Characterizing the Conifer Density Gradient from the Halifax Peninsula to the Hinterlands of the Halifax Regional Municipality

by

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Abstract

The urban-forest tree-species composition is influenced by the urban environment and thus by daily anthropogenic activity. However, in the naturalized woodlands, species composition is primarily influenced by natural disturbances. In moving away from the urban setting to the naturalized forest, there is a shift in the environment leading to a transition of dominant species, ultimately creating a species composition gradient. This study characterized the conifer gradient through assessing the Halifax Peninsula, surrounding communities, and the hinterlands of the HRM. The assessment of the conifer density on the Halifax Peninsula followed a probabilistic sampling technique in which ocular estimates were conducted to produce a conifer inventory for the study area. To assess the conifer density in the other study areas, two independent datasets were analyzed. Further analyses on other cities' conifer densities were conducted to develop benchmark values for the HRM. Through these assessments, it became apparent that there is a steep conifer gradient in the transition from the urban environment to the naturalized environment. These data can be used to question the lack of conifers in the urban forest despite their prominence in the naturalized setting and in other cities.

Key Words: Conifer, Urban Forest, Urban Forest Values, Urban Environment, Density

List of Abbreviations

UFMP	Urban Forest Master/Management Plant
FID	Forest Inventory Dataset
HRM	Halifax Regional Municipality
NSDNR	Nova Scotia Department of Natural Resources and Renewables
LAI	Leaf Area Index

Chapter I: Introduction

1.1 Motivation

The urban forest provides a multitude of services to people and the environment; these contributions can vary from acting as urban climate regulators and promoting the urban aesthetic to improving urban biodiversity (Jim & Chew, 2009; Kielbaso, 2008). As the impacts of climate change exacerbate over time, the urban environment becomes more reliant on the urban forest to provide these services (Handyani & Mardikannigish, 2022). Species selection is pertinent in the urban forest's ability to deliver these services, and including a diverse array of species will make the urban forest more resilient (Hale et al., 2015).

Even casual observations on the Halifax urban forest reveal a dominance of non-conifer tree species and a lack of conifer tree species on the Halifax Peninsula (Foster, 2016). In comparison to Halifax's urban forest, the naturalized hinterlands of the Halifax Regional Municipality are dominated by native conifer tree species (NSDNR, 2022). The dominance of non-conifers and the limited population of coniferous tree species in the Halifax urban forest demands attention.

This query was supported by three separate datasets all which depict a unique aspect of the conifer population in the Halifax Regional Municipality (Foster, 2016; NSDNR, 2022).

1.2 Background and Context

In previous literature, the urban forest has been defined in various ways; this thesis will define it as "trees, forests, greenspace, and related abiotic, biotic, and cultural components in areas extending from the urban core to the urban-rural fringe" (Tree Canada, 2019). The urban forest can deliver many services and several of these services are becoming increasingly important with climate change and continued urbanization (Garschagen & Romero-Lankao, 2015). The benefits cover the broadest range of ecological, economic, and social services to people and the urban environment (Ederny, 2018; Bowyer et al., 2016; Konijnendijk et al., 2005).

As climate change becomes more prevalent in urban areas, and with increased global urbanization (Garschagen & Romero-Lankao 2015), countering its effects in the urban environment is increasingly important. One benefit of the urban forest is its ability to act as a microclimate regulator (Bolund & Hunhammer, 1999). As every tree can deliver distinct services (Nowak & Dwyer, 1998), including a carefully selected diversity of tree species in the urban forest will enhance its ability to mitigate the impacts of climate change in the urban setting. As cities continue to adjust the species composition of their urban forest, factoring in the resiliency and services of each tree is vital.

Moreover, with an estimate that approximately 68% of the global population will be living in urban centres by 2050 (United Nations, 2018), it is crucial to consider how the impacts of climate change in urban settings will influence the human population. The urban forest's ability to benefit the mental and physical health of the human population cannot be overestimated. There is considerable literature focused on how urban forests improve social dynamics in urban areas, from improving mental health by enhancing the urban aesthetic to increasing physical health through creating an appealing environment that encourages physical recreational activity (Gerstenberg & Hofmann 2015; Janeczko et al., 2020).

With urbanization encroaching on naturalized areas, habitat conversion is a predominant threat to the plant and animal species within these areas (Seto et al., 2012). Thus, finding a way to conserve wildlife and integrate biodiversity into urban centres is crucial. Whilst acting as climate mitigators, urban forests are considerable hosts for urban biodiversity beyond just trees; they are one way to bridge the necessity for urban centres with the imperative of conserving wildlife (Alvey, 2006). Each tree species can provide unique services— shelter, fruits/nuts, nesting sites, and reproductive sites, for a wide variety of animals (Alvey, 2006). Therefore, an urban forest with a diverse array of tree species will have more services to offer wildlife and ultimately facilitate a higher enriched biodiversity (Alvey, 2006).

In analyzing species distribution and species selection, it is critical to assess the trees' ability to tolerate disturbance. The major disturbance agents in the hinterlands of the Halifax Regional Municipality are different than the disturbance agents on the Halifax Peninsula. As there are different stressors in the two environments, understanding the thresholds at which trees can survive certain stressors is pivotal in species selection and distribution (Sjoman et al., 2010).

1.3 Introduction to Study

This study will provide insight on the importance of conifer trees species in the urban forest. More specifically, this research hopes to:

Characterize the conifer density gradient from the Halifax Peninsula to the hinterlands of the Halifax Regional Municipality.

Temporally, this project is concerned with the current species composition of the Halifax urban forest; it is not looking at the future management plan. However, the project could create value by arguing for more conifers in the future.

To characterize the conifer population in the urban forest, peri-urban forest, and naturalized hinterlands, I rely on three separate datasets. The first is a dataset collected during the summer of 2022 by myself and other members of the Urban Forest Research Team at Dalhousie University. This dataset generated a conifer inventory for the Halifax Peninsula, enabling us to determine the conifer density in the urban core. The second is the 2016 i-Tree Eco dataset. This includes the conifer population that exists in the surrounding nine Urban Forest Master Plan (UFMP) communities which can then be used to determine the conifer density in these communities. The last dataset is the provincial forest inventory (NSDNR, 2022); it provides a complete inventory of every forest stand in the HRM. This enables an analysis of the conifer population in the hinterlands.

