pay to protect these forests. This would provide the municipality with a better understanding of the forest's values according to Halifax residents, and if more information about the forests needs to be made available. Finally, researchers could develop a study to evaluate the economic value of the six urban forests. This may include determining functional values of hydrological and carbon cycling, existence values, and future potential use values (Adger, Brown, Cervigni & Moran, 1995). With this information, the HRM will have the ability to allocate funds to the forests based on the monetary costs and benefits that the old-growth stands provide.

6.3 Concluding Remarks

The extent of research pertaining to urban old-growth forests in academic literature is limited. This study aims to address this issue, furthering our knowledge of urban old-growth in Nova Scotia. The research question seeks to demonstrate the similarities of forest characteristics within Halifax urban core and in the hinterland of Nova Scotia. The field work and data analysis provided evidence that urban and hinterland forests have similar live tree and deadwood characteristics. This research can be further used to promote visitation to these easily accessible forest locations, and to manage the sites while enhancing old-forest characteristics. Urban old-growth forest is an important area for further study and should be considered when developing urban forest master plans to optimize the forests ecological and economic benefits.

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