THE LIVING AMONGST THE DEAD: THE ROLE OF HALIFAX CEMETERIES AS GREENSPACE AND THEIR POTENTIAL FOR EXPANSION OF THE URBAN FOREST

by

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ABSTRACT

Urban forests provide cities with a multitude of benefits but face many survival challenges. This thesis sought to determine the potential for cemeteries to expand the urban forest in Halifax, Nova Scotia through tree planting. Inventories of existing cemetery trees and potential plantable spots were conducted. Interception surveys with cemetery users and interviews with cemetery managers were used to determine the importance of cemetery trees and identify concerns and barriers to planting trees in cemeteries. The results indicate that Halifax cemeteries have relatively high canopy covers primarily composed of older non-native trees, and that the number of cemetery trees could be nearly doubled. Cemetery users highly value cemetery trees and have very few concerns about them. Cemetery managers also value cemetery trees but cited barriers to planting such as a lack of space, financial constraints, and potential for damage. For current canopy cover to be maintained (and expanded), these barriers need to be addressed.

LIST OF ABBREVIATIONS USED

BA	Basal area
DBH	Diameter at breast height
HRM	Halifax Regional Municipality
UFMP	Urban Forest Master Plan

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CHAPTER 1: INTRODUCTION

1.1 Urbanization and greenspace

The world is becoming increasingly urbanized, with over half of the global population currently residing in cities—a figure that is expected to increase to 70% by 2050 (United Nations, 2018). While urbanization can provide benefits such as increased access to education, healthcare, employment and various amenities, it places increased demand on cities for infrastructure to support housing, transportation, utilities, etc. In response, many cities are attempting to densify to limit urban sprawl by increasing human populations and the built infrastructure needed to accommodate them within the existing area of the city (OECD, 2012). One of the biggest criticisms associated with urban densification is its negative impact on the extent and quality of urban greenspace (Haaland & Konijnendijk Van Den Bosch, 2015), which in turn limits recreation, stormwater management, temperature regulation, and so on (Arnberger, 2012; Dallimer et al., 2011; Lin, Meyers, & Barnett, 2015; Tratalos, Fuller, Warren, Davies, & Gaston, 2007).

Greenspace is a diverse and wide-ranging concept. In this thesis, I have defined it as any urban vegetation, including that contained within public and private parks, back and front yards, gardens, farms, orchards, abandoned lots and derelict lands, street trees, and cemeteries (Taylor & Hochuli, 2017). Scholarly research has identified a long list of social (Maas, van Dillen, Verheij, & Groenewegen, 2009; Schipperijn et al., 2017; M. van den Berg et al., 2016), economic (Czembrowski & Kronenberg, 2016; Zhang, Xie, Zhang, & Zhang, 2012), and environmental (Bolund & Hunhammar, 1999; Millward & Sabir, 2011) benefits provided by urban greenspace. Some of these benefits include stormwater management, mitigation of the urban heat-island effect through shade and

evapotranspiration (Bolund & Hunhammar, 1999), air-pollution removal (Jim & Chen, 2008), support for biodiversity (Alvey, 2006; Tryjanowski et al., 2017), improved physical health (Konijnendijk, Annerstedt, Maruthaveeran, & Nielsen, 2013) and mental wellbeing (Maas et al., 2009; M. van den Berg et al., 2016), enhanced tourism (Deng, Arano, Pierskalla, & McNeel, 2010; Hotte & Sumaila, 2012), increased property values (Czembrowski & Kronenberg, 2016), and many more. The urban forest—defined as all of the trees within a city (Konijnendijk, Ricard, Kenney, & Randrup, 2006)—in particular has been noted to play an important role in the delivery of many of these benefits (Bolund & Hunhammar, 1999; Duinker et al., 2015).

Based upon the wide range of benefits provided by greenspace and urban trees, it is worth considering ways in which they can be increased in number, area, or quality. Given the important role that trees in particular play in the provision of ecosystem benefits and services in urban areas (Bolund & Hunhammar, 1999; Duinker et al., 2015) it is no surprise that cities around the world are aiming to increase their canopy cover. One of the main methods in which cities are doing this is through the planting of street trees along sidewalks and street rights-of-way, which are owned and managed by municipal governments. Street trees provide benefits in commercial, industrial, and residential settings, but they face challenges growing in these environments due to abundant impervious surfaces (Mullaney, Lucke, & Trueman, 2015). Furthermore, street environments can pose problems such as limited space and exposure to high levels of traffic (Lu et al., 2010), threats of vandalism (Nowak, Mcbride, & Beatty, 1990), poor soil quality (Jim, 1998), presence of overhead utility wires (Appleton, 2006), and increased drought (Clark & Kjelgren, 1990), heat (Cregg & Dix, 2001), and pollution

(Benoit, Skelly, Moore, & Dochinger, 1982). One way to circumvent at least some of these issues is to consider planting trees in locations other than streets. A potential location is urban cemeteries. These environments often have minimal infrastructure (typically only grave monuments and the occasional building, bench, and fence), few overhead wires, and relatively low levels of vehicular and pedestrian traffic. However, cemeteries have a function—the interment of human remains and commemoration of individuals—that differs from typical greenspaces and that needs to be considered when determining the suitability of these ecosystems for expanding the urban forest.

1.2 Cemeteries and burial in Canada

Cemeteries have a long history of evolution throughout the world. Burial traditions, attitudes towards death, and places of interment vary across the globe based on different cultures and religions. However, despite these differences, cemeteries around the world function primarily as places of interment and memorialization, where human remains are interred, individuals are enshrined, and loved ones are commemorated.

Burial in Canada began with Indigenous burial grounds, which varied in form based on the rituals of different tribes (Blair, 2005; Dyck, 2009). The arrival of Europeans in the 16th century led to the creation of trading posts (Brown, 1980; See, 2011), and high death rates led to the creation of burial places in close proximity to these areas (Morse, 1969).

Once settlement began in earnest, burials increasingly took place in family burial plots and churchyards (Price, 1966 in Knight, 1973). The arrival of Christianity led to increased numbers of churchyards (Coates, 1987; Rawlyk, 1995), which decreased the popularity of private family burial plots. The location of churchyards within towns began

to be considered unsuitable in the 1800s as concerns for health and sanitation grew (Harvey, 2006; Irwin, 2007; Rugg, 2000).

The demise of the churchyard gave way to the rural cemetery, which was placed on the outskirts of the city and emphasized statuesque monuments and sophisticated landscaping (Harvey, 2006; Irwin, 2007). The beauty of the cemeteries attracted the public and led to use of these spaces for leisure (Linden-Ward, 1989), as they often pre-dated traditional urban parks and thus were able to provide the public with access to a tamed version of nature (Hall & Bowden, 1986; Harvey, 2006). Many of these once rural cemeteries now exist amongst the dense infrastructure of cities that expanded over time to accommodate a growing population.

Rural cemeteries eventually fell out of favour due to rejection of their opulent monuments and landscapes, exaggeration of death and grief, and the rise of professionalism in cemetery management, which led to a demand for decreased maintenance and upkeep costs (Rugg, 2006). The lawn cemetery emerged in response as a pastoral landscape with an open lawn and monuments set low to the ground (Sloane, 1991). Memorial parks/gardens are currently a popular model of cemetery, emphasizing the pastoral landscape but focusing on the creation of large memorials for the collective dead rather than emphasizing individual plots (McNamara, 2002; Mytum, 2004).

Of burgeoning interest in Canada is natural or green burial, whereby traditional interment practices are eschewed in favour of more environmentally-friendly methods (Hockey, Green, Clayden, & Powell, 2012). Currently, most natural burial sites in Canada exist as an extension of cemeteries that also offer traditional options for interring remains (Natural Burial Association, 2013).

Today, there are over 18,000 burial places in Canada (CanadaGenWeb, 2018). These cemeteries are owned by a range of entities, including various levels of government, private companies, non-profits, families, synagogues, and churches (Library and Archives Canada, 2015). The evolution of cemetery styles and the increasing multicultural population has led to diverse and unique cemeteries across the country. Unlike in countries such as Sweden and Denmark, when burial plots or columbaria niches (for the interment of cremated remains) are purchased in Canada, they are owned in perpetuity and graves are not re-used (Kjøller, 2012; Rugg & Holland, 2017). This has led to questions about the ecological and financial sustainability of cemeteries, the ethical implications of soaring burial costs, and how to address the increasing lack of burial space (Lawrence, 2017). Cemeteries that are closed to further interments often have to rely on government funding and donations to support maintenance efforts (Harvey, 2006). Hussein (2006) and Woodthorpe (2011) suggest that diversifying the function of cemeteries may be necessary to ensure their sustainability.

1.3 Cemeteries as multi-functional greenspace

The envelopment of cemeteries and burial grounds during urban expansion has resulted in them being located within cities, despite initial efforts to place them beyond city limits. In landscapes primarily made up of dense infrastructure and limited vegetation, cemeteries are being increasingly considered for their role as urban greenspaces, as they have relatively high levels of vegetation and other similarities with traditional parks, which are readily considered to be public greenspace (Quinton & Duinker, 2019). The literature on urban cemeteries as greenspaces has been increasing

recently, and the academic journal, *Urban Forestry & Urban Greening*, published a special issue on cemeteries in 2018 (Nordh & Swensen, 2018).

Although there is debate regarding whether cemeteries are truly public given the private ownership of burial plots (Swensen & Brendalsmo, 2018), research has shown that cemeteries are increasingly being used by the public for purposes other than interment and commemoration. Exercise, commuting, photography, enjoying nature, education and history, relaxation and restoration, and dog-walking are just some of the many uses that have been observed in European cemeteries (Deering, 2010; Evensen, Nordh, & Skaar, 2017; Grabalov, 2018; Skår, Nordh, & Swensen, 2018; Swensen, Nordh, & Brendalsmo, 2016). The aesthetics of cemeteries have been noted as an important motivator for their public use (Al-Akl, Karaan, Al-Zein, & Assaad, 2018; Harvey, 2006; Nordh, Evensen, & Skår, 2017), as has their calm and restorative atmosphere (Nordh et al., 2017; Swensen & Brendalsmo, 2018).

Beyond recreation, the role of cemeteries as supporters of, and contributors to, urban biodiversity has been increasingly studied. Cemetery environments tend to have a relatively high level of vegetative diversity (de Lacy & Shackleton, 2017; Radecki, 1999; Yımaz, Kuşak, & Akkemik, 2018). They also support populations of birds, bats, beetles, spiders, and small mammals, including populations of species that are rare or tend to avoid urban environments (Čanády & Mošanský, 2017; Kowarik, Buchholz, von der Lippe, & Seitz, 2016; Laske, 1994; Morelli, Mikula, Benedetti, Bussière, & Tryjanowski, 2018; Tryjanowski et al., 2017). Based on the biodiversity contained within cemeteries, and the high canopy cover found in many, there is also potential for cemeteries to provide

other ecosystem services such as stormwater management, micro-climate regulation, and increased pollination (Quinton & Duinker, 2019).

Despite their role in supporting biodiversity and providing recreational opportunities and other ecosystem services, the primary purpose of cemeteries is still the interment of remains and commemoration of individuals. The potential for conflict between recreational users and commemorative users has been noted, as individuals may have different opinions regarding what constitutes appropriate behaviour in a cemetery (Grabalov, 2018; Woodthorpe, 2011). Research indicates that cemeteries are viewed by city planners and managers mainly as places of historical and cultural value and are typically managed separately from other greenspaces (Kjøller, 2012; Nordh & Evensen, 2018), which has implications for the use of cemeteries as greenspace. The financial instability of Canadian cemeteries could result in future losses of their tree canopy and other vegetation due to a lack of tree planting and natural regeneration. This could result in deterioration of the potential for cemeteries to function for purposes beyond that of interment and the degradation of greenspace beyond what is already being lost to urban densification.

Increased research is required regarding how cemeteries contribute urban greenspace, how they are managed as greenspaces, how users feel about cemeteries as greenspaces, and the potential to maintain the "greenness" of cemeteries in the future. As Woodthorpe (2011) pointed out, current research on cemeteries is fragmented by discipline, preventing a holistic view on the complex nature of urban cemeteries. Additionally, the majority of research on cemeteries (particularly on cemeteries as greenspace) has been carried out in Europe, often in Scandinavia (Quinton & Duinker,

2019). Differences in burial traditions, cemetery forms, and attitudes towards death across the world indicate that cemetery management and the use of cemeteries as greenspace is unlikely to be the same in every country. As such, research needs to be carried out beyond Europe.

1.4 Research objectives

This thesis includes two overarching research questions. The first is: What is the current role of cemeteries in the urban forest of central Halifax, Nova Scotia? The second question is: What is the potential to use cemeteries to expand the urban forest in central Halifax? Based on the many considerations that would need to be given to properly answer these questions, they were both divided into further sub-questions:

Question 1: What is the current role of cemeteries in the urban forest of central Halifax?

Sub-question A: What is the current *biophysical* contribution of cemeteries to the urban forest of Halifax?

Sub-question B: What is the current *sociocultural* contribution of cemeteries to the urban forest of Halifax?

Question 2: What is the potential to use cemeteries to expand the urban forest in Halifax?

Sub-question A: What is the *biophysical* potential to use cemeteries to expand the urban forest in Halifax?

Sub-question B: What is the *sociocultural* potential to use cemeteries to expand the urban forest in Halifax?

Sub-question C: What is the *managerial* potential to use cemeteries to expand the urban forest in Halifax?

The objectives are to determine what the current roles of cemeteries are in the urban forest of Halifax, both in the context of their trees and how the trees are viewed by cemetery users and managers. Furthermore, this thesis considers whether cemeteries could physically accommodate additional trees, whether cemetery managers and users would be receptive to additional trees, and any concerns either of these groups might have regarding planting trees in cemeteries in the future.

1.5 Thesis outline

This thesis is built around two journal manuscripts. The first manuscript, seen in Chapter 2, seeks to answer questions 1A and 2A regarding the biophysical contribution cemeteries make to the urban setting and their potential to be used to expand the urban forest of Halifax. This manuscript has been submitted to *Urban Forestry & Urban Greening* and is currently under a second round of revisions. The citation for this paper is as follows: Quinton, J. M., Duinker, P. N., Steenberg, J. W.N., & Charles, J. D. 2019. The living amongst the dead: Cemeteries as urban forests, now and in the future. *Urban Forestry & Urban Greening*. Copyright permission letters from the three co-authors of this paper can be found in Appendix 4.

The second manuscript, seen in Chapter 3, seeks to address questions 1B, 2B, and 2C regarding the user and manager opinions of trees in cemeteries, as well as the sociocultural and managerial potential to use cemeteries to expand Halifax's urban forest. The second manuscript has been published in *Urban Forestry & Urban Greening* and is included in this thesis with permission outlined in the Rights and Access Agreement

signed with Elsevier GmbH at the time of publication. The citation for this paper is as follows: Quinton, J. M., Duinker, P. N., Gallant, K., Steenberg, J. W. N., Charles, J. D. 2019. To tree or not to tree: User and management perspectives of cemetery trees. *Urban Forestry & Urban Greening*. Accepted for publication 2 July 2019. https://doi.org/10.1016/j.ufug.2019.126385.

These two chapters are followed by Chapter 4, which integrates the findings from these two manuscripts to provide a conclusion that satisfactorily answers the overarching thesis questions about the current contribution of cemeteries to the urban forest of Halifax and their potential to be used to increase the canopy cover of the city.

CHAPTER 2: BIOPHYSICAL CHARACTERISTICS OF CEMETERY URBAN FORESTS

Abstract

In the face of increasing population and urbanization, cities are trying to reconcile built infrastructure designed to accommodate human needs while also retaining and improving urban tree canopies. Given the diverse locations in which trees currently exist within cities, including public and private property, gardens, parks, abandoned lots, etc., I discuss the overlooked contribution of cemeteries to the urban forest. Specifically, I discuss the potential to expand the urban forest through planting trees in the cemeteries of Halifax, Nova Scotia (Canada). The objectives of my research were to 1) characterize the existing tree populations in Halifax cemeteries, and 2) estimate how many trees could be planted within these cemeteries.

Our research indicates that Halifax cemeteries are dominated by non-native species such as *Acer platanoides, Tilia cordata, and Ulmus glabra*. Smaller trees are mostly limited to small copses comprised of dense regenerating stock, while the majority of area within cemeteries contains only larger and older trees. Limited natural regeneration and planting efforts, combined with the large size of Halifax's cemetery trees, indicates the likelihood of future canopy losses. However, this study also found over 2000 spots in which trees could be planted in the 27 ha of Halifax cemeteries, indicating that their tree populations could be almost doubled. Barriers such as financial limitations and hesitancy to plant trees amongst monuments need to be addressed and consideration needs to be given to the relationship between cemetery users and trees to determine how best to maintain (and potentially expand) the urban forest within cemeteries.

2.1 Introduction

The growing urban populations worldwide place increased demand on cities for infrastructure such as housing, transportation, and utilities, amongst other necessities. To avoid low-density urban sprawl, which has negative impacts on human health and the environment (Johnson, 2001; Resnik, 2010), cities are increasingly employing methods of urban densification and embracing the concept of "compact cities" (OECD, 2012). However, densification can result in the loss of urban greenspace (Dallimer et al., 2011; Haaland & Konijnendijk Van Den Bosch, 2015), which I define here as urban vegetation, including private and public parks, backyards, gardens, farms, and street trees (Taylor & Hochuli, 2017).

The value of greenspace to humans has been well documented in terms of health (e.g. Schipperijn et al., 2017), economics (e.g. Zhang et al. 2012; Czembrowski and Kronenberg 2016), social connection (e.g. Maas et al. 2009), and the provision of ecosystem services (e.g. Bolund and Hunhammar 1999). Urban forests, which include all of the trees within a town or city (Konijnendijk et al., 2006), have been shown to provide a wide array of benefits enjoyed by humans (Duinker et al., 2015). Despite this, and the burgeoning academic attention given to urban forests, recent research from the United States has indicated that urban tree cover is declining (Nowak & Greenfield, 2018), a trend that is likely seen beyond the United States.

Street rights-of-way and medians are common targets for city tree-planting efforts, as they are owned by municipalities and provide the broadest array of benefits in this location (Mullaney et al., 2015). However, growing street trees can be challenging given the relatively low levels of soil moisture, nutrients, and volume due to impervious

urban surfaces (Mullaney et al., 2015), exposure to vehicular traffic, limited space for growth (Lu et al., 2010), and the presence of overhead utility wires (Appleton, 2006). These challenges, and the benefits trees provide in urban settings, indicate a need to consider areas beyond streets where trees can be planted. I propose that one such area should be urban cemeteries.