In identifying potential reasons for the existing conifer gradient, I will primarily focus on the literature. As there is a lack of literature about conifers in urban areas, I need to use related literature on general conifer benefits and urban forestry in general. In addition to the literature, I will refer to other cities' Urban Forest Master/Management Plans in efforts of finding evidence to address my questions.

1.4 Summary of the Literature

Despite urban forestry (the management of urban forests) not being a new concept, there are substantial gaps in the literature (Russo et al., 2021) particularly in the realm of conifer tree species in urban settings. However, regardless of these gaps, there is literature addressing the importance of urban forests in terms of their ability to be economically, environmentally, and socially beneficial (Ederny, 2018 & Bowyer et al., 2016 & Clapp et al.,2014). It is apparent in the existing literature that to optimize these three domains, incorporating a diverse array of tree species within the urban forest is necessary (Dwyer et al., 2003). Thus, this study acts as a starting point in understanding the importance in the integration of coniferous tree species into the urban forest.

Chapter II: Literature Review

2.0 Introduction

The urban forest can provide many services to the city environment (Bolund & Hunhammer, 1999). These services range from influencing the economy and enhancing the environment to improving society (Handyani & Mardikannigish 2022). The ability of the urban forest to provide services is heavily dependent on the species composition (Wood et al., 2021). Thus, including an array of tree species is warranted. This literature review will provide an overview of the potential benefits of including conifers in the urban forest. It will discuss the values which conifer species can deliver, the components of species selection, and assess conifers' role in the urban forest. Overall, this literature review will summarize the current state of knowledge and identify knowledge gaps regarding conifers in the urban forest.

2.1 The Nature of the Halifax Urban Forest and the Hinterlands of the HRM

The majority of Nova Scotia's naturalized forest is situated within the Acadian/ Wabanaki Forest Region (HRM, 2013). The Acadian Forest is known to be a transitional forest, where the boreal species from the north and temperate species from the south intersect (Loo & Ives, 2003). The intersection of these two forest regions allows for the Acadian Forest to encompass several forest types (Loo & Ives, 2003) ranging from coniferous-dominated forests and non-coniferous forests to mixed forests (DeWolfe et al., 2005). Though the native species of the Acadian Forest region are found within the hinterlands of the Halifax Regional Municipality, the composition of the forest has been altered by human activity (Loo & Ives, 2003). Ultimately, human action – primarily timber harvesting, has caused an increase in early successional species, and a decline in late successional species; effectively changing the dominant species in the hinterlands (Loo & Ives, 2003; Steenberg & Duinker, 2010). The hinterlands of the HRM can be primarily characterized as a mixed wood forest (Government of Nova Scotia, 2010). The stands are dominated by red spruce (*Picea rubens* Sarg), balsam fir (*Abies balsmea* (L.) Mill.), red maple (*Acer rubrum* L.), yellow birch (*Betula alleghaniensis* Britt.), eastern white pine (*Pinus strobus* L.), eastern hemlock (*Tsuga canadensis* (L.) Carriere), and a hybrid of red spruce and black spruce (Government of Nova Scotia, 2010). The species composition within these forest stands is further influenced through natural events and successional phases (HRM, 2013).

Conversely to the hinterlands, the species composition of the urban forest is intensively managed by people. The control that urban foresters have in the species selection process shapes the composition of the urban forest, potentially rendering it rather different than the naturalized environment.

2.1.1 Forest Gradients

In shifting from the naturalized forest ecosystem (the hinterlands of the HRM) to an urban setting (the Halifax Peninsula), the species composition differs with the transition in environment (Blood et al., 2016; Ellis et al., 2012). Many factors contribute to the different species composition along the gradient from a naturalized rural forest to an urban forest; driving the difference in the forest gradient are prominent factors such as logging and changes in land use (Blood et al., 2016; Loo & Ives, 2003; McDonnell & Pickett, 1990). Thus, historically what was once a naturalized environment that may have been dominated by native conifer species has been altered, effectively shifting the composition of species found within the region and altering the degree to which forest composition gradient exists (Blood et al., 2016).

2.2 Conifers as Climate Change Regulators

With the exacerbation of climate change, the urban environment is becoming more susceptible to its impacts, particularly the increased ambient temperature, increased storm frequency and severity, and elevated levels of emissions in the urban setting. Ensuring that the urban environment can offset the local impacts of climate change is critical as the impacts continue to intensify (Gill et al., 2007). It is known that individual tree species can provide services that will help counter the effects of climate change, and that the urban forest plays an integral role in mitigating the changing climate's impacts on the urban environment (Konijnendijk et al., 2005). The urban forest's ability to offset impacts is consequently dependent on incorporating a diverse array of appropriate tree species (Wood et al., 2021). It is critical in the assembly and species selection process to assess the tree species' ability to contribute as a climate change regulator. Thus, the assessment must consider the role that both conifer and non-conifer tree species could have in the urban forest (Clapp et al., 2014). It is known that conifer tree species are particularly effective in their ability to capture emissions, help control and divert stormwater, and to regulate ambient temperatures (Clapp et al., 2014).

2.2.1 Capturing Emissions

Within the urban environment, airborne pollutants pose significant threats to the environment and human population (Manisalidis et al., 2020). Among the many pollutants that are emitted into the atmosphere, carbon and particulate matter are two that can be considered of primary concern (McClellan, 2002). Conifer tree species are known to have elevated particulate matter removal and carbon sequestration abilities (Cao et al., 2022 & Hounshell, 2020; Czaja et al., 2020). Research from Ozdemir, (2019) and Mori et al. (2018) indicates that the larger surface area and the highly structured needles of conifer tree species enable them to have efficient emission capture. The ability of coniferous trees to keep their highly structured needles year-round allows them to remove pollutants throughout the entirety of the year, thus providing relatively high levels of pollutant removal (Chen et al., 2020; Ozdemir, 2019).

2.2.2 Regulating Stormwater

Among the many impacts associated with climate change is the increased frequency of weather events (Blakely, 2007). In urban areas, rainfall events are problematic when it comes to managing and diverting the excess water (Wilby, 2007). Conifer tree species can reduce stormwater flow in the urban environment; the dense canopy of conifer trees enables high rates of rainwater interception (Berland et al., 2017). Evidently, the ability of conifers to keep their needles during the winter season allows for considerably more interception and rainwater control (Clapp et al., 2014). Moreover, in comparing the transpiration rates of conifer and non-conifer trees, it has been found that conifers are capable of higher rates of transpiration than non-conifer trees (Clapp et al., 2014). The increased transpiration rate allows for a higher water holding capacity, leading to higher rates of water absorption in the roots of the tree (Clapp et al., 2014). However, the ability of a tree to absorb water is heavily dependent on its surrounding environment. If the tree is planted in heavily compacted soil on the side of the road, it will have a lower capacity to control stormwater than a tree located in uncompact soil. Thus, the location of where the tree is located may have a larger impact on stormwater control than what species is planted (Pataki et al., 2021).

2.2.3 Control Ambient Temperature

Trees in the urban forest play a significant role in mitigating the ambient temperature within the urban environment (Clapp et al., 2014). The urban heat-island effect (UHI) and its associated impacts are becoming increasingly prevalent with urbanization (Zhou et al., 2019). Thus, the ability of the urban forest to counter UHI effects is imperative for human and environmental health. With proper management of the urban forest, conifer tree species can be used to create dense areas of shade due to their dense foliage (Speak et al., 2020). The dense areas of shade can strategically be used to help reduce the summer air conditioning requirements when placed properly near a building (Clapp et al., 2014). Among conifer species, some have larger leaf area indices (LAI) than others (Clapp et al., 2014). The conifer species that have larger LAI efficiently cool ground surfaces, including soils; this plays a role in retaining Carbon in the soil rather than being transferred into the atmosphere as CO_2 (Peters et al., 2010; Clapp et al., 2014). However, due to their usually conical shape, the shadow that conifers cast is narrow; therefore, spatial awareness is vital when planting conifers to attain elevated levels of shade (Speak et al., 2020).

2.3 Other Conifer Services in the Urban Forest

Aside from the many climate-regulating services that conifers provide, they are inherently capable of offering other services to their surroundings (Clapp et al., 2014). These services range from environmental and economic to social benefits. It is known that conifers excel at providing canopy-dependent services, as they keep some of their foliage throughout the entirety of the deciduous off-leaf season, ultimately allowing them to provide these services when non-conifer tree species cannot (Clapp et al., 2014). Some canopy-dependent services include improving the urban aesthetic (health benefits included), acting as sound and visual buffers, improving urban biodiversity, and strengthening sustainability within the urban environment (Clapp et al., 2014). However, it is important to note that not all conifers retain their needles throughout the entire year. In Nova Scotia, the eastern larch/tamarack (*Larix laricina* (Du Roi) K.Kock) is considered to be a deciduous conifer species, as it loses its needles during the fall months like other deciduous species (Gower & Richards, 1990). Thus, the canopy-dependent services noted above cannot be extended to the eastern larch species.

2.3.1 Improved Urban Aesthetics (and the associated health benefits)

As the urban forest is central to the urban environment, it plays an integral role in the lives of the human residents (Nowak et al., 2001 & Tesler et al., 2022). The species included in the urban forest play an important part in creating a naturalized aesthetic in the urban core (Trees Canada, 2022). Despite the naturalized aesthetic that the urban forest introduces, grey infrastructure will still dominate the urban environment. The dominant grey infrastructure is particularly noticeable during the winter months when non-conifer tree species lose their leaves. The lack of green foliage in the winter months can create a dreary environment, which can ultimately lead to negative social implications for the human population (Sulaiman et al.,2016; O'Brienia et al., 2022). Sulaiman et al. (2016) linked the presence of winter foliage to mental health. Thus, the use of coniferous tree species can introduce a naturalized aesthetic during this off-leaf season (Clarke, 2017; Clapp et al., 2014), ultimately reducing the dull urban environment during the winter months and improving mental health (Tree Canada, 2022). Furthermore, Liu et al. (2021) determined that conifer forest stands were the most restorative for people with anxiety compared to mixedwood and non-conifer stands. Thus, incorporating conifers into the urban forest could be an effective approach to reduce stress in people who live in the urban core.

2.3.2 Buffer Capacity

In addition to their ability to provide a continuous naturalized aesthetic to the urban environment, conifers are well known for their ability to act as noise and wind buffers (BlueGreen, 2015; Clapp et al., 2014). As the urban environment generates considerable amounts of noise, its abatement is critical. As noise abatement is dependent on the canopy of the tree species, the ability of conifers to provide this canopy-dependent service throughout the entire year allows for consistent noise reduction in the urban environment (BlueGreen, 2015). However, a mix of both conifer and non-conifer tree species has been deemed as the most effective configuration of trees to mitigate elevated levels of noise (BlueGreen, 2015). Similar to their ability to attenuate noise, conifers are more than capable of blocking wind (Clapp et al., 2014). The use of trees in creating wind buffers is similar to noise buffers; a study from Wyatt (2020) claims that systematic planting of both conifer and non-conifer trees is required to achieve elevated wind buffering. The benefits of wind buffers in the urban environment are multifaceted; both environmental and economic benefits can be obtained (Bentrup, 2009). Economically, creating a wind break with trees can help reduce the amount energy a building requires in the winter months (Wyatt, 2020). This benefit transitions to benefitting the environment, as less energy will be used leading to lower levels of emissions being emitted in attempting to heat buildings.

2.3.3 Enhance Urban Biodiversity

The urban environment is dominated by grey infrastructure – the built environment including roads, sidewalks, and water treatment plants, with green infrastructure usually acting as a minor constituent (Dong et al., 2017). Despite green infrastructure existing in a limited capacity, it is vital for maintaining urban biodiversity (Filazzola et al., 2019). Therefore, to strengthen biodiversity within the urban environment, incorporating a variety of types of green infrastructure is critical as it creates a naturalized aesthetic in the urban setting (Dong et al., 2017). The urban forest is one form of green infrastructure that plays a pivotal role in preserving biodiversity on the urban environment (Alvey et al., 2006).

Within the urban forest, each species of tree is capable of supporting wildlife in its own way. Research conducted by Fontana et al. (2011) determined that native bird species preferred native conifer species to other species of trees; this may correlate to conifers having a dense canopy that allows for superlative nesting sites (Fernandez-Juricic et al., 2005; Ference et al., 2014). Conifers are particularly important for bird species in the wintertime, their ability to retain foliage allows for elevated overwintering opportunities for many bird species (Jokimaki et al., 1999). It is prudent to assess the connection between native conifer tree species and native animal species; it is known that animals will gravitate towards native tree species if given the choice (McKinney, 2002). Thus, in creating wildlife corridors in the urban setting, conifer tree species play an integral role in supporting biodiversity in the transition from a naturalized to urban environment (McKinney, 2002).