Cemeteries have a long and complex history around the world and take on various forms based on local traditions and culture (Quinton and Duinker, 2019). Although their primary purpose is typically commemoration and memorialization of the deceased, cemeteries are being embraced as locations suitable for low-impact recreational activities such as jogging, walking, photography, education, relaxation, and socialization (Deering, 2010; Grabalov, 2018; Swensen et al., 2016). The low-impact uses of cemeteries reduce the potential for soil compaction, and this, combined with the lack of overhead utility wires, vehicular traffic, and impervious surfaces, suggest that cemeteries may be ideal locations for the survival of young trees. The lack of built infrastructure within cemeteries, other than monuments and the occasional building, indicate that there may be open space suitable for expanding tree populations.

Academic interest in urban cemeteries has been increasing within the greenspace narrative, both in terms of their non-commemorative uses (see for example: Evensen et al., 2017; Grabalov, 2018; Swensen et al., 2016) and their contributions to plant (de Lacy & Shackleton, 2017; Jaganmohan, Sujay Vailshery, Mundoli, & Nagendra, 2018) and animal (Kowarik et al., 2016; Morelli et al., 2018) biodiversity. These studies have taken place around the world from Scandinavia (Grabalov, 2018; Swensen et al., 2016) to mainland Europe (Kowarik et al., 2016; Morelli et al., 2018), Africa (de Lacy &

Shackleton, 2017), Asia (Jaganmohan et al., 2018) and the Middle East (Al-Akl et al., 2018), indicating global interest.

Despite this global interest, the concept of cemeteries as greenspace has received little academic attention in North America, and the use of cemeteries as repositories for urban trees has not yet been discussed (Quinton & Duinker, 2019). The two main objectives of this study were to examine ten urban cemeteries in Halifax, Nova Scotia (Canada) to: 1) characterize their existing trees in terms of species, canopy cover, size diversity, and interference with monuments/overhead wires to determine the current and potential future state of their urban forests; and 2) estimate how many more trees could theoretically be planted within these cemeteries based upon available space.

2.2 Methods

2.2.1 Study sites

Halifax is a coastal city and the capital of Nova Scotia, a province in Atlantic Canada. The population centre has an area of 234.7 km, and is home to 316,701 people, resulting in a density of 1349 people/km^2 (Statistics Canada, 2017). The Halifax peninsula is the most densely populated area of the city, and ten cemeteries on the peninsula were used as study sites (Figure 1). The cemeteries differed in terms of area, location, age, ownership, and whether they are still open to interments (Table 1).

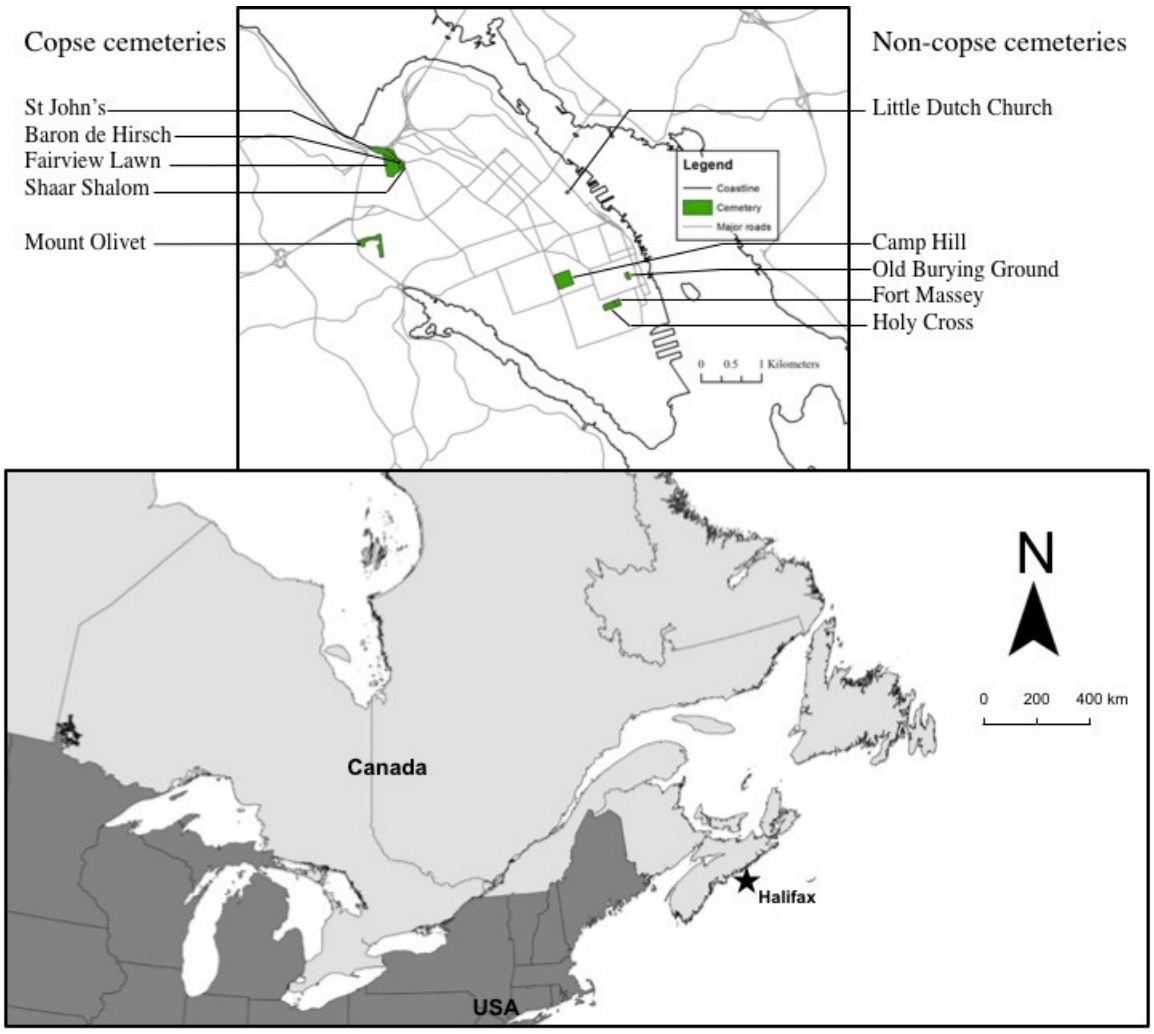

Figure 1: The ten cemeteries used as study sites in Halifax, Nova Scotia (Canada). Bottom map modified from Nitoslawski et al. (2017).

Table 1: The ten study cemeteries on the peninsula of Halifax, Nova Scotia (Canada).

Area (ha)	Internment status	Ownership	Year established	Cemetery
6.47	Plot-holders only	Halifax Regional Municipality	1844	Camp Hill
2.19	Cremation only	Roman Catholic Archdiocese of Halifax-Yarmouth	1843	Holy Cross
0.93	Spouses only	Government of Canada	1778	Fort Massey
0.72	Closed	Parish of St. Paul's Church	1749	Old Burying Ground
0.24	Closed	Parish of St. George's Church	1752	Little Dutch
7.41	Open	Halifax Regional Municipality	1893	Fairview Lawn
4.78	Cremation only	Roman Catholic Archdiocese of Halifax-Yarmouth	1896	Mount Olivet
3.52	Open	Parish of St. John's Church	1839	St. John's
0.82	Open	Beth Israel Congregation	1893	Baron de Hirsch
0.41	Open	Shaar Shalom Congregation	1953	Shaar Shalom

With several university and college campuses, the city has a relatively young population between September and April. Average daily temperatures range from -4.1°C to 19.1°C, with an average yearly precipitation of 1468 mm (Government of Canada, 2010). Most of the entire province of Nova Scotia, including Halifax, is located within the Acadian forest region of Canada, which is characterized by the presence of *Picea rubens*, *Abies balsamea,* and *Betula alleghaniensis* (Natural Resources Canada, 2017).

2.2.2 Tree inventory

A census of trees within the ten cemeteries with a diameter at breast height (DBH) ≥2.5 cm was conducted between June and August, 2018. Each individual was identified to the species level when possible and the genus otherwise. DBH was collected using a diameter tape or caliper, and up to six stems were measured for multi-stemmed trees. For the diameter distributions, DBH measurements for multi-stemmed trees were averaged.

Each tree was defined as belonging to a "copse" (an unmaintained patch of relatively dense vegetation) or not. It was noted (Yes/No) whether each tree was interfering with overhead utility wires (e.g. branches tangled in them), interfering with a monument (e.g. visibly pushing the monument over, lifting or obscuring it), within 1 m but not currently interfering with a monument, and the presence of epicormic shoots. Each tree was geolocated with a minimum accuracy of 2 m (usually <1m) using an EOS Arrow 100 Global Navigation Satellite System (GNSS) device, in conjunction with the Esri Collector App for Android.

Species were identified as native or non-native based on the Nova Scotia Acadian forest region (Natural Resources Canada, 2017; see Appendix 1 for a complete list of native vs. non-native species identified in this study). Basal area (BA) of each tree was

calculated using the formula BA = π x DBH^2/40000. BA for multi-stemmed trees was calculated by summing separate BA calculations for each stem. BA (m^2/ha) was calculated based on the area of the cemetery in which it was located. Species diversity for each cemetery was calculated using the Shannon Diversity Index ($H' = -\sum_{i=1}^{R} p_i \ln p_i$) and species evenness was calculated using Pielou's Evenness ($J' = \frac{H'}{H'_{max}}$), whereby H_{max}= lnS and S = species richness. Due the non-linear nature of some variable relationships, Spearman's rank correlation (ρ) was calculated using SPSS 25 to determine whether stem count, diversity, richness, evenness, or BA were correlated with cemetery age or area. Overall composition, stem density (# individuals/ha) and basal area (m^2/ha) were compared to data obtained from nineteen 0.04-ha plots from the Halifax peninsula which were used as part of a prior i-Tree assessment (Foster & Duinker, 2017).

2.2.3 Canopy-cover estimates

Canopy cover was estimated for each cemetery using i-Tree Canopy v6.1, which uses random-point generation and Google Maps aerial imagery. The user classifies each point as either "tree" or "non-tree", and this is used to determine both % canopy cover and standard error. Random points were classified within each cemetery until the standard error was equal to 2%. The number of random points per cemetery varied depending on each cemetery's canopy cover, whereby the closer the canopy cover was to 50%, the more points were necessary to lower the standard error (Parmehr, Amati, Taylor, & Livesley, 2016). The random-point method was used (vs. remote-sensing or other methods) given the relative simplicity of this method and its ability to still provide accurate results.

2.2.4 Plantable-spots inventory

The number of trees that could theoretically be planted within each cemetery was determined in November 2018. An EOS Arrow 100 GNSS device was used in combination with the Esri Collector App to map polygons representing areas within which trees could be planted. Three types of potential planting areas were defined, including: 1) along existing pathways; 2) in open space free of infrastructure; and 3) amongst monuments. All polygons were created with a minimum of 1-m distance from any monuments or other infrastructure and 5.64 m from the trunk of existing trees. These distances were based on the average distances between trees and monuments and trees and other trees already within cemeteries, under the assumption that these existing distances are considered acceptable by cemetery management and users. The 5.64-m distance from existing trees was also based on the desire to have a 2.82-m radius around trees to allow a 25-m^2 growing space. Area was not omitted if it fell beneath the canopy of an existing tree, as trees (certain species in particular) are able to grow in full or partial shade.

Once the polygons were mapped, Esri's ArcMap 10.5 was used to determine the number of trees that could be planted within each polygon. A 25-m^2 buffer was created around all existing trees measured during the tree inventory, to ensure that the 5.64-m-distance criterion between an existing tree and a plantable spot was not inadvertently violated due to inaccuracies during field mapping. Any overlap between this buffer and a plantable-spot polygon was removed to ensure this area was omitted from the plantable-spots calculation. For the Open-Space polygons and most of the Amongst-Monuments polygons, the area (m^2) was divided by 25 m^2 to determine the number of trees that could

be planted within them, under the assumption that $25m^2$ would allow adequate room for growth. For the Along-Pathway polygons and the Amongst-Monument polygons <5.64 m in width, the length of the polygon was measured at its longest length (m) and divided by 5.64 m to determine the number of plantable spots that could be placed along these polygons. The length was used instead of the area as they would only have a single row of trees planted within them based on their width, and thus only the 5.64 m between the trees in that single row mattered. Spearman's rank correlation (ρ) was calculated to determine whether the number of plantable spots was correlated with cemetery age or area.

2.3 Results

2.3.1 Species composition, richness, evenness, and diversity

Overall, there were 63 species-level identifications and 34 genera (including seven genus-level identifications) across the ten cemeteries. Species richness within the cemeteries ranged from 5 to 40 (Figure 2). Fifteen coniferous species were identified, but they represented only 5% of the total stem count. Species diversity was similar across the cemeteries, with most values falling between 1.78 and 2.25. Similarly, species evenness ranged between 0.59 and 0.92. Species richness (ρ=0.782; p=0.008) was positively correlated with cemetery size. Cemetery age was not correlated with species richness, evenness, or diversity.

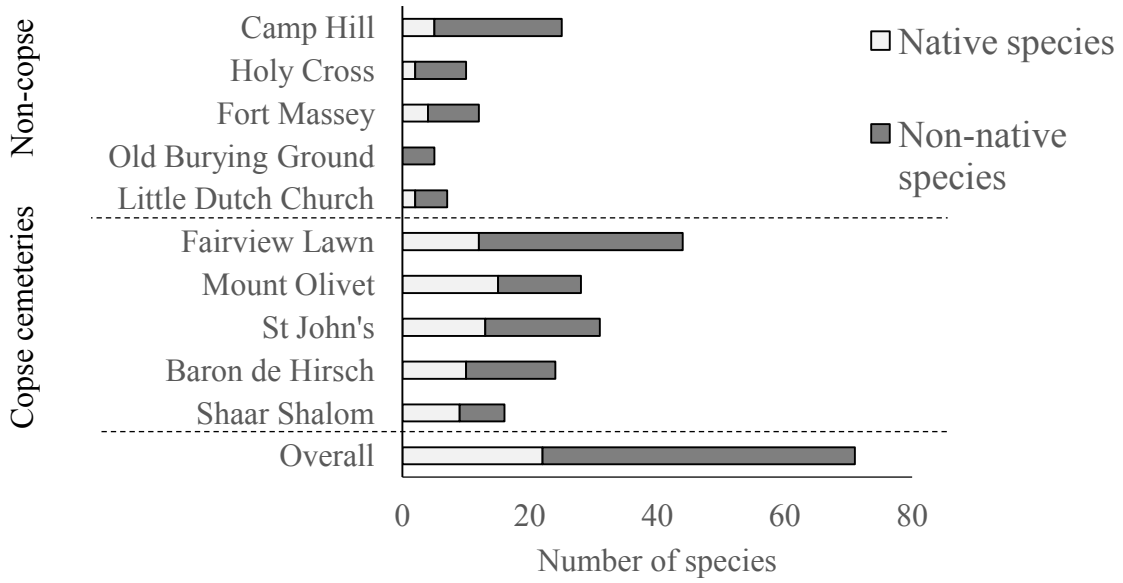

Figure 2: Tree species richness and number of native and non-native species in the ten cemeteries across the peninsula of Halifax, Nova Scotia.

Acer platanoides (Norway maple) dominated most of the copse cemeteries (i.e., cemeteries containing copses) both in terms of stem count and basal area (m^2/ha; Figure 3). *Tilia cordata* (Little-leaf linden) and *Ulmus glabra* (Scots/Wych elm) dominated both the stem count and basal area of the non-copse cemeteries. Overall, *A. platanoides* was the most dominant species according to stem count, but *T. cordata* was dominant according to basal area.

	Acer platanoides	*Acer pseudoplatanus*	*Acer rubrum*	*Acer saccharum*	*Aesculus hippocastus*	*Amelanchier spp.*	*Betula alleghaniensis*	*Betula papyrifera*	*Crataegus spp.*	*Fraxinus excelsior*	*Hydrangea spp.*	*Pinus sylvestris*	*Populus spp.*	*Prunus pennsylvanica*	*Quercus robur*	*Tilia cordata*	*Ulmus americana*	*Ulmus glabra*
Camp Hill											46					183		88
Holy Cross										17						26		16
Fort Massey			8	10					11									
Old Burying Ground		7														28		13
Little Dutch Church		3								3						4		6
Fairview Lawn	245											48						27
Mount Olivet			222				75	76										
St John's	66	43																38
Baron de Hirsch	116	32													15			
Shaar Shalom	36					16								22				
Overall	525		290													265		

Camp Hill					3.2											11		4.1
Holy Cross										1.3						4.9		2.6
Fort Massey					0.9					0.9			1.3					
Old Burying Ground		3.2														13		8.7
Little Dutch Church		0.4								0.4								1.6
Fairview Lawn	3.9											1.2					1.1	
Mount Olivet			2.8				1.1	0.6										
St John's	1.8															0.9		1.1
Baron de Hirsch	3.6		1.7												3.4			
Shaar Shalom	2.5		5.8												1			
Overall	1.6															3.6		1.8

Figure 3: Top three dominant tree species across the ten cemeteries based on total number of individuals (top grid) and basal area (m^2/ha; bottom grid). Dark grey indicates most dominant species, medium grey indicates second-most dominant species, and light grey represents third-most dominant species.

2.3.2 Stem count, density, basal area, and canopy cover

Two of the copse cemeteries had the greatest tree densities, while two non-copse cemeteries had the greatest basal area (m^2/ha; Figure 4). Total stem count was positively correlated with cemetery area (ρ= 0.830; p=0.003), as was basal area (m^2; ρ=0.903; p<0.001). Total stem count was positively correlated with cemetery age (ρ=-0.717, p=0.02), but basal area was not. Overall cemetery-tree density was 2.7 times lower than the surrounding peninsula, but basal area (m^2/ha) was 1.4 times greater in the cemeteries. Both the cemeteries and surrounding peninsula had very similar proportions of naturally regenerating stems and basal area (e.g. trees within copses). However, this natural regeneration was limited to only two of the 19 plots and five of the 10 cemeteries. Canopy cover ranged from 18.6% to 62.8% (Figure 5), with an average of 35.2% (±16.1). Canopy cover was not significantly correlated with cemetery age, area, tree density, or basal area.

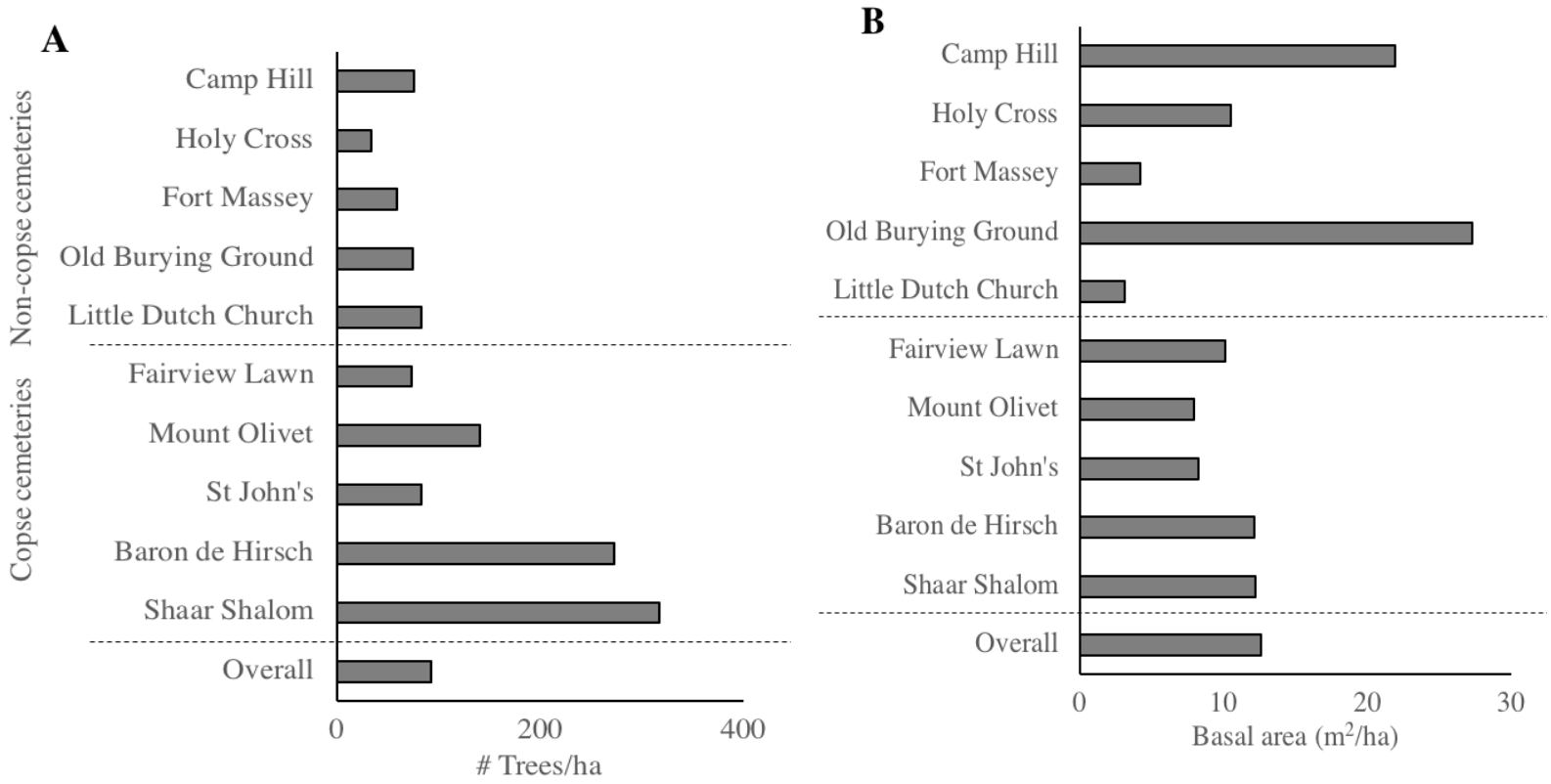

Figure 4: Total **A)** tree density (# trees/ha) and **B)** tree basal area (m^2/ha) of the ten cemeteries across the peninsula of Halifax, Nova Scotia.

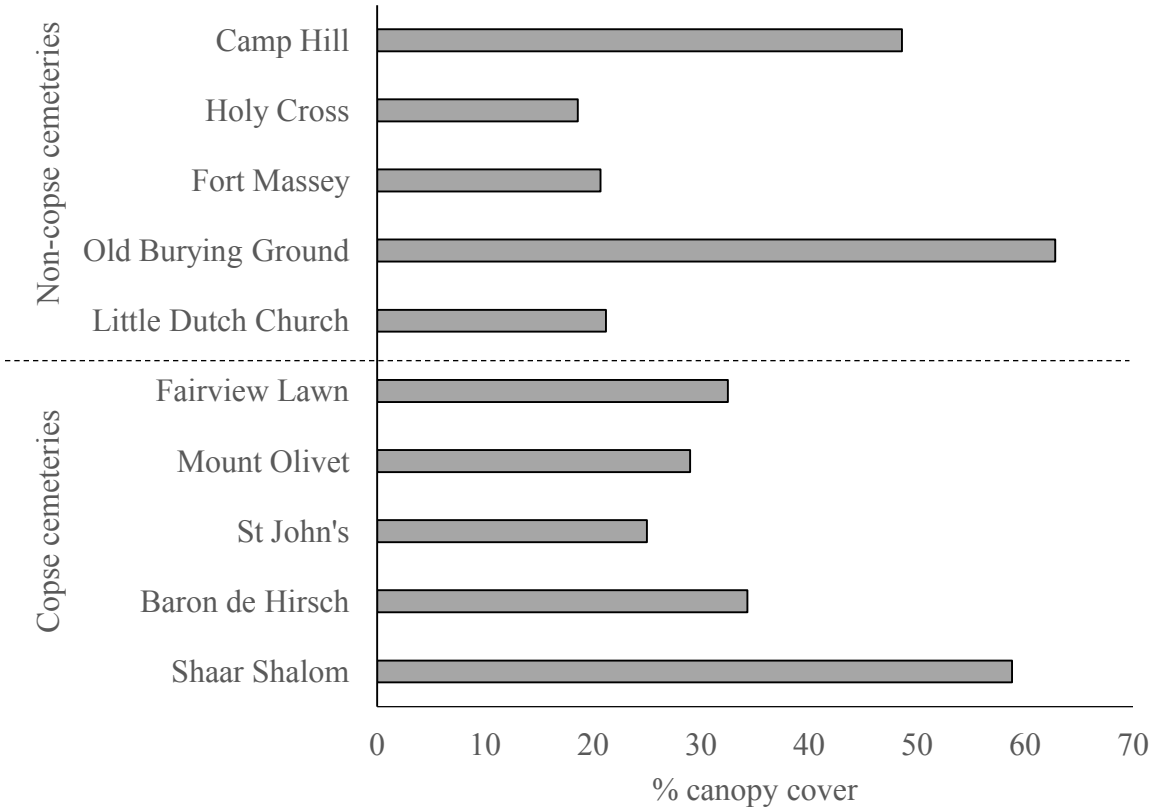

Figure 5: Canopy cover of the ten cemeteries in Halifax, Nova Scotia.

2.3.3 Copse vs. non-copse trees and native vs. non-native species

Copses were identified only in the five cemeteries located furthest outside of downtown Halifax: St. John's, Fairview Lawn, Mount Olivet, Baron de Hirsch, and Shaar Shalom. Within these copse cemeteries, copse trees represented anywhere from 30% to 92% of the stem count but only 5% to 66% of the total basal area (Figure 6). Tree density was positively correlated with the proportion of copse basal area ($\rho=0.756$, $p<0.011$). Trees within copses made up 82% of individuals within the smallest DBH size class (2.5-9.9 cm) whereas the non-copse trees and trees in non-copse cemeteries made up a much greater proportion of the larger DBH classes (Figure 7).

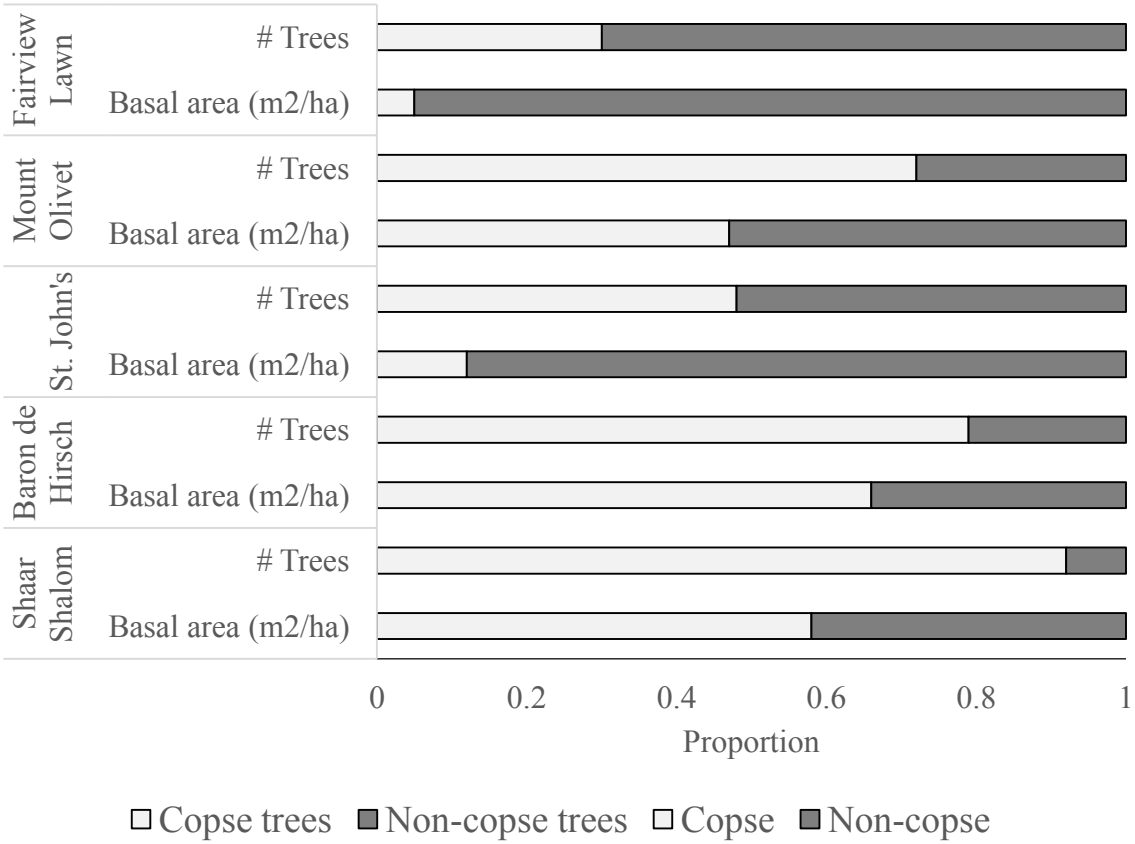

Figure 6: Proportion of copse vs. non-copse trees and basal area (m^2/ha) in the five copse cemeteries in Halifax, Nova Scotia.

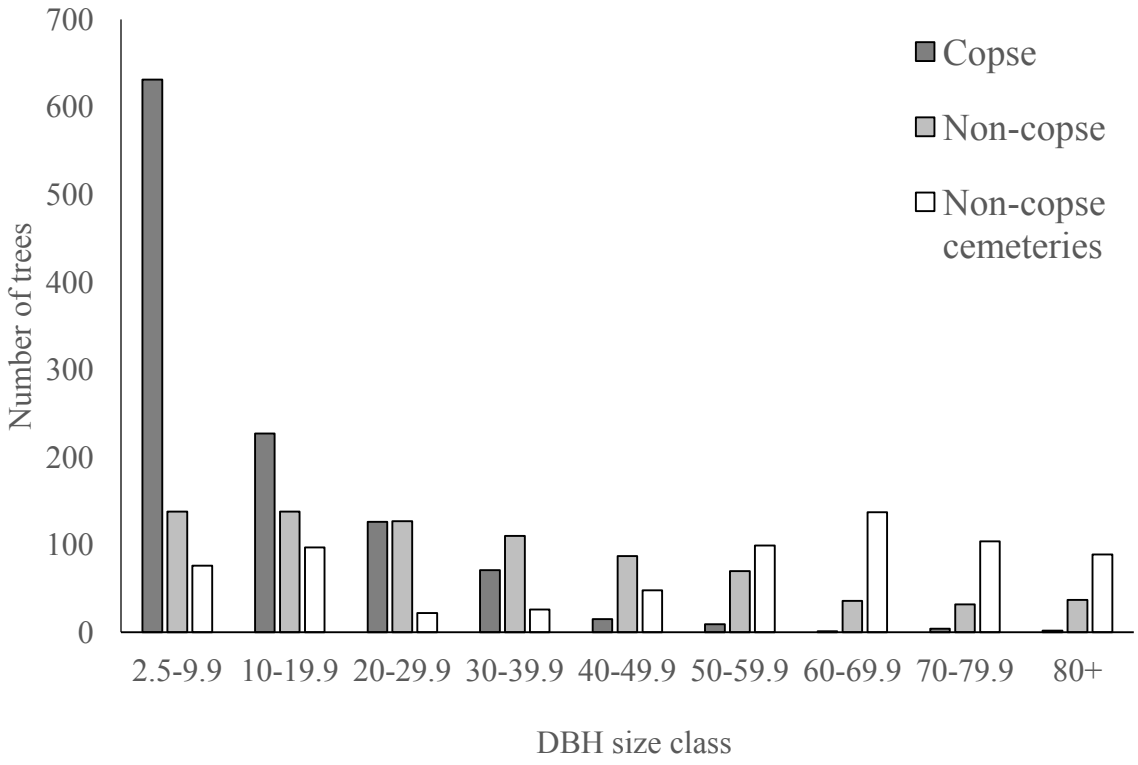

Figure 7: The DBH distribution for copse and non-copse trees in the five copse cemeteries, as well as the non-copse cemeteries in Halifax, Nova Scotia.

Overall, non-native species represented 71% of the total number of individuals and 83% of the total basal area (m^2/ha) (Appendix 2). Only two cemeteries had a greater proportion of native than non-native individuals and basal area. The copse cemeteries typically had a greater proportion of native trees and basal area than the non-copse cemeteries (Appendix 2).

2.3.4 Epicormic growth and interference with utility wires and monuments

Only 6.5% of trees interfered with monuments, while an additional 2.3% were not interfering but within 1 m. Monument interference was seen more frequently in non-copse cemeteries. Four cemeteries had one tree or no trees interfering with, or even within 1 m, of a monument. Only 3.1% of trees were interfering with overhead utility

wires, the highest proportion being 11.6% in St. John's. Overall, 7.2% of trees showed abundant, ground-level epicormic growth, mainly in two non-copse cemeteries.

2.3.5 Plantable spots inventory

A total of 2124 plantable spots were identified, but the numbers varied across cemeteries (Figure 8) as did the density (plantable spots/ha; Appendix 2). There were similar numbers of total plantable spots found Along Pathways (817 spots) and Amongst Monuments (827), but only approximately half as many in Open Space (Figure 8). The number of plantable spots was positively correlated with area (ρ=0.939; $p<0.001$) but not cemetery age.

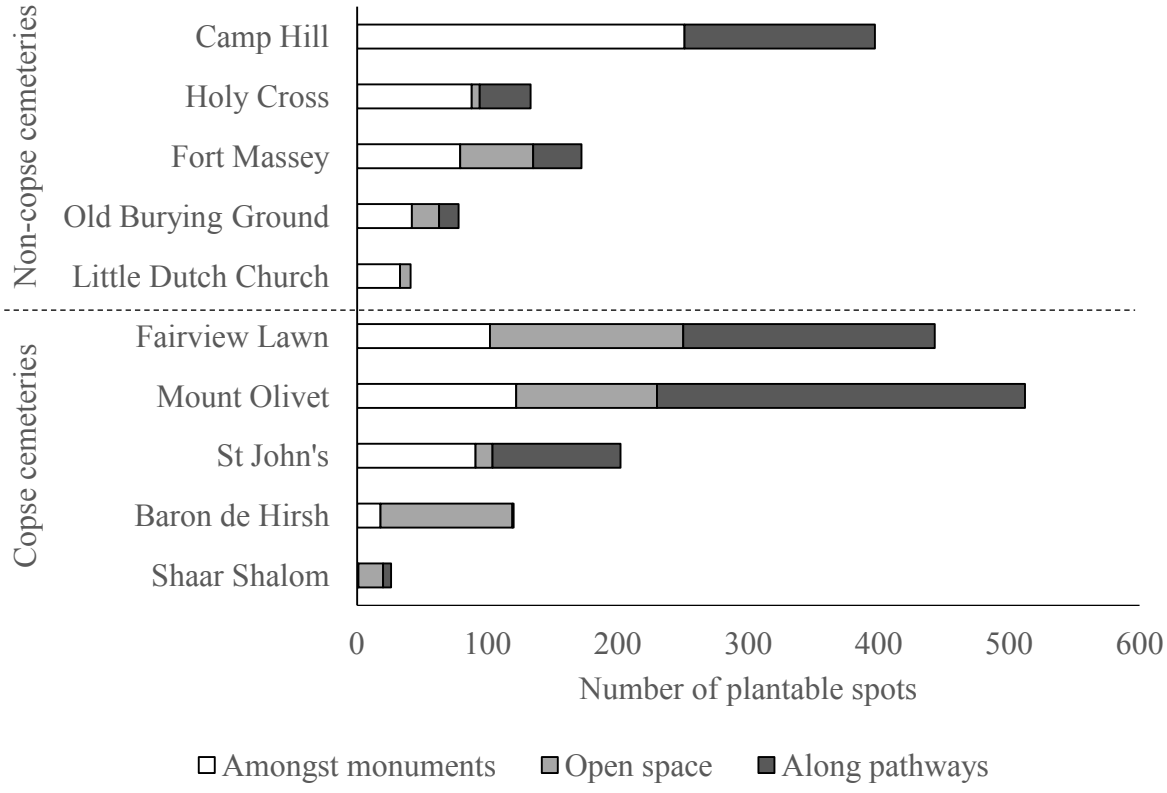

Figure 8: The total number and number of each of the three types (Amongst Monuments, Open Space, and Along Pathways) of plantable spots across all ten cemeteries in Halifax, Nova Scotia.