2.4 Species Selection

The ability of the urban forest to thrive and survive in the urban environment is heavily dependent on the species that are planted (Sjoman et al., 2012). Assessing attributes that each species is capable of contributing is imperative in the species selection process (Nowak et al. 1998). Urban forestry can be defined as “the art, science, technology of managing trees and forest resources in and around the urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide to society" (Konijnendijk et al., 2006). Within the urban forestry industry there is the phrase "right tree, right place" (MacPherson et al., 1997), which is applied to exclude trees from locations where they are thought to be inconvenient; this ideology is prudent for successful tree planting. In selecting the location of a tree, one must take into consideration how the surrounding environment can facilitate the services that the tree can offer (MacPherson et al., 1997). This concept ties into the realm of species tolerance, and how stressor thresholds can limit a tree species' ability to survive and effectively offer services to their surrounding environment (Esperon-Rodriguez et al., 2020; Sjoman et al., 2010). Therefore, following the concept of prioritizing location and identifying tolerance thresholds is essential in selecting species and building a resilient urban forest (Hale et al., 2015).

2.4.1 Species Tolerance

As the urban forest is situated, by definition, in the urban environment, it is subject to numerous actions of the human population. Thus, the trees within the urban forest will inevitably be disturbed by people's activities. As stress from the urban environment is unavoidable, species that are tolerant to urban stressors will have a higher survival rate (Luttge & Buckeridge, 2020). Furthermore, it is prudent to consider how the exacerbation of climate change influences the ability of a tree species to survive in the urban environment (Esperon-Rodriguez et al., 2020). Evidently, climate change will shift natural and anthropogenic stressors; therefore, species selection must consider the tree species' ability to adapt to the shift in the urban environment (Steenberg et al., 2017). Within the literature, there are mixed views on the tolerance that conifers have to salt spray. Certain research links conifer species to being resistant to salt spray (University of Maine, 2017), whereas other studies have identified conifers as being susceptible to salt spray (Bryson & Barker, 2006). This susceptibility can lead to needle burn and/or stunted growth in certain coniferous tree species (Nackley et al.,2015). Conifers have been further considered to be vulnerable to SO2 pollution (Saebo et al., 2003) and have been linked to issues with soil compaction due to their shallow roots (Aven et al., 2016). Clearly, there is concern with conifers' ability to tolerate the harsh impacts that are associated with the urban environment; thus, incorporating conifers in highly urban areas may be problematic for their survival (Almas et al., 2016).

2.4.2 Conifers in the Urban Forest

In solidifying the role that conifers can have in the urban forest, considering spatial placement—how correct planting placement can facilitate species' values and minimize external stress and pressure – is prudent (MacPherson et al., 1997). Within the literature, there are no directions regarding the placement of conifers in the urban forest (Almas et al., 2016; Clapp et al.,2014). However, several sources have recommended and addressed why conifers are avoided as street trees (Almas et al., 2016; Aven et al., 2016). One concern is that the low-hanging foliage and the dense canopy of conifers limit visibility for pedestrians and drivers alike (Xin & Brimblecombe., 2020). Thus, it would be hazardous for drivers and pedestrians if these tree species were planted alongside roads (Davey Resource Group, 2011). The dense conical shape of conifers is problematic if they are planted near or underneath power lines. There is concern over the amount of maintenance required to avoid causing damage to the surrounding infrastructure and the tree itself (Straigyte, 2012). Indeed, damage to conifer trees in keeping them away from powerlines is inevitable.

Despite conifers' superior ability to provide canopy-dependent services throughout the entirety of the year, there are negative implications among the benefits that are discussed. One implication is the shade that is cast during the winter months; the shade cast by conifers can prevent ice from melting on the road surface (Clapp et al., 2014). Evidently, this creates safety concerns for drivers and pedestrians. Alternative planting locations to avoid the aforementioned concerns associated with conifers is one way to increase the conifer population in the urban forest (Aven et al., 2016). Incorporating coniferous tree species in areas such as parks, greenways, and larger spaces that have less constrictions on the growth of the tree is ideal (Clapp et al., 2014; Aven et al., 2016). The implementation of conifers in these areas allows for the full array of values while minimizing the concerns. Ultimately, conifers have a space and place in the urban forest; however, it is apparent that the disadvantages associated with conifers outweigh the benefits when planted as street trees along larger roadways (Almas et al., 2016).

2.4.3 The Impacts of Climate Change on Conifers and Non-Conifers

With the exacerbation of climate change, it is important to understand how conifers and non-conifers respond to the effects that are associated with the changing climate. One concern is how tree species will react to an increase in frequency and severity in weather events. The literature shows that certain species of conifers such as spruce, have shallow roots which can lead to weak anchorage, and creates concern surrounding their blow down potential (Achim & Nicoll, 2009; Dobrowolska, 2015). Whereas non-conifers such as species of Maple (*Acer*) and Oak (*Quercus*) have root systems that allow for a lower blow down potential (Dobrowolska, 2015). The literature further suggests that as local temperatures continue to increase and the environment becomes drier, conifers will require prolonged periods of time to regenerate in the naturalized setting (Tepley et al., 2017). Contrasting conifers, non-conifer species are expected to endure the increased temperatures; Ghirardo et al. (2021), identify that non-conifers have a higher plasticity which enables them to acclimate to the changing climate (Ghirardo et al., 2021).

2.5 Knowledge Gaps

In my assessment of conifers in the urban forest, it has become apparent that there is scant literature that focuses directly on this topic. There is considerable literature on non-conifer trees in the urban forest, yet the conversation of conifer trees in the urban forest is relatively paltry. Most of the findings surrounding conifers in the urban forest are brief and scattered in small concentrations within the topic of non-conifer tree species. The high abundance of literature based on non-conifer trees is in part due to the current practice of urban foresters to plant mostly non-conifers in the urban forest. Fortunately, there is an excellent report that directly addresses conifers in the urban forest: Clapp and his colleagues are the main contributors in analyzing coniferous trees and the urban environment. Despite the research that Clapp et al. (2014) has completed, there are still significant gaps in the literature surrounding conifers in the urban forest.

2.6 Summary of Literature Review

This literature review has profiled conifer tree species in the urban forest, especially in terms of the values they offer, the tolerance of conifers to urban stressors, and their place within the urban forest. It has reviewed how the incorporation of more conifers could strengthen the urban forest and ultimately improve the urban environment while identifying the importance of planting conifers in a location where they can provide services and be minimally impacted from their surrounding environment. There is room for more research on the relationship between conifers and the urban forest, and the benefits that conifers can have in the urban environment.

Chapter III: Methods

3.1 Overview of Methods

This project assessed the conifer density that exists on three scales: the urban forest of the Halifax Peninsula, the peri-urban forest in surrounding communities, and the hinterlands of the Halifax Regional Municipality. The assessment was conducted partly via the collection of conifer tree data across selected blocks on the Halifax Peninsula. Once these data were collected, a map was created in ArcGIS to depict the spatial pattern of identified conifers. To assess the conifer density in the surrounding communities and the hinterlands of the HRM, an analysis of the i-Tree Eco dataset surrounding communities (see Foster & Duinker, 2017) and the Provincial Forestry Inventory Database (hinterlands of the HRM) was conducted. Lastly, to develop a contextual perspective on the conifer density within the Halifax urban forest, 37 other Canadian cities' tree inventory summaries were analyzed, allowing for comparison across cities.

3.2 Study Area

3.2.1 Entire Study Area

The study area consists of three spatial extents: the Halifax Peninsula, the surrounding communities, and the hinterlands of the Halifax Regional Municipality. Another way of describing this gradient is urban forest, peri-urban forest, and hinterlands/naturalized forest.

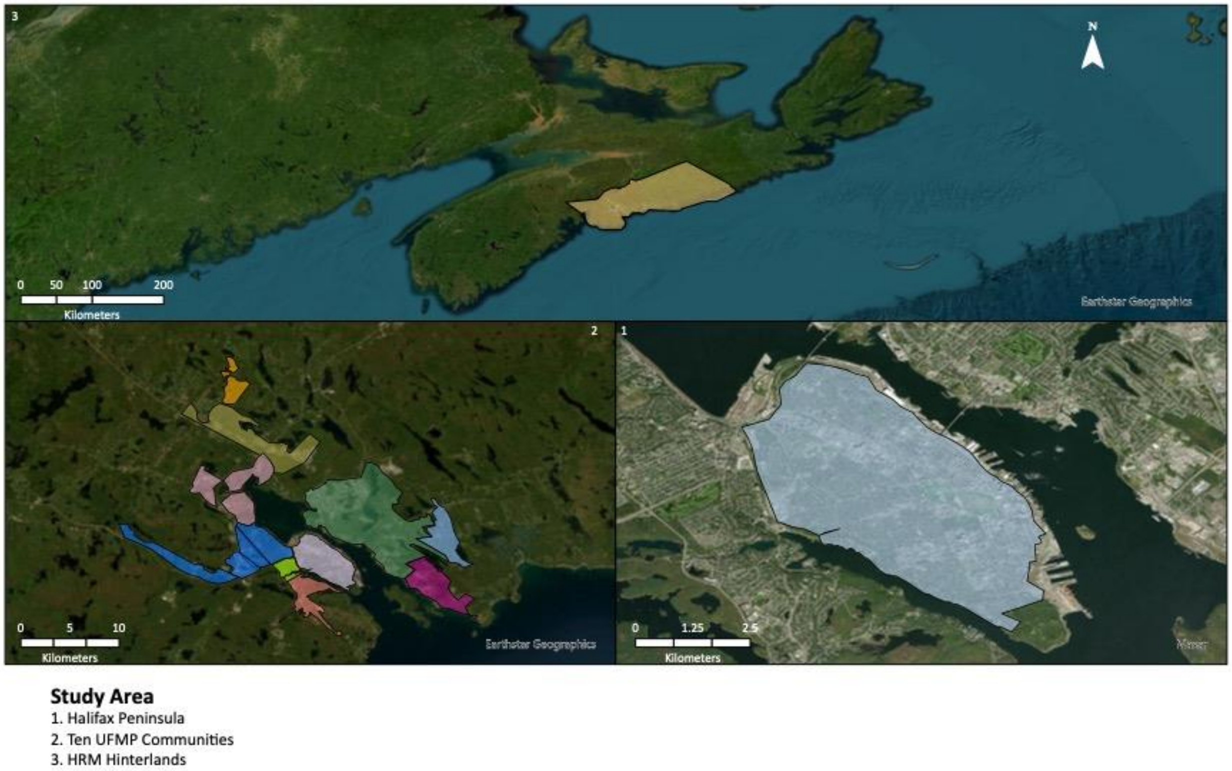

Figure 3.1 Three study areas selected for conifer density assessment: (1) Halifax Peninsula, (2) Ten UFMP communities, and (3) the hinterlands of the HRM.

3.2.2 The Halifax Peninsula

The Halifax Peninsula is divided into eight neighbourhoods as outlined and defined by the Halifax Urban Forest Master Plan (HRM, 2013). The total area of the study area is 1171 ha (HRM, 2023) and does not include Point Pleasant Park nor Africville Park.