2.4 Discussion

2.4.1 The current urban forest of Halifax cemeteries

The composition of trees within the ten cemeteries differed widely in terms of species richness and composition, and the presence/extent of non-native species and copses.

2.4.1.1 Dominant species

Species richness varied across cemeteries (Figure 2), but three species, *A. platanoides, T. cordata,* and *U. glabra,* dominated the stem count and basal area of many cemeteries (Figure 3). All three of these species originate from Europe and are considered non-native in Halifax. The dominance of *A. platanoides* is unsurprising, as it has been commonly planted in urban settings in North America since the 1800s (Nowak & Rowntree, 1990) and is still found in high numbers in Halifax (HRM Urban Forest Planning Team, 2013; Nitoslawski & Duinker, 2016; Turner, Lefler, & Freedman, 2005). It was found in abundance in the five copse cemeteries, mainly as regenerating stock with a DBH <10 cm. The prominence of *A. platanoides* in the copses is likely due to its invasive nature and ability to outcompete native vegetation (Martin, 1999).

T. cordata and *U. glabra* generally were not found in copses and only 6.7% had a DBH <10 cm. Instead, these two species tended to exist as larger trees along pathways or amongst monuments, particularly in the older non-copse cemeteries. This likely reflects historical planting preferences, as *Tilia* and *Ulmus* species are found in large numbers on the Halifax peninsula, although *U. americana* is more common than *U. glabra* (HRM Urban Forest Planning Team, 2013). Some cemeteries did have dominant species besides the three discussed previously, such as *A. pseudoplatanus* and *A. rubrum*, but overall it

seems the cemeteries contribute little to the overall species diversity of Halifax. One notable exception is Mount Olivet, which resides in a neighborhood where *A. platanoides* makes up 60% of the canopy, whereas the cemetery is dominated by native *A. rubrum* and *B. alleghaniensis*.

2.4.1.2 Native vs. non-native species

Overall, 71% of stems and 83% of basal area were non-native. These results are not surprising, despite findings indicating that urban environments are not always dominated by non-native species (see for example: Pregitzer et al., 2019; Sjöman et al., 2011). Many tree inventory datasets from Halifax indicate a dominance of non-native species (HRM Urban Forest Planning Team, 2013; Lapaix & Freedman, 2010; Nitoslawski & Duinker, 2016). Cemeteries may be more likely to have non-native species given the historical and contemporary desire for ornamentals in such a setting (Radecki, 1999; Sloane, 1991), and the various cultural meanings, values, and/or symbolism attached to some species, such as *Taxus*, *Salix* and *Crataegus* spp. (Gough, 1996; Jones, 2007).

The merit of native vs. non-native trees in urban areas has been discussed in detail (Kendle & Rose, 2000; Sjöman, Morgenroth, Deak Sjöman, Saebø, & Kowarik, 2016), and thus I will avoid restating the same arguments at great length. I believe the importance of the native vs. non-native debate in relation to cemetery trees is that 1) the tree species richness and diversity in cemeteries (including the non-native species) can contribute to the health and provision of ecosystem services (Alvey, 2006; Quijas, Schmid, & Balvanera, 2010) by the overall urban forest of Halifax; and 2) the presence of non-native species may simultaneously contribute to and threaten (particularly invasive

species, such as *A. platanoides*) the health of the urban forest and provision of ecosystem services (Dickie et al., 2014).

2.4.1.3 Copse vs. non-copse areas

Copses were found only in the five cemeteries located furthest from downtown Halifax. Their presence may be explained, at least in part, by the terrain. The copses in four of the cemeteries had steep elevation, and the other had copses bordering a brook, where the use of grass-mowing equipment would be difficult. These areas were also infrequently used for interments, which likely made their maintenance a lower priority. Copses also often existed along exterior and interior borders within the cemeteries, typically in the absence of fences. The lack of copses in downtown cemeteries may be due to any combination of the following factors: 1) lack of space due to these cemeteries being near (or at) capacity for interments; 2) perceived safety concerns due to unmaintained vegetation (Kuo, Bacaicoa, & Sullivan, 1998); or 3) that such "wild" vegetation would look out of place amongst the dense surrounding built infrastructure.

The proportion of stems found within copses was greater than the proportion of basal area in every copse cemetery (Figure 6), although the difference between the proportions varied. This was because copses were dominated by dense populations of small (DBH < 10cm) trees (Figure 7), which also contributed to greater overall tree density in these cemeteries (Figure 4). The non-copse trees in these cemeteries were larger and thus had greater basal area (Figure 7). The non-copse cemeteries had lower tree densities and larger basal area due to their lack of regenerating stock.

In three of the five copse cemeteries, the copses had lower species richness and fewer unique species than the non-copse areas and contained only between one and four

unique species. However, the other two cemeteries had greater species richness in their copses and contributed seven and eight unique species. In addition to contributing to the composition and extent of the urban forest of each cemetery, these copses, with their increased tree density and habitat complexity, may also play a role in habitat provision for insects, birds, and small mammals (Dickman, 1987; Evans, Newson, & Gaston, 2009). Thus, it is highly recommended that cemetery managers retain these copses and potentially expand them through natural regeneration and seed dispersal where the absence of interments allows.

2.4.1.4 Canopy cover

Canopy cover ranged widely between cemeteries, but all of the cemeteries had a 2- to 51-percentage-point greater canopy cover than their surrounding neighbourhood (HRM Urban Forest Planning Team, 2013). Two cemeteries that particularly exemplify the contribution of cemeteries to Halifax's tree canopy are Camp Hill and the Old Burying Ground, with 48.6% and 62.8% canopy cover, respectively. They both exist in the Downtown Halifax neighbourhood, where tree cover is particularly low, at 11% (HRM Urban Forest Planning Team 2013). These two cemeteries had the largest basal area (m^2/ha), and it is likely that the large size of their trees is the main reason for their higher canopy cover.

The canopy cover of the cemeteries seems to be the greatest way in which cemeteries contribute to Halifax's urban forest. The canopy cover, combined with the locations of these cemeteries amongst dense city infrastructure, and the reluctance of the public and city planners to remove cemeteries in favour of development (Harvey, 2006), makes these cemeteries tremendously valuable for their potential role in providing

ongoing tree-related benefits such as opportunities for recreation and restoration, stormwater management, shade and cooling, and so on.

2.4.2 Tree-planting opportunities in Halifax cemeteries

2.4.2.1 Plantable spots

The inventory of plantable spots in the cemeteries indicated over 2100 spaces where trees can be planted, suggesting that the number of trees in Halifax cemeteries could be almost doubled (Figure 8). The number and type of spaces (Amongst Monuments, Open Space, and Along Pathways) varied across the cemeteries depending on factors such as the spacing between monuments and the location and extent of existing trees. Open-Space spots were the least abundant, likely due to the pressure on urban cemeteries to accommodate as many interments as possible to both generate revenue and address burial-space shortage (Capels & Senville, 2006). Due to these reasons, many of the Open Space spots are unlikely to remain in the future as these areas are increasingly used for interments.

Amongst Monuments and Along Pathways each constituted twice as many plantable spots as those in Open Space. The number of Amongst Monuments spots was low in cemeteries where monuments were placed close together and in neat rows, whereas the number was higher in cemeteries where monuments were more randomly placed, leaving wider gaps in which trees could be planted. The low number of Along Pathways spots in some cemeteries was mainly due to their lack of extensive pathways.

4.2.2 Environment

This study found a lack of interference between trees and overhead utility wires, with four cemeteries having no interference at all and the average across cemeteries being 3.1%, whereas previous studies of urban trees in Indiana and Maryland, US, have found average interference proportions of 9.8% (Fischer, Mincey, Steinhoff, & Dye, 2007) and 11.7% (Cumming, Galvin, Rabaglia, Cumming, & Twardus, 2001), respectively. Some utility wire interference was caused by cemetery trees touching wires located outside of the cemeteries, but the high interference seen in St. John's (11.6%) was due to a utility wire running through a dense copse.

Despite the lack of utility interference, there may be concerns with the successful growth of trees in cemeteries due to the potential for groundwater and soil pollution from caskets, medical appliances, and so on (Oliveira et al., 2013). However, this is an issue that only affects certain cemeteries, based on many other environmental factors such as geology, soil type, water table, type of human remains interred, etc. (Oliveira et al., 2013). Given the dense canopy cover and high abundance of trees in the cemeteries currently, this seems unlikely to be a problem in Halifax.

2.4.2.3 Concerns and barriers to planting trees in cemeteries

When it comes to planting trees in cemeteries, certain barriers and concerns arise. One of the most prominent is the cost associated with planting and maintaining trees (Vogt, Hauer, & Fischer, 2015). Interment traditions in North America are not financially sustainable in the long term, given the limited space within cemeteries (especially urban ones) and the lack of re-use of burial spaces that is seen in some other countries (Rugg & Holland, 2017; Woodthorpe, 2011). The limited fiscal capacity of most cemeteries means

there is little money to spend on trees and their maintenance. A second concern is potential damage from trees within this setting, particularly damage to monuments and other infrastructure through uprooting and falling trees/limbs. However, I observed way more monuments in poor condition (i.e., leaning, broken, or toppled) independent of trees rather than because of them.

A third concern is where to plant trees in cemeteries. Most open space is dedicated to interring remains. The resistance to planting trees amongst monuments can be inferred from the rules and regulations of cemeteries in Halifax (e.g. Council of the Halifax Regional Municipality 2013) which forbid planting anything on a purchased plot without management's consent. A final barrier is the lack of long-term planning in cemetery management (Capels & Senville, 2006). Although cemeteries in Halifax currently have a thriving urban forest and high canopy cover, this is unlikely to be the case in the future given the relative age of these trees. However, planting trees now to enjoy a mature forest within several decades is not on the timespan that cemetery managers are accustomed to working within. I address these concerns further below.

2.4.3 The future urban forest of Halifax cemeteries

2.4.3.1 Potential canopy loss

The landscape of cemeteries has evolved over the past several centuries. We currently reside in the era of lawn cemeteries and memorial parks, which are characterized by flat monuments and/or sparse memorial walls with limited and intentionally placed shrubs and trees (Quinton & Duinker, 2019; Rugg 2006). Lawn cemeteries and memorial parks are relatively easy to maintain, thus making them an economically attractive option (Rugg, 2006). However, the de-emphasis on trees

indicates a potential threat to cemetery urban forests. In Halifax, only half of the cemeteries have planted trees in the past ten years. Of these, only two have planted trees besides small, shrubby species like *Magnolia*.

Many of the smaller trees in Halifax cemeteries were contained within copses (Figure 7) while the majority of non-copse trees and trees in non-copse cemeteries were ≥ 20 cm in diameter. Much of the smaller stock in the non-copse areas and the non-copse cemeteries are smaller species such as *Hydrangea*, *Crataegus*, and *Magnolia* spp., although there are some cases of regenerating stock, mainly around fences and between monuments where new growth has escaped lawn-mowing equipment. Although diameter is not necessarily correlated with age, the diameter distributions seen in Figure 7 clearly depict a lack of smaller (and likely younger) trees in the non-copse areas and cemeteries. Little work has been done on what constitutes an ideal age structure for urban forests, but Millward & Sabir (2010) suggest 40% of DBH class 0-15 cm, 30% 15-60 cm, 25% 60-90 cm, and 5% 90+cm. Although the data from this study are not split into these particular DBH classes, it is clear from Figure 7 that Halifax cemetery tree populations are not close to this ideal distribution: the copses have far too many individuals in the smallest size class while the non-copse cemeteries have too many individuals in the 60-90-cm range. This suggests a high potential for large canopy losses in the future, particularly in the non-copse cemeteries, given the lack of smaller, younger trees.

In the future, if left undisturbed, the copses are likely to decrease in tree density and species richness due to succession and competitive exclusion, which will have variable outcomes based on site-specific factors and broader phenomena such as climate change (Sheil, 2016). Despite the high number of small trees contained within copses

(Figure 7), which suggest that they could offset future canopy loss, these copses are small in area and unlikely to contribute to future canopy beyond their current extents as any tree growth outside the copses is likely to be removed by lawn mowing.

2.4.3.2 Considerations for avoiding canopy loss

Planting native species whenever possible has been emphasized, although species availability and site characteristics sometimes makes this a challenge (Alvey, 2006; Conway & Vecht, 2015). The Halifax Urban Forest Master Plan (UFMP) emphasizes planting and retaining native tree species in the city for multiple reasons, including conservation of species-at-risk, better habitat provision for native fauna, opportunities for learning about native Nova Scotian species, and decreased risk of invasive species (HRM Urban Forest Planning Team, 2013). Species diversity is acknowledged to be important to the health of urban forests in the face of increased threats from invasive forest pests (Alvey, 2006) and climate change (C Ordóñez & Duinker, 2014) indicating that cemeteries should makes efforts to diversify their species composition.

Some tree species can pose problems for cemetery management and for urban biodiversity in general. The prominence of *A. platanoides* is undesirable given its invasive nature and ability to outcompete native vegetation (Wyckoff & Webb, 1996). This can reduce species diversity within the urban forest and is particularly problematic in Halifax given the prominence of *A. platanoides* in the city beyond the cemeteries (Nitoslawski & Duinker, 2016; Turner et al., 2005). Ideally, cemetery managers should consider their trees in the larger context of their city's urban forest.

The presence of *T. cordata* presents a different issue: this study found that 72.7% of this species showed signs of epicormic shoot growth at the base of the trunk. The

epicormic growth becomes a financial burden as the shoots can grow quite tall and obscure monuments and potentially present safety concerns, thus requiring them to be trimmed back. Ideal species for cemeteries would be low-maintenance and not require additional costs such as those associated with trimming epicormic growth.

Another consideration of species selection in some circumstances may be which species to plant to maintain the cemetery's history and culture. Which species are considered historical depends on the chosen reference period, but a historical cemetery species is likely to be associated with species planted in a cemetery and not the species that existed prior to cemetery establishment. For example, the Old Burying Ground is a registered National Historic Site, and listed as one of the cemetery's defining elements is "the surviving "Victorian" tree species" which includes non-native Linden (Parks Canada, n.d.). The issues with *Tilia* (Linden) species were discussed previously, leading to the following question: in this scenario, do cemetery managers plant trees to maintain historical precedent or to lessen associated costs or emphasize native species? Perhaps it would be suitable to plant a native species (e.g. *Tilia americana*) similar to the character-defining species.

Tree-planting efforts in cities tend to focus on street trees, and deciduous trees are typically preferred over coniferous (Pauleit et al., 2002; Saebø, Benedikz, & Randrup, 2003) significantly due to their shape, which allows their canopy to grow over streets and sidewalks. Cemeteries may present a good opportunity to increase the proportion of coniferous trees in Halifax, which is recommended in the city's UFMP (HRM Urban Forest Planning Team, 2013). Perhaps an ideal location for coniferous trees in cemeteries

are the borders between adjacent cemeteries and between cemeteries and the surrounding streets, to offer a greater degree of privacy.

There can be significant costs associated with planting and maintaining urban trees, which can vary based on species, location, and size owing to equipment and personnel required, purchase of stock, watering, pruning, and other maintenance costs (Vogt et al., 2015). Financial costs are of particular concern to cemeteries since their revenue comes from the sale of burial plots, and the number of plots that can be sold is limited (Quinton & Duinker, 2019). After all the plots have been sold, cemeteries often have to rely on donations and government funding (Harvey, 2006).

The costs associated with tree planting and maintenance can be reduced through careful consideration of species, size, method, and location. Planting smaller stock (e.g. seedlings, saplings, etc.) can reduce costs as heavy machinery is not required and in the case of copse cemeteries, stock could be pulled from copses and re-planted elsewhere in the cemetery. Volunteers can be used for planting smaller stock (vs. employees trained to use equipment necessary for caliper trees). However, another consideration for planting smaller stock in cemeteries is the potential issue with grass-mowing equipment (although this can be avoided with the use of flagging tape and stakes, as well as communication with maintenance workers). If cities are interested in using cemeteries to expand their urban forest, municipalities may even help offset costs. Memorial-tree programs in which bereaved families purchase a tree to be planted in honour of their loved one could also be a cost-effective means of expanding the canopy cover of those cemeteries still open to interment. Non-profit environmental organizations and tree-planting grants are other potential avenues that could be pursued by cemeteries to fund tree plants.

Future maintenance costs in Halifax cemeteries can be reduced through planting low-maintenance and long-lived native species (such as *Quercus rubra, A. saccharum,* and *B. alleghaniensis*) and avoiding problematic ones like *Tilia* and *A. platanoides*. Interference with utility wires can be avoided by planting species that are not tall at maturity (such as various *Amelanchier*, *Prunus, Syringa, Ostrya, and Celtis* spp.) beneath them. A better age diversity of cemetery trees would also allow maintenance costs to be spread out over years or even decades (Millward & Sabir, 2010).

Perhaps one of the most-common responses to the query of whether cemeteries are good locations for trees is something along the lines of "what about damage to monuments?" Only 6.5% of trees measured were interfering with a monument, and much of the interference was limited to two older cemeteries. While a more satisfying answer may be derived from determining how many *monuments* are being interfered with by trees, I am comfortable stating that monument interference can be avoided in future plantings given the careful selection of species and planting location. Most interference witnessed in this study was from planting trees between two monuments or directly adjacent to monuments. This can easily be avoided and a high number of plantable spots still maintained. There is still the risk of damage from falling trees/branches but that is a risk even for trees planted outside of cemeteries.

While cemetery managers may be wary to plant trees amongst monuments, given the large amount of space containing monuments and lack of open space and extensive pathways in some cemeteries, avoiding planting trees amongst monuments would be a major loss of plantable space. Planting smaller-at-maturity trees amongst monuments

may reduce the risk for damage from roots and falling limbs/trees while still contributing to the cemetery's canopy cover.

2.5 Conclusion

Halifax cemeteries represent an overlooked contribution to the city's urban forest due to their high canopy cover, central location, relative permanence, and ability to provide numerous benefits to the public. However, this contribution is threatened by future canopy losses in the absence of intervention. Although this study sought to determine the use of cemeteries to expand Halifax's urban forest, it also became an exercise in determining how to *maintain* current canopy cover. The large size and old age of cemetery trees, along with the lack of newly planted or naturally regenerating growth beyond copses, calls into question future cemetery canopy cover in Halifax. However, I identified numerous places in which trees can be planted—almost as many spaces as there are existing trees. Thus, it is possible for trees to be planted now to maintain or even expand canopy cover.