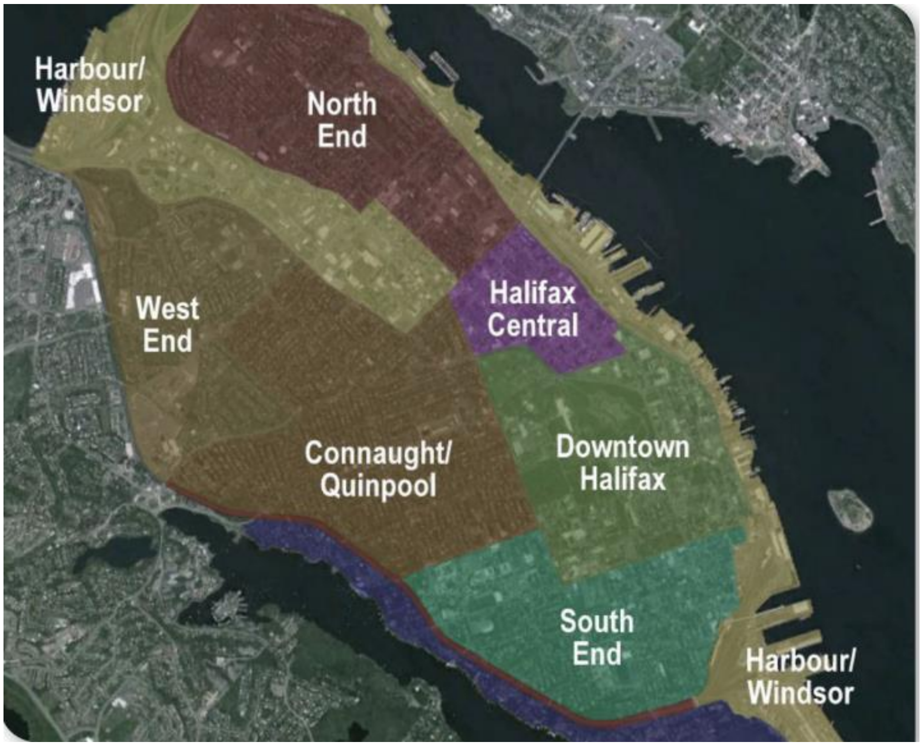

Figure 3.2 The eight neighbourhoods on the Halifax Peninsula as outlined by the HRM Urban Forest Master Plan. Retrieved from: HRM, 2013.

3.2.3 Surrounding Communities

The second study area is the UFMP communities. This area is separated into nine communities that are outlined in the HRM Urban Forest Master Plan (HRM, 2013). This study area represents the peri-urban forest, the beginning of the transition from the urban to the rural environment (Blood et al., 2016). It is important to note that the term “surrounding communities” will be used interchangeably with “UFMP communities”.

Figure 3.3 The communities as outlined in the HRM Urban Forest Master Plan.

3.2.4 Hinterlands of the HRM

The hinterlands of the Halifax Regional Municipality represent the largest study area of the project. The HRM is divided into two regions, Halifax East, and Halifax West (Figure 3.5).

Figure 3.4 The division of the Halifax West and the Halifax East regions that form the Halifax Regional Municipality.

3.3 Data Collection

3.3.1 Block Selection

The primary data collected for this project were the conifer densities on the Halifax Peninsula. The data were collected on a sample of all possible city blocks, so it was not a census of all the conifers on the Halifax Peninsula. A sample of approximately 1/3 of all the street blocks within the eight neighbourhoods would give a statistically sufficient representation of the conifer density. The blocks were selected randomly using Microsoft Excel. Point Pleasant Park was not selected as an area, as it has an established conifer population; moreover, it is not included as part of the eight neighbourhoods on the Halifax Peninsula.

3.3.2 Field Methods

Once the sample blocks were identified, data collection commenced using an ocular estimate technique. This technique relies on visual observations. From the street environment, the research team would search for all conifer trees visually and identify each to the species level (or genus if species could not be determined from a distance – as the data was collected from outside private property), the size class of the individual tree – which was delineated into categories of small, medium, or large, and the block/neighbourhood within which it was located. Once the observation was made, the data were entered onto a physical observation sheet, then later digitized into a master inventory using Microsoft Excel.

3.4 Data Analysis

3.4.1 Analysis of Halifax Peninsula Conifer Inventory

Using the Microsoft Excel, the data were split into respective neighbourhoods and analysed in terms of conifer density, conifer species richness, and conifer species abundance per block. As only the conifer trees were identified, calculating the conifer proportion for this scale wasn't possible; the non-conifer population would be required to produce this calculation.

3.4.2 ArcGIS Analysis

The data were transferred from the spreadsheet software into ArcGIS mapping software. A map was then created to indicate, block by block, the location of conifers on the Halifax Peninsula. Each sampled block, represented as a polygon, was assigned all the data of the conifer trees it contains for analysis of conifer density, species abundance, and species richness.

3.4.3 Analysis of the i-Tree Eco dataset

Within the i-Tree Eco dataset, this project focused on the plot type and the species composition within each plot. This dataset contains 20 plots in each of the ten UFMP communities, thus, there are 200 plots in total. Each plot is 0.0405 ha in extent and is geographically categorized as being within a residential area, a vacant area, a transportation area, a multi-family residential area, a park, or a commercial/industrial area. All plots were randomly placed within the communities. The analysis of these data began by creating three categories in which data would be placed in: native conifers, non-native conifers, and non-conifers. Through assigning each recorded tree to one of three categories, I assessed the plot composition. Therefore, once the species composition of the plot is known, the conifer density within each plot was calculated. Once the conifer density in each plot is known, then conifer density per community was calculated. To ensure consistency across the communities, the analysis assessed all 20 plots in each community regardless of where the plots fell spatially.

3.4.4 Analysis of the Nova Scotia Provincial Forestry Inventory

The provincial forest inventory includes data at the stand level (NSDNR, 2022). This study is focused on determining the conifer proportion within each stand in the hinterlands; thus, it focused on each stand's species composition. Each stand is characterized by the four most abundant tree species in categories of ten percentage points of the total composition. The species composition led to the determination of the conifer proportion within each stand and ultimately the conifer proportion that exists in the hinterlands. For the purpose of this study and to simplify numerical analysis, only the three most abundant species within each stand were noted. Moreover, the analysis only included three out of the four most abundant species as the fourth most abundant species was rarely noted within the provincial forest inventory dataset (FID). The end calculation was a conifer proportion rather than a conifer density, as the stand composition within the dataset was given based on the canopy cover proportion per species.

3.4.5 Analysis of other Canadian Cities UFMP

The analysis took Urban Forest Master/Management Plans (UFMP) of 37 cities into consideration. The assessment of these cities' UFMPs was to determine the tree species composition within other Canadian cities, thus allowing a comparison with the Halifax urban forest. The main interest here is to understand the conifer population of a range of Canadian cities, effectively determining whether the conifer density in the Halifax urban forest is abnormal or consistent with other cities across Canada.

3.5 Limitations

The data collection process has several limitations that could represent potential sources of error. The data collection followed an ocular estimation technique, which means that the accuracy of the data is dependent on the reliability of the person collecting the data. Within the research team, there is diversity among the individuals that must be taken into consideration; each researcher is a different height, has different visual acuity, and has different experience with conifer identification. Additionally, the replicability of the data collection is essential for data accuracy; the entire data collection process must follow the same steps to ensure consistent data collection. Furthermore, the data collection process took place during the month of May. This presented some issues in that the non-conifers were starting to grow leaves and that meant increased difficulties first to find the conifers and then to identify their genus. Conducting this data collection during the winter months when only coniferous tree species have their leaves would allow for better visibility and have less potential for error.

Another limitation was the inability to access several cities' UFMPS. During the analysis of the UFMPs I could find, several did not reveal a tree inventory. As not every UFMP and inventory was accessible, there was little representation from Quebec and Alberta, and none from Manitoba nor Prince Edward Island, creating spatial bias in the comparison of conifer abundances across Canadian cities.

Chapter IV: Results

The following section characterizes the conifer density on the Halifax Peninsula, the nine other UFMP communities, and the hinterlands of the Halifax Regional Municipality. Ultimately, defining the degree to which the conifer gradient exists in the transition from the urban to woodland setting.

4.1 Halifax Peninsula

There is a low conifer density in the eight neighbourhoods on the Halifax Peninsula. The North-West Arm is an anomaly in terms of its elevated conifer density. Aside from the one exception, it is evident per Figure 4.1 that the conifer distribution among the neighbourhoods is fairly even, with the lower tail of the distribution belonging to the Windsor/ Harbourfront neighbourhood with 0.26 conifers per hectare and Downtown Halifax with a density of 0.75 conifers per hectare.

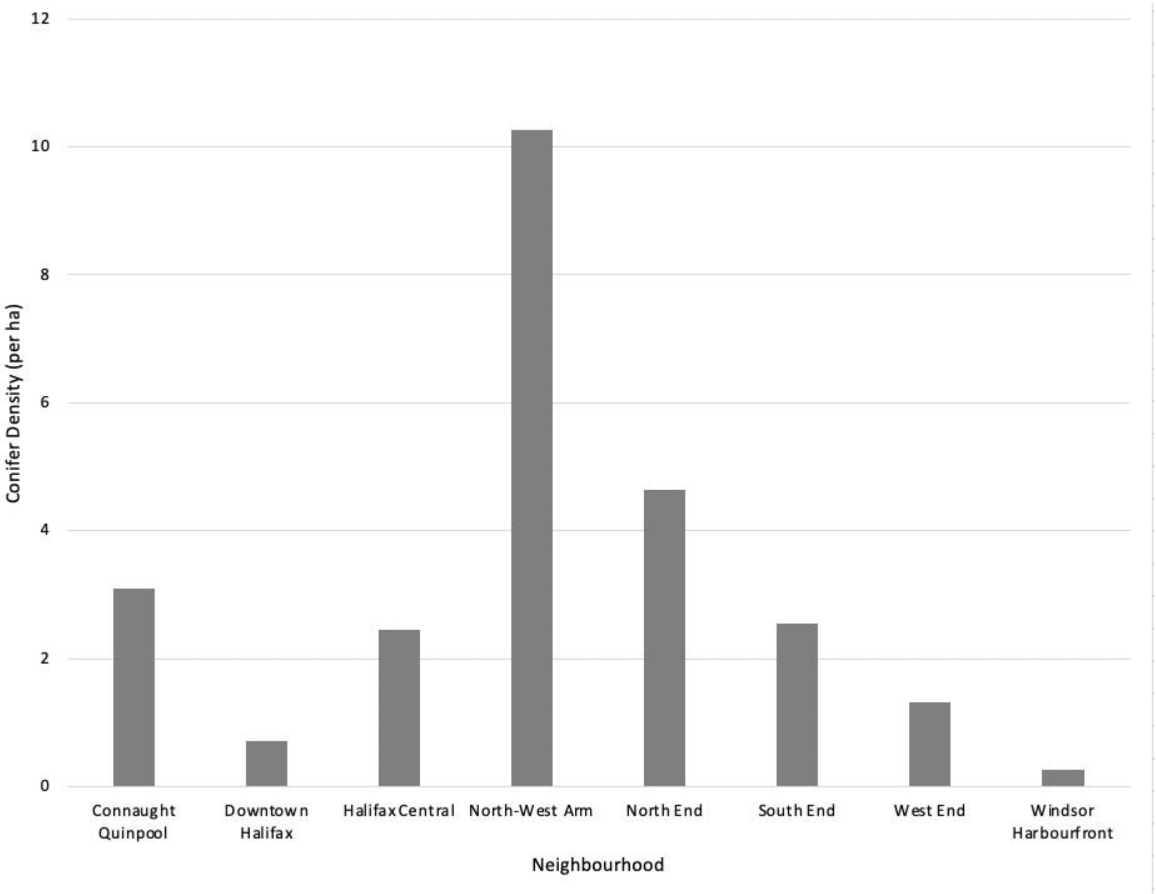

Figure 4.1 The conifer density per hectare in the eight neighbourhoods on the Halifax Peninsula.

There is no discernable spatial pattern in the conifer density of the sampled blocks within the eight neighbourhoods on the Halifax Peninsula (Figure 4.2), nor grouping of areas with higher conifer densities; the distribution is relatively even across the entire peninsula. However, there is one anomaly – the North-West Arm neighbourhood. There, the sampled density was calculated to be 10.28 conifers per hectare; this is more than twice the conifer density of the next most conifer-dominated neighbourhood. The other seven neighbourhoods were relatively similar in their conifer densities: five fall into the density class of 2.01-5.0 conifers per hectare and two in the density class of 0-2.0 conifers per hectare.