There are, however, barriers to planting trees in cemeteries, the biggest of which is financial. Government funding, volunteers, memorial-tree programs, and additional tree-planting grants are potential solutions. Careful species and site selection when planting trees within cemeteries is also critical for reducing planting and maintenance costs as well as the risk of damage.

A potential issue not addressed in this research is the perspective of the cemetery user. While research has been conducted on recreational uses of cemeteries, little is known about how users view cemetery vegetation. Cemetery users may feel that more trees would make the cemetery too parklike and detract from its primary role.

Alternatively, users may desire more trees and believe that they contribute to its overall atmosphere. Additional research on how cemetery managers currently maintain their trees and how they envision their cemetery's future urban forest would highlight potential barriers and opportunities for using cemeteries to maintain and/or expand a city's urban forest.

Given the multitude of benefits provided by trees in cities, growing urban populations, and declining canopy covers, consideration should be given to ways in which we can maintain and expand our urban forests. This means considering existing trees and potential planting sites on all types of property—not only street medians and rights-of-way. Cemeteries, with their existing tree canopies and potential planting sites, may represent an overlooked current and potential future contribution to the urban forest in cities around the world, as is the case in Halifax, Nova Scotia.

CHAPTER 3: SOCIOCULTURAL AND MANAGEMENT PERCEPTIONS OF CEMETERY TREES

Abstract

The global population is becoming more urban, which has increased demand for built infrastructure. This has had negative impacts on the extent and quality of urban greenspace, including tree canopy cover. Tree-planting efforts have mainly focused on street rights-of-way but consideration should also be given to alternative locations such as cemeteries, which are free of many of the challenges facing street trees. However, the primary function of cemeteries for the interment of human remains indicates that the human dimensions need to be considered before planting trees in these environments. I employed interception surveys and manager interviews to determine how cemetery trees are valued and what concerns people have about increasing tree cover in cemeteries in Halifax, Nova Scotia (Canada).

My results indicate that cemetery users highly value cemetery trees, particularly for shade provision, aesthetics, improved personal wellbeing, and their contribution to a sense of place. These values differ somewhat from previous values obtained using street surveys, suggesting that urban-forest values depend on the environment in which surveys take place. While cemetery managers valued trees for the creation of a park-like atmosphere, they focus their efforts primarily on interring remains, preserving history, and maintaining a neat lawn. Tree maintenance is mainly reactive, and concerns such as a lack of space and the potential for damage to monuments have limited tree-planting efforts. Unlike management personnel, cemetery users have few concerns about trees in cemeteries, and I believe they would not object to more trees being planted. Given the old age of most of the trees in Halifax cemeteries, it is likely that cemetery tree cover will

decline in the future due to a lack of planting and natural regeneration. Based on the high value placed on trees by cemetery users, this may have negative implications for the future role of cemeteries as urban greenspace.

3.1 Introduction

The world has become increasingly urban, with over half of the global population residing in cities (United Nations, 2018). Urban areas have been increasing in extent, through sprawl, and population density, through densification, to accommodate the urbanization trend. As a result, increased pressure has been placed on natural environments located both adjacent to and within cities, often resulting in loss of extent and function (Dallimer et al., 2011; Haaland and Konijnendijk van den Bosch, 2015; Resnik, 2010).

Greenspace can be conceptualized in multiple ways, and I define it as any urban vegetation, including that contained within parks (both public and private), front and backyards, gardens, farms, orchards, streets, cemeteries, and other ecosystem types (Taylor & Hochuli, 2017). The values of urban greenspace are tremendous and include multiple social, economic, and environmental benefits such as stormwater management, air filtration, mitigation of the urban heat-island effect, increased tourism and property values, improved human physical health and mental wellbeing, provision of wildlife habitat, and many more (Bolund & Hunhammar, 1999; Konijnendijk et al., 2013; Wolf, Measells, Grado, & Robbins, 2015). In particular, the urban forest—constituting all of the trees within a city (Konijnendijk et al., 2006)—plays an important role in the delivery of these benefits (Duinker et al., 2015; Nesbitt, Hotte, Barron, Cowan, & Sheppard, 2017). Despite this, research has found that urban tree cover is declining across the United States (Nowak & Greenfield, 2018)—a finding that may well be true for countries across the globe. Additionally, the high proportion of trees and greenspace located on private

property suggests that their benefits cannot be accessed equally by everyone (Lin et al., 2015; Loram, Jamie, Ae, Ae, & Gaston, 2007).

One of the main ways in which cities try to maximize urban-forest benefits is by planting trees, primarily along streets but also in parks, yards, and other locations. Although street trees are located where they can provide a wide array of benefits, they face multiple challenges to their growth and survival due to the extent of permeable surface surrounding them (Mullaney et al., 2015), limited space and high traffic volumes (Lu et al., 2010), as well as interference with overhead utility wires (Appleton, 2006). Thus, alternative planting locations are warranted.

One such alternative planting location is the urban cemetery. As an environment with relatively little built infrastructure, impervious surfaces and vehicular traffic, cemeteries may represent a location in which trees can be planted to help maintain and potentially expand urban canopy cover. Despite their primary function for the solemn interment of human remains, the role of cemeteries as greenspace has been increasingly discussed, with research on their value for biodiversity (de Lacy & Shackleton, 2017; Kowarik et al., 2016), recreational opportunities (Grabalov, 2018; Swensen et al., 2016), and mental reflection and restoration (Nordh et al., 2017; Skår et al., 2018). Although there may be a private element to cemeteries based upon burial-plot ownership (Swensen & Brendalsmo, 2018), they are typically viewed as public space and thus can provide increased access to greenspace within cities.

Research has indicated that trees are a valued component of the cemetery landscape (Al-Akl et al., 2018; Nordh et al., 2017), but to date, this value has been relatively unexplored and undocumented. The role of cemeteries as urban greenspace has

been relatively understudied in North America in general (Quinton & Duinker, 2019), which is surprising given the vast urban-forest literature from this continent (Krajter Ostoić & Konijnendijk van den Bosch, 2015). Management is the most-studied discourse in the field of urban forestry (Krajter Ostoić & Konijnendijk van den Bosch, 2015), likely due to its important role in maintaining healthy urban forests. Cemetery managers focus on the primary function of interring remains and as such, the priority of managing trees is unknown. Although cemeteries may make ideal tree-planting locations due to their biophysical characteristics, cemetery-user and manager perspectives are integral in determining whether cemeteries are suitable locations for maintaining or expanding a city's urban forest. As such, I employed a combination of user surveys and manager interviews to determine how and why cemetery trees are valued and whether cemeteries can be used to expand the urban forest in Halifax, Nova Scotia (Canada) through future tree-planting efforts. This aim was subdivided into four main objectives: **1)** Identify user perceptions of trees in cemeteries; **2)** Determine user receptivity to planting trees in cemeteries; **3)** Identify manager perspectives of cemetery trees and how they are maintained; and **4)** Determine barriers and opportunities for using cemeteries to expand the urban forest of Halifax.

3.2 Methods

3.2.1 Study sites

Halifax is the capital city of the province of Nova Scotia, which is located on the east coast of Canada. The population centre is 234.7 km^2, and average daily temperatures range from -4.1°C in January to 19.1°C in August (Government of Canada, 2010). The municipality has an urban population of approximately 316,000 and a density of 1349

inhabitants/km^2 (Statistics Canada, 2017). The Halifax peninsula is the most densely populated area of the city, and this is where the study cemeteries were located (Figure 9). There are ten cemeteries on the Halifax peninsula, and each was given consideration for both the interviews and the surveys. Based on the response from cemetery managers, only seven cemeteries were included in the interview data. Only four of the ten cemeteries were used for the interception surveys, as the other six had very low levels of human visitation. The cemeteries differed in their area, canopy cover, year established and interment status (Table 2). The four cemeteries used in the interception surveys are described in greater detail below and are pictured in Figure 10.

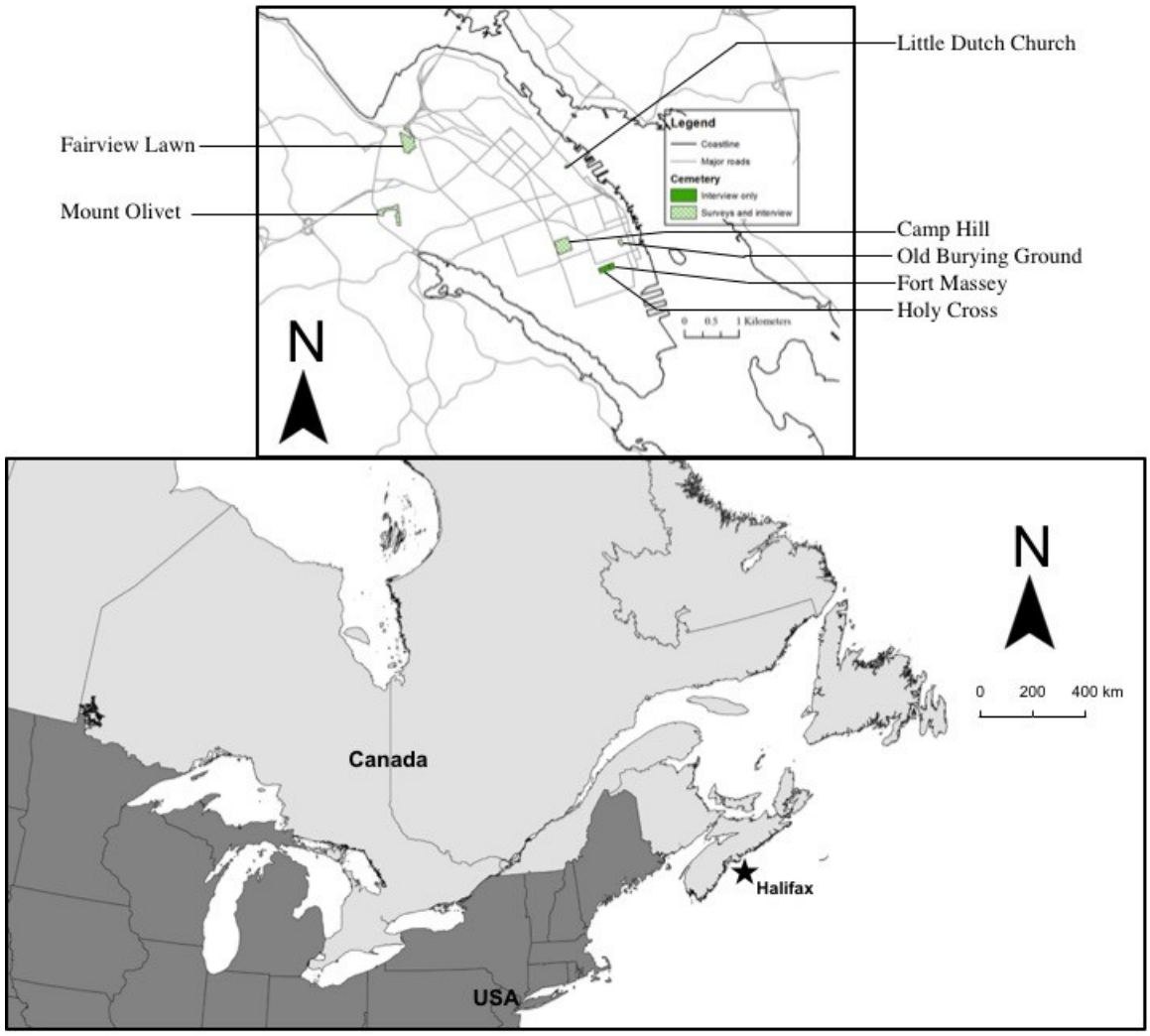

Figure 9: Seven cemeteries used as study sites in Halifax, Nova Scotia. Four cemeteries were the subject for interviews and interception surveys, while the other three were only subjects of interviews.

Table 2: The seven cemeteries in Halifax, Nova Scotia used for the study.

Cemetery/ Cemeteries	Ownership	Interment status	Year established	Canopy cover (%)	Area (ha)	Interview (N)	Survey (N)
Fairview Lawn	Halifax Regional Municipality	Open	1893	32.5	7.41	2	148
Camp Hill		Plot-holders only	1844	48.6	6.47		172
Mount Olivet	Roman Catholic Archdiocese of Halifax-Yarmouth	Cremation only	1896	29	4.78	1	85
Holy Cross			1843	18.6	2.19		N/A
Fort Massey	Veteran's Affairs Canada	Spouses only	1778	20.7	0.93	1	N/A
Old Burying Ground	Parish of St. Paul's Church	Closed	1749	62.8	0.72	1	167
Little Dutch Church	Parish of St George's Church	Closed	1752	21.2	0.24	1	N/A

3.2.1.1 Fairview Lawn

Fairview Lawn is a municipal cemetery located outside of downtown Halifax. Three other non-municipal cemeteries are located adjacent to it, two of which are accessible from within Fairview Lawn. In some areas, fences separate this cemetery from the other three and from the surrounding area. A network of paved and unpaved pathways allows for both vehicular and pedestrian traffic. There are two entrances to the cemetery, only one of which (located off a busy highway) can be accessed by vehicles. More than 120 victims of the *RMS Titanic* disaster are buried in this cemetery, and signage directs visitors to the memorial and graves dedicated to the ship's sinking.

3.2.1.2 Camp Hill

Camp Hill is a municipal cemetery located in downtown Halifax, surrounded by streets on three sides and apartment buildings on one. It is completely enclosed by an iron fence but has three entrances that always remain open. A vehicular unpaved path runs around the outer perimeter of the cemetery, and two additional paths cut through the centre, meeting in the middle. Notable interments include Alexander Keith, a famous brewer and previous Mayor of Halifax, as well as Viola Desmond, a Canadian civil rights activist.

3.2.1.3 Mount Olivet

Mount Olivet is a Roman-Catholic cemetery located outside of downtown Halifax, in a largely residential area. The cemetery is surrounded by fencing on all sides except for one. There is a main entrance that is always open, as well as additional entrances that lead to the adjacent residential area and to individual properties. A brook runs through part of the cemetery, but the cemetery lacks the many benches found in

other cemeteries. Mount Olivet also has interments from the *RMS Titanic* disaster, as well as from the deadly 1917 Halifax Explosion. Signage provides historical information about both events and the remains interred from them.

3.2.1.4 Old Burying Ground

The Old Burying Ground is a registered National Historic Site located in downtown Halifax and is the oldest cemetery where interception surveys were conducted. The cemetery is surrounded by a wrought-iron fence, which has one main front entrance, as well as a smaller entrance along the back. The cemetery is closed all winter, and the gates are locked every night during the other seasons. Interpretive signage highlights the history and notable interments of the cemetery.

Figure 10: a) Fairview Lawn Cemetery, b) Camp Hill Cemetery, c) Mount Olivet Cemetery, and d) the Old Burying Ground

3.2.2 Interception surveys

Approximately 35 hours were spent conducting surveys in each cemetery, between Tuesday and Friday, 8:00 a.m. to 6:00 p.m., during the months of June through September 2018. Overall, 572 interception surveys were conducted, but the number in each cemetery varied widely (Table 2) due to differing levels of human visitation. Individuals aged 18 years and older were approached while in one of the four cemeteries and asked to participate in a short survey about trees in cemeteries. Most surveys were conducted in the same, high-traffic spots within each cemetery, although a few were conducted while interviewers were wandering around the pathways. Care was taken to avoid individuals who were part of a funerary process due to the sensitive nature of such visits, but this rarely occurred. Respondents were asked the questions and their answers were written down, except in cases where language barriers made individuals more comfortable with reading and writing their own answers, which was rare. Surveys were conducted one-on-one, although some respondents had companions who also provided answers. Only answers from the initial respondent were recorded.

Standard demographic data regarding the respondent's place of residence, education level, occupation, and decade born constituted the first information collected. The date, time, and weather (hot/warm/cold; sunny/overcast) were also recorded. The survey itself consisted of six open-ended, one rating-scale, and two multiple-choice questions. Surveys lasted approximately five minutes, but this varied among respondents. Respondents were asked how often they visit any cemetery on the Halifax peninsula and the purpose of their current visit. The rating-scale question asked respondents to rate the importance of trees in the cemetery on a scale of 1 to 5, with 1 being not important and 5

being very important. If they gave a rating of ≥3, they were asked what was important about the trees, to ascertain what they value about cemetery trees. The word "important" was used to elicit values that reflected the respondent's personal thoughts and not their knowledge of benefits provided by trees. Up to two responses were recorded per respondent. Respondents were asked if they had any concerns about the impact trees have on the cemetery and conversely, any concerns about the impact that growing in a cemetery would have on the trees. Finally, respondents were asked if they believed the cemetery could use more trees, fewer trees, or if it already had a good amount.

Some survey questions required answers to be coded or grouped for further analysis. Visit frequency was grouped into six categories based on divisions that emerged from the data: first time (never visited before), very rarely (<1/year), rarely (1-5/year), sometimes (6-24/year), often (1-3/week), or very often (4+/week). The purpose of the respondent's visit was thematically coded based on content as per Braun and Clarke (2006), and the coding structure can be found in Table 3. Responses regarding the importance of cemetery trees were coded based on a previous study examining public values of the urban forest in three Canadian cities through street-interception surveys that also asked about the importance of trees (Ordóñez et al., 2016; Table 4). If the respondent did not respond to a question it was coded "No response". Given the similarities between the grouped first- and second-value responses, only the results of the first responses are discussed.

Counts were recorded for the nominal and ordinal data obtained from coded and non-coded responses. Chi-square (χ^2) tests were conducted to determine whether there were any significant deviations between observed and expected responses between

different cemeteries, demographics, and responses to other questions. Adjusted standardized residuals were used to determine which categories contributed to significant deviations. When >20% of expected counts were <5 and any expected count was <1, the Chi-square results were deemed invalid, and a Fisher's exact test was conducted instead (Campbell, 2007). The values ascribed to trees in this study were compared to the values obtained in Halifax in 2011 by Ordóñez et al. (2016) in their street interception surveys to determine differences between values ascribed to cemetery trees and those ascribed to the city's urban forest in general.

Table 3: Coding structure for the "purpose of visit" of survey respondents.

Code	Explanation	Example
Curiosity	Intrigued by an unspecified aspect of the cemetery.	"Wandered in", "Curiosity"
Exercise	Cemetery used for physical exercise.	"Dog walking", "Running"
History	Visiting for historical value (personal or otherwise).	"History", "Genealogy"
Likes cemeteries	Likes cemeteries and/or visiting them in general.	"I like old cemeteries"
Nature	Cemetery used as a "greenspace".	"Enjoying spring," "Sitting outside"
Other leisure	Recreational activity/pastime that does not fit into other categories.	"Lunch break", "Relaxing"
Remembrance	Visiting/tending to burial plots.	"Visiting mother-in-law"
Thoroughfare	Walking through cemetery on the way to another destination.	"Walking through", "Shortcut"
Tourism	Visiting notable sites/monuments as part of a trip/tour.	"Titanic graves", "Keith's monument"
Work	Job requires being present in the cemetery.	"Tour guide"

Table 4: Coding structure for the "importance of trees" based on Ordoñez et al. (2016).

Code	Explanation	Example
Aesthetics	Beauty/appearance of the trees	"Looks nice"
Air quality	Purify/clean the air	"Oxygen", "Clean air"
Biodiversity*	Support flora and fauna	"Bird habitat"
Environmental quality*	Provides some other benefit for the environment/humans	"Trees are good", "Stormwater management"
Miscellaneous	Responses that do not fit into any other category	"Science"
Naturalized	Make cemetery seem more natural or park-like	"Reduced noise", "Greenness"
Personal wellbeing	Improve human mental health, promote positive feelings	"Peace", "Comfort"
Sense of place	Contribute to/define the atmosphere/feel of the cemetery	"Age", "Ambience"
Shade/cooling	Reduce temperatures through shade and other means	"Shade provision"
Shelter*	Provide protection from a specific or unspecified element	"Protect graves", "Protection"
Spiritual	Connection between life and death	"Represent the continuity of life"

*Values with <10 responses were consolidated into the "Miscellaneous" category for subsequent analysis

.3.2.3 Cemetery manager interviews

Six interviews were conducted with six cemetery managers and one municipal employee in the urban forestry division. At the request of two interviewees who manage the same cemeteries, their interview was conducted together. A generic e-mail was sent to addresses provided online for each of the 10 peninsular cemeteries and was forwarded on to the person deemed most appropriate to participate. This yielded responses from seven cemeteries, including all of those used for the interception surveys. The cemetery managers were in charge of day-to-day running of their cemeteries and typically had a high degree of decision-making authority. The urban forester was included because of that person's role in managing all municipal trees, including those in municipal cemeteries.

Interviews consisted of ten open-ended questions, many of which had multiple sub-questions that were used as further prompts. Interviews lasted anywhere from 20 to 45 minutes, with an average length of 38 minutes. Interviews were conducted either at the office of the interviewee or while walking around a cemetery they manage. All interviews were audio-recorded and later transcribed. Interview questions covered topics surrounding the cemetery (or cemeteries) managed by the interviewee, such as decision-making, financial structuring, landscape maintenance, public use, values of the natural environment, changes to the landscape, and any concerns about increasing the number of trees within the cemetery.

The interview transcripts were thematically coded as per Braun and Clarke (2006). The text was iteratively analyzed for recurring themes across interviews

regarding management priorities, feelings towards cemetery trees, tree maintenance, and concerns and barriers to planting more trees.

3.3 Results

3.3.1 Cemetery use and demographics

The four cemeteries differed greatly in user demographics and the purpose and frequency of visits (Table 5; Figure 11). Overall, the most common reasons for visiting were tourism and using the cemetery as a shortcut/thoroughfare. Only 3% of respondents were visiting for commemorative/remembrance purposes. Approximately 32% of respondents reported visiting cemeteries often or very often, while 42% were visiting for the first time ever.

Table 5: Most common survey demographics, visit purpose and frequency of the four cemeteries in Halifax, Nova Scotia (Canada).

Cemetery	Purpose	Frequency	Decade born	Residence
Fairview Lawn	Tourism	First visit	1950s	Canada, International
Camp Hill	Thoroughfare	Very often, often	1920/30s, 1990s	Halifax
Mount Olivet	Thoroughfare, exercise	Very often, often		Halifax
Old Burying Ground	History, curiosity, tourism	First visit		Canada, International

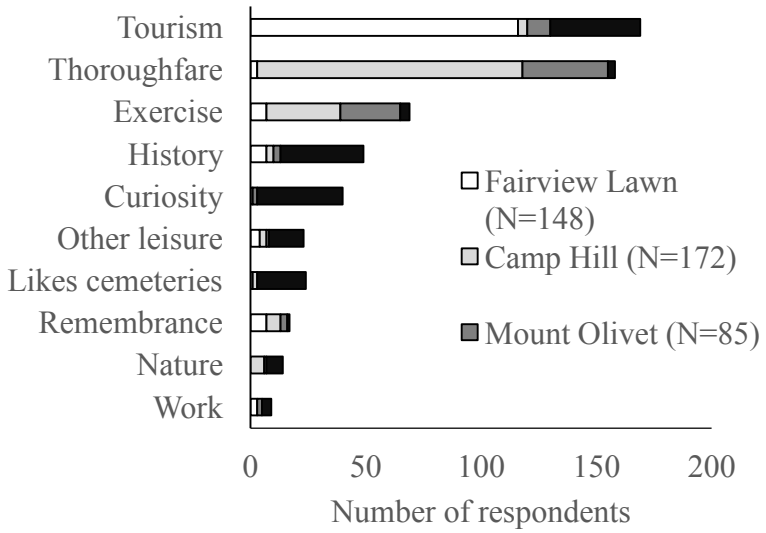

Figure 11: Visit purpose for the four cemeteries in Halifax, Nova Scotia. The definition of each purpose is outlined in Table 2.

3.3.2 Public values of cemetery trees

Across all cemeteries, 79.7% of respondents gave trees the highest possible rating of importance (5/5), and an additional 15.2% gave them the second-highest possible rating. Only 1.2% rated trees as not important (1 or 2). The most commonly coded values of cemetery trees were shade/cooling, aesthetics, increased personal-wellbeing, and sense of place (Figure 12). The values significantly differed from the expected counts based on temperature (hot/warm/cold; χ^2=24.4, p=0.001), residence (Fisher's exact test; p=0.007), purpose of cemetery visit (Fisher's exact test; p=0.04), and frequency of cemetery visits (Fisher's exact test; p=0.02) (Table 6). The values did not differ significantly based upon education level.

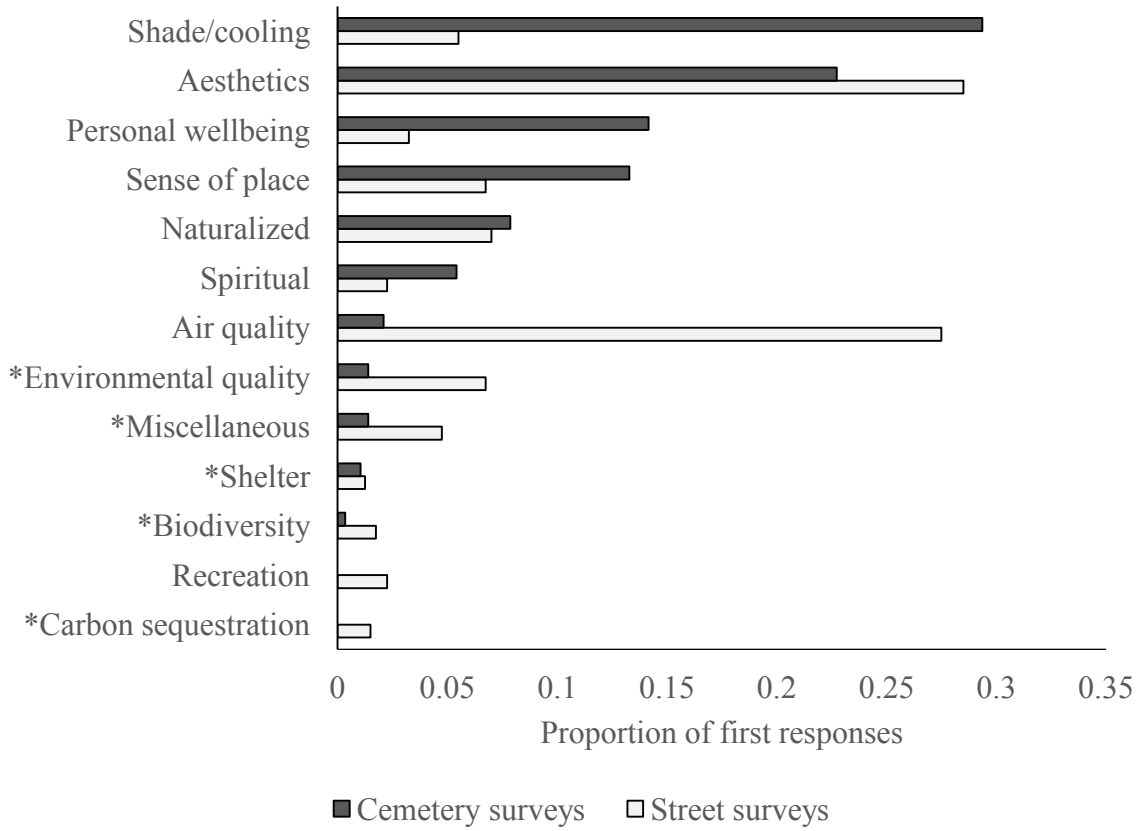

Figure 12: Coded values of the importance of trees in Halifax, Nova Scotia based on street and cemetery surveys. *Indicates values that were grouped together for statistical analysis based on total responses summing to <10.

Table 6: Statistical deviations from the expected counts for values ascribed to cemetery trees in Halifax, Nova Scotia.

Variable	Statistical significance	Deviations from expectations
Temperature	χ^2=24.4, p=0.001	Shade/cooling cited more in hot weather Sense of place cited more in cool weather
Respondent's residence	Fisher's exact test; p=0.007	Aesthetics cited more for Halifax Personal wellbeing cited more for Canada
Purpose of visit	Fisher's exact test; p=0.04	Tourists cited more personal wellbeing Remembrance users cited more spiritual
Frequency of visits	Fisher's exact test; p=0.02	Personal wellbeing cited more amongst first time visitors Aesthetics cited more amongst rare visitors

3.3.3 Comparison of cemetery- and street-survey values

Both the cemetery and street surveys indicated a high value placed on the aesthetics of trees (Figure 12). However, the cemetery surveys indicated more value on shade/cooling, personal wellbeing, and sense of place, whereas the street surveys found that air quality, sense of place, and other environmental qualities were stated most often. Recreation and carbon sequestration were coded in the street surveys but not the cemetery surveys.

3.3.4 User concerns and desire for cemetery trees

Most respondents (83.9%) were satisfied with the number of trees in the cemetery, while 15.5% desired more. A significantly higher than expected proportion of individuals wanted additional trees in Mount Olivet, while a significantly lower than expected proportion wanted additional trees in the Old Burying Ground (χ^2=18.5, p=0.001). These results contrast the street-tree surveys, where 60.5% of respondents wanted more trees in the city of Halifax.

Only 22.7% of survey respondents were concerned about damage trees may cause to the cemetery, and 83% of respondents with concerns prefaced them with “maybe” or “might”, suggesting a low level of concern. When split into causes and effects of damage, the most common cause for concern were tree roots (nearly half of the causes). The most common effect of concern was damage to monuments/graves (over half of the effects). Only 8.2% of respondents had concerns about detrimental effects the cemetery could cause to the trees, while 10.6% believed that tree-growing in a cemetery would be beneficial.

3.3.5 Manager interviews

In general, cemetery managers appreciated their existing trees for the pleasant park-like atmosphere they provided, and as one interviewee stated, "We're very fortunate that we have this many trees." However, the managers had concerns about planting new trees due to the lack of space and potential for damage (Table 7). For example, one interviewee said, "I don't see that we could put many more trees in here because I don't know where you'd put them." For cemeteries still open to interments, managers focus on selling burial plots and interring remains, whereas in those closed to interments, the focus is on preserving history. A common focus of all cemeteries is lawn maintenance, and as one interviewee pointed out, "… even though the grass is difficult to maintain around the grave markers, it's a traditional aspect of the graveyard."

Cemetery planning is typically done on a short-term basis, with the exception of specific projects. Due to the need for efficient and economical maintenance, and the focus on maintaining the lawn, tree management is mainly reactive and relies on cemetery managers to identify potential problems. However, one manager did note the potential for damage to monuments from falling trees and stated, "So that's why we have to be proactive, can't be reactive." There has been little tree planting in the cemeteries in the past ten years, and only a few cemetery managers have any intention (and none has a formal plan) of planting trees in the future.

Table 7: Summary of general themes encountered during the cemetery-manager interviews.

Topic	Common themes
Public use of cemeteries	Common activities: Genealogy, commemoration, dog-walking and exercise, tourism, reflection and enjoying the quiet/solitude
	Encouraged uses: History, learning, relaxing
	Discouraged uses: Sports, vandalism, drugs/drinking/partying
	Most wanted more visitors but were not actively encouraging it
Plans and policies	Mainly short term (≤3 years)
	Lack of policies/plans for tree maintenance/management
Management priorities	Active cemeteries: Sale of burial plots, interment of remains
	Inactive cemeteries: History conservation
	All cemeteries: Grounds maintenance, primarily keeping the grass cut
Tree management	Mostly reactive
	Focused on removal of dead/dying trees and branches, sucker removal
Tree planting/removal	Either no change to the number of trees or a decrease in the past ten years
	Very little recent planting of trees
	Few removed trees being replaced
	Little planning for future tree planting
Concerns/barriers to tree planting	Barriers: Lack of space, lack of finances
	Concerns: Damage to monuments and fences, safety

3.4 Discussion

3.4.1 Cemetery demographics and uses

There were many differences in demography and purpose of visits across the cemeteries. Camp Hill and Mount Olivet had more Halifax residents who visited often or very often, likely due to their proximity to the cemetery. Camp Hill is located in downtown Halifax and used as a thoroughfare, often as a daily means of commuting on foot. Mount Olivet is located next to a residential area and is used frequently for commuting and exercise. The use of cemeteries for commuting and exercise has been documented previously (Evensen et al., 2017; Grabalov, 2018), and research has found that people are willing to commute an extra distance to pass through a naturalized area such as a cemetery or treed street (Nordh et al., 2017; Sinclair, Diduck, & Duinker, 2014) which, anecdotally, was also heard from several participants in this study.

Fairview Lawn and the Old Burying Ground had more first-time visitors and visitors from outside of Nova Scotia due to tourism. Fairview Lawn has a large *Titanic* disaster memorial and is a common stop for large tour buses. The Old Burying Ground is the oldest settler cemetery in Halifax and is located downtown, which draws people in for tourism as well as simple curiosity as they walk past. Young and Light (2016) suggested that "dark tourism", such as visiting cemeteries, has increased in popularity over the past several decades.

The surveys and manager interviews identified some common public uses, but cemetery managers also indicated genealogy and commemoration as common uses, which were seen rarely in the survey data. Most cemetery managers indicated a desire for increased visitation and public use of their cemeteries, although none was actively

encouraging this. Nordh and Evensen (2018) found that Scandinavian cities are increasingly recognizing the recreational value of cemeteries, and the city of Copenhagen even has a long-term plan to promote recreational cemetery use. This plan may represent the emergence of a new attitude towards the multifunctional use of urban cemeteries. In general, activities like learning about the history/stories and enjoying the quiet and reflective atmosphere were encouraged by managers while sports, vandalism, and drinking/drugs/partying were discouraged. One of the cemetery managers indicated wanting to discourage tourism because it was interfering with the cemetery's ability to function as a place for interments and commemoration. Such potential for conflict between cemetery uses has been highlighted in previous studies (Grabalov, 2018; Swensen, 2018; Woodthorpe, 2011).

3.4.2 The importance of cemetery trees

The high rating of importance of cemetery trees is unsurprising, given the high importance people typically assign to the urban forest in general (see for example Mullaney et al., 2015; Ordóñez et al., 2016). Al-Akl et al. (2018) and Nordh et al. (2017) found that users of cemeteries valued trees as restorative components of the cemetery landscape.

The importance of cemetery trees aligns with values elicited in other studies on public perceptions of urban forests, with shade and aesthetics being the top two most-stated values (Mullaney et al., 2015; Camilo Ordóñez et al., 2016; Sinclair et al., 2014). This may be because they are values that immediately come to mind, particularly on hot sunny days during the leaf-on period when deciduous trees (which dominate the Halifax cemeteries) are greenest. The aesthetics of an environment are also related to personal

wellbeing (Kaplan & Kaplan, 1989; Ulrich et al., 1991) which may indirectly increase the value humans place on aesthetics. Similarly, shade is connected to many other social, economic, and environmental benefits (Duinker et al., 2015).

Personal wellbeing and sense of place were the third- and fourth-most frequently mentioned values of cemetery trees. The positive impact of trees and other vegetation on mental health and promoting positive feelings has been well-documented and researched (see for example Kaplan and Kaplan, 1989; van den Berg et al., 2010; Wolf et al., 2015), whereas the impact of trees on social health, including sense of place, has been less well-studied (Nesbitt et al., 2017).

Many of the responses coded as "personal wellbeing" were originally stated by respondents as trees providing a sense of peace or calm. The calming effects of trees have been identified as highly valued (Lohr, Pearson-Mims, Tarnai, & Dillman, 2004), and Jiang et al. (2016) found that calm feelings increase as tree density increases. The four cemeteries studied had relatively high canopy covers ranging from 29 to 63%, whereas the Halifax peninsula itself has a canopy cover of only 19% overall and 11% downtown, where two of the cemeteries were located (HRM Urban Forest Planning Team, 2013). This indicates a higher potential for feelings of calm and relaxation within cemeteries. Cemetery trees may provide a sense of calm and peace by blocking out the city and providing visual relief from infrastructure, which has been identified as an important mechanism in previous Canadian urban-forest studies (Peckham, Duinker, & Ordóñez, 2013; Sinclair et al., 2014) as well as previous cemetery studies (Al-Akl et al., 2018; Nordh et al., 2017).

Cemeteries have been described as calm and peaceful environments (Evensen et al., 2017; Nordh & Evensen, 2018; Nordh et al., 2017). This, in combination with the value placed on trees for their calming effects, may in part explain the high value placed on cemetery trees contributing to a sense of place. Nearly half of the responses coded as "sense of place" talked about the contribution of trees to the "atmosphere" or "ambience" of the cemetery, which could be interpreted as peaceful, calming, and/or restorative. Other responses coded as sense of place included the history and age of the trees, which likely reflects their perceived fit in these old, historic cemeteries. In essence, the trees contribute to the calm and historic identity of the cemeteries.

3.4.2.1 Differences between cemetery- and street-survey values

Similar proportions of respondents in the cemetery and street surveys indicated aesthetics as one of the most important values (Figure 12). Aesthetics is a value commonly stated by individuals in studies of urban vegetation (e.g. Chiesura, 2004; Mullaney et al., 2015; Peckham et al., 2013) possibly due to its association with many other benefits, such as improved social wellbeing, stress reduction, and increased property values (Nesbitt et al., 2017). Nasar (1998) indicated the importance of vegetation in the aesthetic value and likeability of urban environments, and the unsightliness of typical urban elements such as poles and wires. Thus, it is not surprising that in contrast to these undesirable elements, trees are valued aesthetically. Aesthetics may also be such a common value of trees simply because it is easy to respond with a comment such as "beauty" and "they look nice".

Although shade was the most-common value for the cemetery surveys, it was mentioned far less in the street surveys. This is likely due to the timing of the surveys, as

the cemetery surveys were conducted during the summer whereas the street surveys were done in the fall. Shade was reported significantly more often in hot weather during the cemetery surveys (Table 6), suggesting that higher temperatures give more immediacy to the value of shade. The same street surveys were conducted in two other Canadian cities during summer months and Ordóñez et al. (2016) noted the same trend of increased value placed on shade in higher temperatures.

Further comparison of the cemetery and street values indicates higher proportions of cemetery respondents citing sociocultural values such as sense of place, personal wellbeing, and spirituality. Conversely, a higher proportion of street respondents indicated environmental or ecological values such as air quality, biodiversity, carbon sequestration, and other environmental qualities. Air quality, in fact, was the greatest overall discrepancy between the cemetery and street values (Figure 12). The sociocultural vs. environmental/ecological divide may be explained by the different environments. Streets tend to be bustling areas with large traffic volumes (both vehicle and pedestrian) and set within dense infrastructure. Cemeteries, on the other hand, tend to be shielded from this environment. Many elements of cemeteries, such as the history, culture, and nature, as well as their function as a refuge from the rest of the city, make them a restorative landscape that promotes reflection and contemplation (Nordh et al., 2017). Thus, the cemetery environment may have more often elicited values such as personal wellbeing and sense of place, which align with its restorative nature. Conversely, the hustle and bustle of the street environment and the proximity of vehicular traffic may have encouraged respondents to think about air pollution and the role trees play in filtering it. The results of this study suggest that human values of urban vegetation may

differ depending on the type of greenspace they are in and the context within which the greenspace exists.

3.4.2.2 The importance of trees in cemeteries and beyond

Academic literature indicates some discrepancies between the benefits of the urban forest and the values held by cemetery users. Air filtration, improved physical health, recreation opportunities, carbon sequestration, and stormwater management are commonly cited benefits of urban trees (Bolund & Hunhammar, 1999; Duinker et al., 2015; McPherson, Simpson, Peper, Maco, & Xiao, 2005; Nowak & Dwyer, 2007) but were infrequently mentioned by cemetery users. The infrequent mention of carbon sequestration, air filtration, and stormwater management may have been due to the question eliciting responses regarding the *value* of trees and not asking about the *benefits* they provide. As pointed out by Ordóñez et al. (2016), asking about the importance of trees elicits answers that may reflect more of a psychological state than an element of environmental awareness. However, they found that air quality was often cited as a value of the urban forest despite asking "What do you consider important . . .?". In neither the work reported by Ordóñez et al. (2016) nor this work was any emphasis placed on the words "to you" – they were just there to encourage respondents to interpret the question as a matter of personal opinion rather than a knowledge-testing question that asks: "What is important about trees?" In my opinion, this distinction between question formats is less important in the formulation of respondents' answers than the immediate surroundings where the questions were asked.

The omission of physical health as a value was surprising, given that exercise was the third-most common visit purpose and physical health benefits attributed to greenspace

are often linked to increased physical activity (Konijnendijk et al., 2013; Nesbitt et al., 2017). However, it could be that other values frequently mentioned, such as aesthetics and shade, were motivating factors for exercising in cemeteries, and thus contributed to physical health despite not being explicitly stated. The same explanation may also be applicable to recreation.

3.4.3 Desire for additional trees

The majority of respondents indicated that Halifax cemeteries have a good number of trees, which is in contrast to the high proportion of street-survey respondents who indicated the city of Halifax could use more trees. This could be because cemeteries already have a higher canopy cover than the surrounding area of the peninsula (29-62.5% vs. 19% according to HRM Urban Forest Planning Team (2013)) and because other elements of cemeteries, such as open lawn areas and historical monuments, are also desirable and appreciated in cemeteries (Al-Akl et al., 2018; Nordh et al., 2017; Skår et al., 2018). Additionally, the expressed desire for more trees in the city overall could be attributed to the existence of specific places within Halifax that respondents believe could use more trees.

Within the cemetery data, a significantly higher than expected proportion of respondents in Mount Olivet desired additional trees. The desire for more trees in this cemetery can be explained by it having the lowest canopy cover of the four cemeteries used for the surveys. Interestingly, Fairview Lawn only has a 3.5-percentage-point greater canopy cover but was seen by a greater proportion of respondents as having an adequate number of trees. This could in part be due to the differences in use between the cemeteries, as users of Fairview Lawn tend to come to look at the *Titanic* memorial only

and not wander around the entire cemetery, whereas users of Mount Olivet tend to walk through a greater area of the cemetery (as a thoroughfare or for exercise) and thus see areas of the cemetery with particularly low canopy cover. Many respondents referred to needing more trees in these areas in particular.

Despite individuals stating that, for the most part, the cemeteries do not need additional trees, I suggest that trees could be planted in these cemeteries and users would not object or think there were too many trees. The canopy cover of these four cemeteries ranged from 29 to 62.8%, with hardly any respondents indicating they wanted fewer trees, suggesting a wide range of acceptable cemetery canopy covers. There were also very few concerns about the negative impacts of trees on cemeteries. This, combined with the high value humans tend to attribute to the urban forest (e.g. Mullaney et al., 2015; Ordóñez et al., 2016), suggests that people would accept increased cemetery canopy cover. However, Al-Akl et al. (2018) found that crowdedness was a disliked feature of cemeteries, although it was unclear what contributed to this "crowdedness". Planting too many trees in a cemetery could create an environment that is perceived as crowded, indicating that care should be taken not to plant too densely when installing trees in cemeteries.

3.4.4 Cemetery management and maintenance of trees

Interviews with cemetery managers indicated that tree management and maintenance is not a high priority. This is understandable, given the financial constraints on cemeteries and their primary role as places of interment. The active cemeteries require selling burial plots and conducting interments to earn revenue to remain in operation, while the inactive cemeteries have to maintain their historical elements to ensure

continued government funding. Thus, the focus on selling burial plots and conserving history is justified. However, the survey results indicate that the majority of cemetery users do not visit for commemorative purposes and consideration should be given to how cemeteries and their trees can be managed for purposes beyond interment and the conservation of history. This brings up two questions: 1) Who should be charged with this task and bear the financial cost? and 2) How can cemeteries be managed for recreational use in a way that does not threaten their primary functions?

Most cemetery managers also emphasized the importance of maintaining a neatly mown lawn, which is a typical element of military and modern cemeteries (Nordh & Evensen, 2018; Rugg, 2006). Open lawn is valued by cemetery users (Al-Akl et al., 2018) and Swensen et al. (2016) suggested it may instill feelings of calmness, making it a welcome attribute. An unkempt lawn may be taken as a sign of disrespect for the deceased and even be associated with safety concerns. A well-maintained lawn is not only valued in cemeteries but has become a widespread Western phenomenon found in backyards, parks, gardens, golf courses, and road verges (Ignatieva et al., 2015). Thus, the emphasis on maintaining the lawn in Halifax cemeteries may be indicative of a larger landscape preference amongst urbanites. Regardless of the reasoning for keeping a well-maintained cemetery lawn, it is important to note that this maintenance prevents the natural regeneration of trees.

The interviews indicated that, for the most part, cemetery tree management is reactive and conducted on an as-needed basis, relying on cemetery managers to identify problems (such as dead branches) and have them addressed. The most-common tree-management activities were trimming problematic branches, removing dead/dying trees,

and removing suckers/epicormic growth from the base of trees. Only one manager indicated that their cemetery trees had been professionally assessed and had a specific tree management plan. The other cemetery managers indicated that they had no formal plan for tree management but many thought it would be useful.

3.4.5 The future urban forest of Halifax cemeteries

Most cemetery managers indicated positive feelings towards the trees in their respective cemeteries due to their contribution to the park-like atmosphere. It is clear from the survey data that cemetery users also highly value cemetery trees and are unlikely to object to trees being planted in cemeteries in the future. However, only one cemetery manager indicated that trees had recently been planted to replace those that had been removed. Two other managers indicated that a few trees had been planted in their cemeteries, but these were not in replacement of removed trees and were the result of tree donations from bereaved families and the municipality. The interviews indicated that cemetery managers have limited plans to plant trees in the future, due to concerns regarding the lack of space and the potential for damage. Some cemetery managers seemed aware that the older tree populations of their cemeteries would eventually fail and canopy cover would decline. However, hesitation was evident when it came to replanting trees that currently or recently exist(ed) amongst monuments due to the potential for damage, despite the majority of these trees not causing any damage currently (Quinton et al. 2019, unpublished data). The removal of these trees will constitute a remarkable loss of canopy in Halifax cemeteries. While it could be argued that, given the high value users place on cemetery trees, planting trees and maintaining canopy cover could attract more clients and result in the purchase of more burial space, the limited supply of burial space

around the world (McManus, 2015) and the tendency for individuals to be interred near where they live, indicates that it will always be in high demand whether or not there are trees in the cemetery.

In contrast to managers, cemetery users had very few concerns about cemetery trees, with <25% of respondents indicating any concerns. Those who did have concerns mainly referred to damage caused by roots and the potential for damage to monuments/graves. Many concerns were prefaced with a "maybe", thus suggesting a low level of confidence about whether this was a valid concern; respondents may have been simply trying to find an answer for the question. The difference in concerns about trees between cemetery managers and users is likely due to managers having to directly deal with and handle concerns such as monument damage. Cemetery users are likely to be particularly unconcerned about the potential for damage if they do not have a loved one interred in the cemetery.

Interestingly, increased costs associated with maintenance was not mentioned as a barrier to tree planting during the manager interviews, despite this being one of the reasons for the shift to the "lawn cemetery" that deemphasizes trees (Rugg, 2006). Although not stated as a barrier by interviewees, it was evident that planning for most Halifax cemeteries does not extend beyond three years into the future. As such, planting trees now to address future canopy loss in cemeteries is not within the planning horizon of Halifax cemetery managers. Similarly, limited finances were not stated as a barrier to planting trees within cemeteries although it can be inferred from discussions about financial constraints in general, coupled with the low priority of tree management, that there are limited funds for planting new cemetery trees.

3.5 Conclusion

This study indicates the high value users place on cemetery trees, particularly for their contributions to shade, aesthetics, personal wellbeing, and sense of place. While there is some overlap with urban-forest values obtained through street surveys, there is indication that the values ascribed to trees may differ based on their context and environment. The values placed on cemetery trees align with the concept of cemeteries being contemplative and restorative ecosystems within the city. Future research could be conducted to examine whether the values associated with cemetery trees (and other vegetation) differ if it is not well-maintained or is overgrown. The maintenance of cemetery vegetation may be integral to its value.

Cemetery trees are not only valued by cemetery users but also by cemetery managers for the atmosphere they create. However, tree maintenance is a relatively low priority largely because of the need to sell burial plots, perform interments, and/or conserve history to ensure continued funding and operation. None of the cemeteries included in this study were owned privately, and further research could be conducted to ascertain whether the same financial limitations are seen in private cemeteries and how this affects tree management. Similarly, cultural differences may also influence cemetery-tree management and should be investigated to determine how cemetery trees are managed outside of Canada and whether there are more-effective strategies.

The high value placed on cemetery trees and the lack of concerns cited by cemetery users suggests there would be little public objection to increasing tree cover in cemeteries. However, the lack of tree planting now and planned for the future, combined with the intensive lawn-cutting regime (and associated interruption of natural tree

regeneration), highlights the potential for extensive canopy loss in Halifax's cemeteries. Given the high value users place on trees in this environment, it is likely that their loss would affect the role of cemeteries as urban greenspace and may result in reduced non-commemorative use of these spaces. While this may not seem like an issue given that the primary function of cemeteries is not to provide recreational opportunities, in cities where rapid densification and increased population densities are putting greater pressure on typical urban greenspaces, cemeteries may offer another opportunity for urbanites to access the myriad benefits associated with greenspaces and nature. As such, there is a need for cemetery managers and municipalities to consider how urban cemeteries and their trees can be managed not only for the dead but also for the living.

CHAPTER 4: CONCLUSION

Cemeteries represent a unique land use in our cities. While their primary function is the interment of human remains and commemoration of individuals, their capacity to contain high levels of vegetation—often in stark contrast to surrounding built infrastructure—make them valuable urban greenspaces. Recent European research has shown that urban cemeteries are increasingly being used for purposes beyond interment and commemoration, such as recreational uses like cycling, jogging, dog-walking, commuting, photography, experiencing nature, learning about history, relaxation, restoration, and many more (Deering, 2010; Evensen et al., 2017; Grabalov, 2018; Skår et al., 2018; Swensen et al., 2016). Data collected for this thesis corroborates these uses of cemeteries, indicating that it is not just a European phenomenon.

It is not only their increasingly multifunctional use that make cemeteries such valuable greenspaces. Their vegetation provides biodiversity support (Čanády & Mošanský, 2017; Kowarik et al., 2016; Laske, 1994; Morelli et al., 2018; Tryjanowski et al., 2017), and the diversity of vegetation itself provides benefits such as stormwater retention, micro-climate regulation, and increased pollination (Quinton & Duinker, 2019). While cemeteries can have a range of vegetation types, it is their trees in particular that are adept at providing these benefits and many others (Bolund & Hunhammar, 1999; Duinker et al., 2015). The importance of trees to a city and its inhabitants led to the first objective of this thesis, which was to determine the current role cemeteries play in the urban forest of central Halifax.

When examining the first objective from a biophysical perspective, it was determined that Halifax cemeteries contain relatively high tree canopy coverage in comparison to their surrounding neighbourhoods. The difference between the canopy

cover in cemeteries and their surrounding neighbourhoods was minimal in some cases but substantial in others, resulting in some cemeteries existing as green oases in densely built areas. In addition to having relatively high canopy cover, Halifax cemeteries were found to have an abundance of larger and older trees, which are able to provide a multitude of benefits to a greater degree than younger and smaller trees. However, the lack of size-class diversity in many of the cemeteries has negative implications for maintaining their current canopy cover in the future. The dominant tree species in the cemeteries studied typically mirrored the dominant species of their neighbourhoods, indicating that cemeteries contribute limited additional species diversity to Halifax's urban forest. Additionally, many cemeteries were dominated by non-native species, including the invasive and problematic *A. platanoides* (Norway maple).

One of the greatest contributions of cemeteries to the urban forest is seen when examining the sociocultural perspective. It is evident from this research that trees are a highly valued component of the urban-cemetery landscape. Cemetery users indicated that trees are important to them for a wide variety of reasons, the most common being the provision of shade/cooling, aesthetics, contribution to personal wellbeing, and creating a sense of place. These values contrast those previously ascribed to the Halifax urban forest in general, as a prior study (Ordòñez et al., 2016) found that environmental/ecological values, such as improving air quality, were more frequently cited than the sociocultural values emphasized in this research. These findings suggest that cemetery trees make important and unique contributions to how people experience the city's urban forest and help create a desirable environment for cemetery visitors.

Although this research yielded valuable insights on the current role of cemeteries in the Halifax urban forest, the primary motivating factor for this research was to determine the potential of cemeteries to expand the city's urban forest. This potential was assessed from three different and critical perspectives: biophysical, sociocultural, and managerial. The biophysical perspective was assessed through an inventory of places in the cemeteries in which trees could be planted in the future. Many spots were identified, primarily along pathways and amongst monuments, indicating that the number of trees within Halifax cemeteries could be nearly doubled.

From the sociocultural perspective, most cemetery users were satisfied with the number of trees in Halifax cemeteries. However, a relatively high number of users of the cemetery with the lowest canopy cover indicated a desire for more trees. Hardly anyone wanted fewer cemetery trees, even in the cemeteries with the highest canopy covers. Cemetery users also held very few concerns about potential negative impacts that trees could have on the cemeteries. These data suggest that while cemetery users may not necessarily be lobbying for additional trees to be planted in cemeteries, they are unlikely to oppose such efforts.

Although the biophysical and sociocultural perspectives support—or at least do not oppose—the concept of planting trees in Halifax cemeteries, barriers emerged when examining the managerial perspective. The top priorities for cemetery managers are selling burial plots and interring remains, preserving history, and maintaining a neatly mown lawn. Tree maintenance and management are conducted on a reactive basis and the lack of long-term cemetery planning in Halifax means that planting trees now for a healthy urban forest in the future is not a priority. Barriers such as a lack of open space,

concerns for damage to monuments and other infrastructure, and limited finances discourage cemetery managers from planting many trees. In fact, very few of the cemeteries on the Halifax peninsula had any trees planted in the past five to ten years. Many of the trees that were planted were only small shrubby species like *Magnolia* spp.

The lack of tree planting in Halifax cemeteries, emphasis on lawn maintenance (and the subsequent disruption of natural tree regeneration), and the older age of the trees all contribute to a threat of future canopy loss. Canopy loss would not only reduce the ability of urban cemeteries to provide benefits such as shade provision, stormwater management, micro-climate regulation, and so on, but may also have an impact on how cemeteries are used. The loss of cemetery trees will result in the loss of the values they provide to cemetery users, such as aesthetics, a sense of place, and a positive impact on personal wellbeing. This loss could influence the frequency and purpose of cemetery use, although further research would be required to establish a clear link between trees and cemetery use.

For Halifax cemetery managers to maintain current tree canopy covers, let alone using cemeteries to expand the city's urban forest, the barriers to tree planting faced by cemetery managers need to be addressed. While there is little open space in many cemeteries, this research indicates plenty of spots along pathways and amongst monuments in which trees can be planted. Cemetery managers are hesitant to plant trees amongst monuments, particularly in the historical cemeteries, due to the potential for damage. Planting trees that are smaller at maturity, such as species from the Serviceberry (*Amelanchier*), Cherry (*Prunus*), Lilac (*Syringa*), Hornbeam (*Ostrya*), and Hackberry (*Celtis*) genera, will reduce the risk of damage due to their smaller size. Minimizing the

financial costs associated with tree planting and maintenance will also be essential and could involve government funding, partnerships with non-governmental organizations, memorial-tree programs (in cemeteries still open to interments), and other donations. Planting saplings and seedlings (vs. larger stock) will reduce costs associated with purchase and planting, and in some cemeteries, small trees could be removed from the copses and replanted in other locations within the cemetery (or within other cemeteries).

Research on cemeteries as urban greenspace is still in its infancy. Further research on how cemeteries and their trees can be managed within the context of the wider city—despite not all cemeteries being municipally owned—would be beneficial for maintaining these areas as multifunctional greenspaces. Research into how cemetery governance structures differ around the world may also provide valuable insight into how cemeteries can be managed for purposes beyond interment and commemoration. It is important to note that the results found within these studies may not be generalizable to all cities. Different cultures and religions have unique burial traditions and customs, as well as cemetery landscapes and governance. These factors may affect all three of the perspectives examined here in regard to cemetery trees.

While the plantable-spots inventory within this research gave an indication of the number of trees that could theoretically be planted in Halifax cemeteries, it would be beneficial to conduct a similar inventory with greater cemetery manager input. Such an enhanced inventory would include greater consideration of factors such as planned future burial space and potential conflicts with infrastructure and provide a more realistic output. Furthermore, it could highlight other potential conflicts that may have been overlooked or omitted by other data-collection methods.

The surveys highlighted the values cemetery users attribute to trees in these landscapes, but they did not account for the opinions of people who do not use cemeteries and may have different opinions about trees in such places. It could be that some individuals do not visit or use cemeteries for any purpose because they believe they have too many trees, which makes them feel unsafe or unwelcome. Future research on the inclusivity of cemeteries as greenspace should seek to address how vegetation influences a sense of belonging in these landscapes. Furthermore, the survey did not highlight potential sociodemographic biases in the population of individuals who visit cemeteries or the neighbourhoods in which these cemeteries are situated. This could have implications for the equity and social justice of promoting tree planting in cemeteries if this action would only serve to benefit a privileged subset of the Halifax population.

Without conscious thought and long-term planning, Halifax cemeteries are going to look very different in the future. The loss of cemetery trees will constitute the loss of an integral component of these landscapes, which may have implications for how these spaces are used and how residents and visitors experience the urban forest. It will also result in the loss of canopy cover in the city and the subsequent loss of the many benefits trees provide in urban areas. Given the pressures being exerted on existing greenspace in the face of increased urbanization and demand for additional built infrastructure, it is imperative that cities consider how even the atypical greenspaces can be managed to transform urban areas into healthier, happier, and more sustainable places to live.

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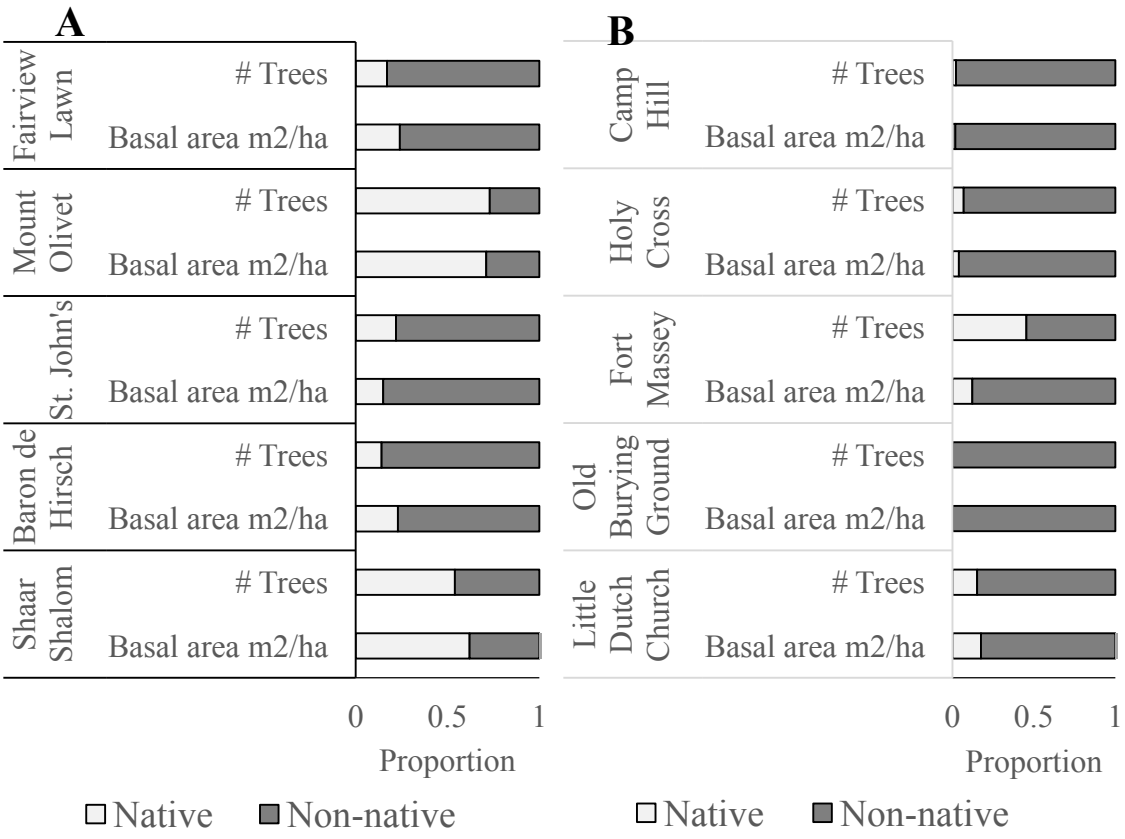
APPENDIX 1: Native and non-native species found in the ten cemeteries of the peninsula of Halifax, Nova Scotia.

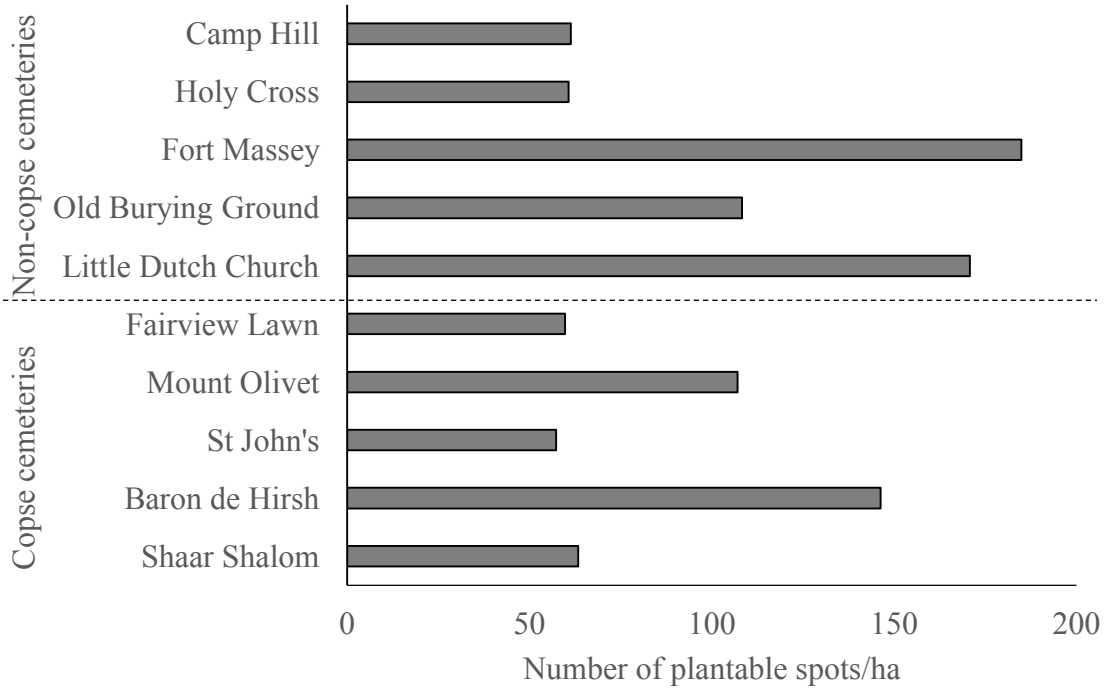
Native species		Non-native species	
Latin name	**Common name**	**Latin name**	**Common name**
Abies balsamea	Balsam fir	*Acer palmatum*	Japanese maple
Acer rubrum	Red maple	*Acer platanoides*	Norway maple
Acer saccharum	Sugar maple	*Acer pseudoplatanus*	Sycamore maple
Amelanchier spp.	Serviceberry spp.	*Acer saccharinum*	Silver maple
Betula alleghaniensis	Yellow birch	*Aesculus hippcastanum*	Horse chestnut
Betula papyrifera	White birch	*Aralia elata*	Japanese angelica tree
Fagus grandifolia	American beech	*Betula pendula*	European white birch
Fraxinus americana	White ash	*Betula populifolia*	Gray birch
Fraxinus nigra	Black ash	*Cercidiphyllum japonicum*	Katsura tree
Fraxinus pennsylvanica	Green ash	*Crataegus spp.*	Hawthorn spp.
Picea glauca	White spruce	*Fagus sylvatica*	European beech
Pinus resinosa	Red pine	*Fraxinus excelsior*	European ash
Picea rubens	Red spruce	*Fraxinus quadrangulata*	Blue ash
Pinus strobus	White pine	*Ginkgo biloba*	Maidenhair tree
Populus tremuloides	Trembling aspen	*Hydrangea spp.*	Hydrangea spp.
Prunus pennsylvanica	Pin cherry	*Juniperus spp.*	Juniper spp.
Prunus virginiana	Common chokecherry	*Juglans nigra*	Black walnut
Quercus rubra	Red oak	*Juniperus virginiana*	Eastern red cedar
Taxus canidensis	Canada yew	*Laburnum anagyroides*	Golden chain tree
Thuja occidentalis	Easter white cedar	*Malus spp.*	Apple spp.
Ulmus americana	American elm	*Magnolia spp*	Magnolia spp.
		Metaseqouia spp.	Dawn redwood spp.
		Morus spp.	Mulberry spp.

Native species		Non-native species	
Latin name	**Common name**	**Latin name**	**Common name**
		Picea abies	Norway spruce
		Pinus nigra	Austrian pine
		Pinus pungens	Blue spruce
		Pinus sylvestris	Scotch pine
		Platanus hybrida	London planetree
		Populus spp.	Poplar spp.
		Populus deltoides	Eastern cottonwood
		Populus grandidentata	Largetooth aspen
		Prunus avium	Sweet cherry
		Pyrus calleryana	Callery pear
		Quercus alba	White oak
		Quercus palustris	Pin oak
		Quercus robur	English oak
		Rhododendron spp.	Rhododendron spp.
		Robinia pseudoacacia	Black locust
		Salix sericea	Silky willow
		Sorbus aucuparia	European mountain ash
		Syringa spp.	Lilac spp.
		Taxus baccata	English yew
		Tilia americana	Basswood
		Tilia cordata	Littleleaf linden
		Ulmus glabra	Wych/Scots elm
		Ulmus thomasii	Rock elm

APPENDIX 2: Proportion of native and non-native trees and basal area (m^2/ha) across **A)** the five copse cemeteries and **B)** the five non-copse cemeteries in Halifax, Nova Scotia (Canada).

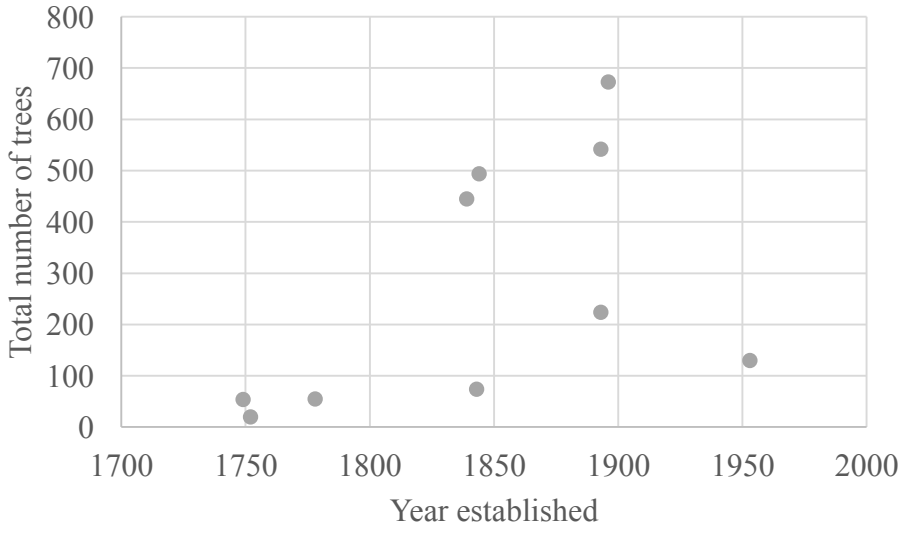


APPENDIX 3: Density of plantable spots per hectare for each of the ten cemeteries in Halifax, Nova Scotia.



APPENDIX 4: Statistical-analysis rationale

Spearman's rank correlation was used instead of Pearson's correlation coefficient in the study in Chapter 2 because of the non-linear relationships between many of the variables (e.g. between cemetery area and number of trees, as shown in the scatterplot below). Pearson's correlation coefficient measures linear relationships, whereas Spearman's rank can be used on non-linear relationships. Furthermore, the data were monotonic, which is an assumption of Spearman's rank. The second assumption of Spearman's rank—that the data are ordinal, interval, or ratio—was also met by these data. Finally, the assumption or normality required for the Pearson coefficient was not met by all variables. Spearman's correlation does not require normal distribution of data.



APPENDIX 5: Survey questions

Date: _____ Time: _____ Cemetery: _____

Weather: Hot / Warm/ Cool/ Cold Sunny / Overcast / Rain

Decade born: 20 / 30 / 40 / 50 / 60 / 70 / 80 / 90 / 00

Education level: High school Undergraduate Graduate College diploma

Occupation: _____ Where do you live? _____

1. How often do you visit a cemetery in Halifax?

2. Which cemeteries on the Halifax peninsula have you visited in the past 12 months?

Mount Olivet	Holy Cross	Fort Massey	St John's Anglican
Fairview Lawn	Little Dutch	Camp Hill	Shaar Shalom
Baron de Hirsch	Old Burying Ground		

3. What is the purpose of your current visit to this cemetery?

4a) On a scale of 1 (not important) to 5 (very important), how important are trees in this cemetery to you?

1 2 3 4 5

4b) What is important to you about the trees in this cemetery?

5) What else about the natural environment of this cemetery is important to you?

6) Do you have any concerns about the impact that trees have on this cemetery?

7) Do you have any concerns about how growing in a cemetery environment may impact the trees?

8) Do you think this cemetery could use more trees, fewer trees, or do you think it has a good amount?

9) Is there anything else you would like to add?

APPENDIX 6: Interview questions

1. What is your position, and what does it entail?

- Is it a volunteer or paid position?
- How long have you had this position?
- What does a typical day of work look like for you?

2. *How are decisions about your cemetery made?

- What is the hierarchal structure of your organization?
- Are there plans/policies in place regarding the management of your cemetery?
    - If not, are there any currently in development?
- How far into the future do you make plans and decisions for the cemetery?
- Do any of your plans/policies involve trees?
- Do you have any documentation about plot layout, policies, plans etc. for your cemetery that you could share with me?

3. *How is/are your cemetery/cemeteries financially structured?

- Is it not-for-profit or for-profit?
- Where does the funding for your cemetery come from?
- What does your perpetual care fund cover? (Just plots, or both plots and the surrounding landscape?)

4. *What is the current landscape maintenance regime for your cemetery/cemeteries in the summer?

- Who performs the maintenance tasks?
- How many hours per week are spent on maintenance?
- What maintenance is done to the trees, shrubs, and flowers?

5. *What activities do you notice/hear of people participating in when they are in your cemetery/cemeteries?

- Are there any activities besides those associated with interment?
- Are there any activities you want to encourage or discourage?
- Would you like to see fewer or more visitors in your cemetery?
- Are there rules/regulations against certain activities/uses in your cemetery/cemeteries?
    - How are they enforced?
    - How often are they enforced?
    - What are the most common violations?

6. What aspects of the natural environment of your cemetery/cemeteries is important to you?

7. What do you think the people who use your cemetery/cemeteries value about the natural environment of the cemetery?

- *Do residents/visitors/plot-holders every talk to you/make suggestions about the landscape in your cemetery/cemeteries?

8. *How has the landscape of your cemetery/cemeteries changed in the recent past?

- Were these changes intentional?
- Do you think the number of trees has increased or decreased?
- Have you planted any trees in the past few years?
- How do you make decisions about landscaping in your cemetery?
    - How do you decide when and where to plant something new?
- How many interments do you currently have per year?
    - If interments have stopped, when did they stop?

9. *What changes would you like to make to the landscaping of your cemetery/cemeteries?

- If they do not mention trees: Would you consider planting trees in your cemetery?
    - If yes: What kind of trees would you plant?
- Are you satisfied with the number of access points to your cemetery?
- Are you satisfied with the types of access points your cemetery has?

10. *What concerns do you have about increasing the number of trees in your cemetery/cemeteries?

11. Would you be interested in receiving information on the species composition of the trees in your cemetery, as well as an inventory of where trees could be planted in the future?

*Questions that should be answered for each cemetery if interviewee is involved with more than one

APPENDIX 7: Co-author permission forms for inclusion of the manuscript in Chapter 2

23 August 2019

Dear Co-author,

I am preparing my Master of Environmental Studies thesis for submission to the Faculty of Graduate Studies at Dalhousie University, Halifax, Nova Scotia, Canada. I am seeking your permission to include a manuscript version of the following paper, which you are a co-author on, as a chapter in the thesis:

Quinton, J. M., Duinker, P. N., Steenberg, J. W. N. & Charles, J. D. 2019. The living amongst the dead: Cemeteries as urban forests, now and in the future. *Urban Forestry & Urban Greening* [revised manuscript submitted 20 July 2019].

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Name: Peter Duinker Title: Prof Emeritus

Signature: Date: 2019-08-23

23 August 2019

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Name: John Charles Title: Adjunct

Signature: Date: Aug. 23/2019

23 August 2019

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Name: James Steenberg Title: Research Analyst / Adjunct Prof

Signature: Date: Aug 23/2019