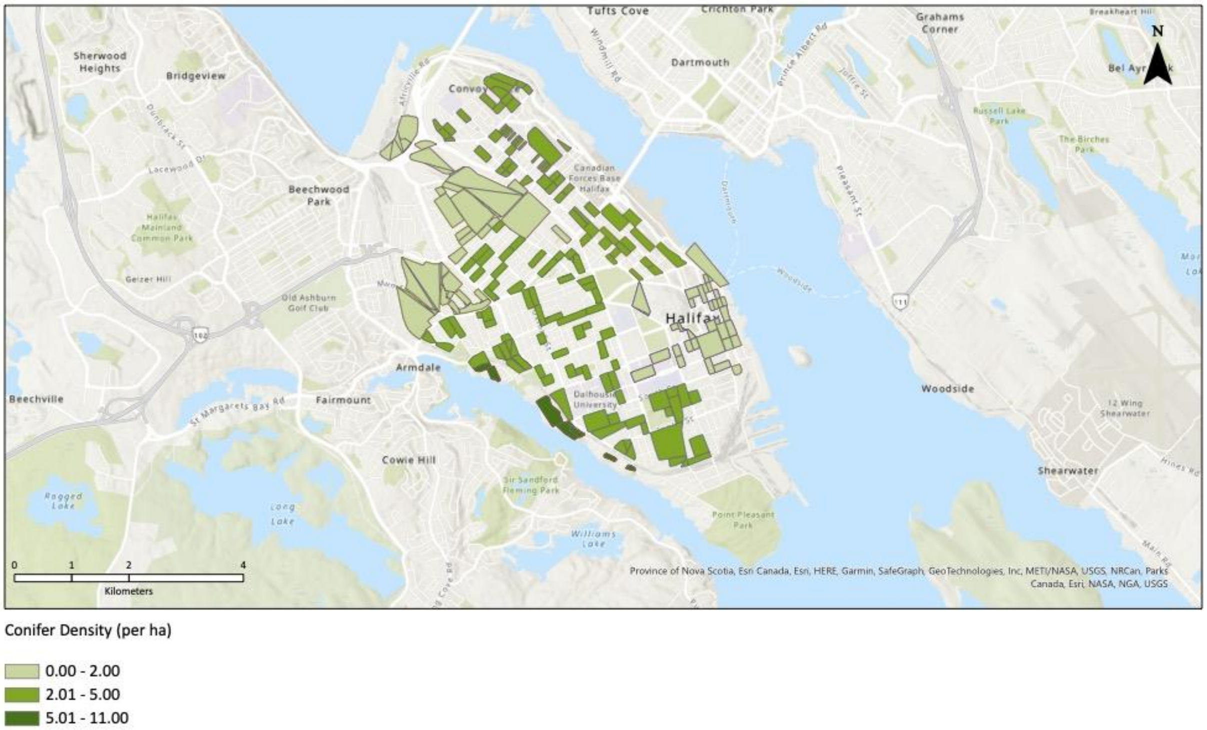

Figure 4.2 Map of the eight sampled neighbourhoods on the Halifax Peninsula organized into a conifer density gradient (per ha).

From sampling one third of the Halifax Peninsula, 1988 trees were identified. As evident in Figure 4.3, the sampled blocks were dominated by species in the *Picea* genus - 920 individual trees. On the lower end of the spectrum, only 20 trees were identified as being part of the *Abies* and *Larix* genera.

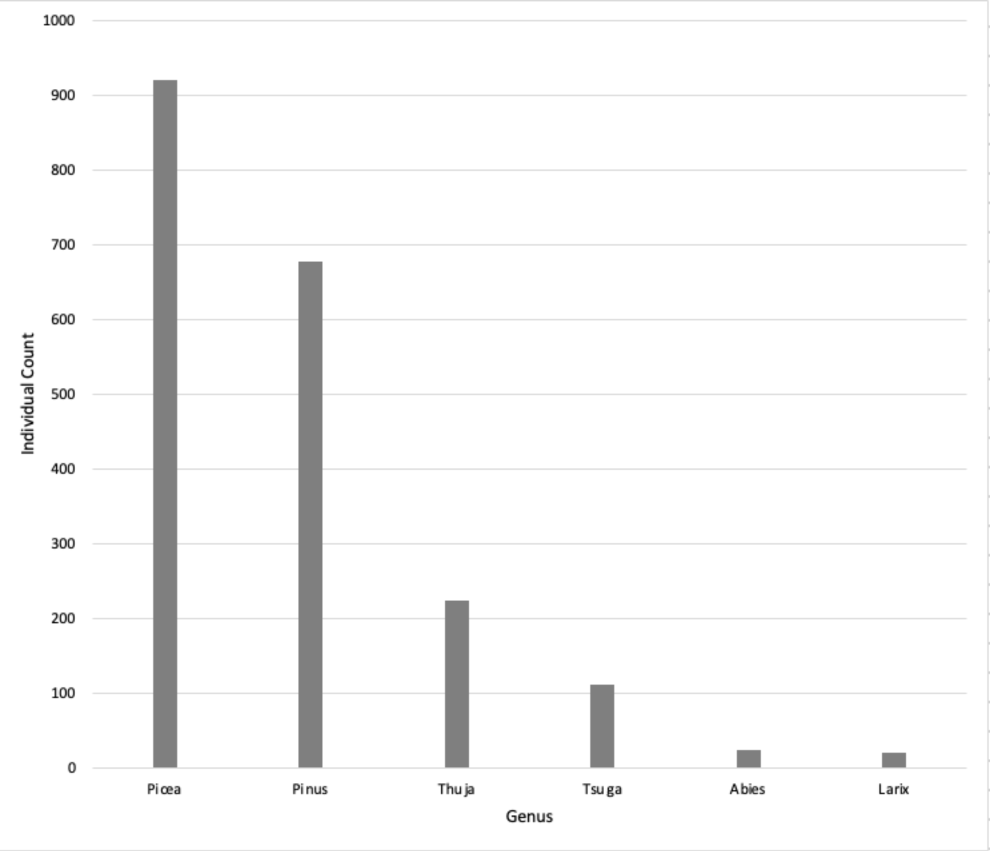

Figure 4.3 The abundance of the identified conifer genera on the Halifax Peninsula.

Moreover, it can be seen in Table 4.1 that spruce trees are prominent in most of the neighbourhoods, with the lowest composition belonging to the Windsor/ Harbourfront neighbourhood with 21% of the identified trees being a part of the spruce genus. Contrasting Windsor/Harbourfront is the North End which had 82% of its sampled trees belonging to the spruce genus.

Table 4.1 The percent composition of spruce species in each of the eight neighbourhoods.

Neighbourhood	Spruce Genus Percent Composition (%)
Quinpool/ Connaught	48
Halifax Central	57
Downtown Halifax	23
North End	82
North-West Arm	39
South End	41

West End	41
Windsor/ Harbourfront	21

4.2.0 The Surrounding Communities

In assessing the UFMP communities' conifer proportion, it is apparent from Figure 4.4 that there is a trend suggesting that communities further away from the urban centre (the Halifax Peninsula) have higher conifer proportions. The communities furthest away from the Halifax Peninsula are Beaver Bank, Cole Harbour, and Dartmouth which have conifer proportions in the highest range (55%-65%).

However, this pattern doesn't necessarily hold true as the communities closest to the urban centre, which are Ashburn/Armdale, the Halifax Peninsula, and Spryfield, all have conifer proportions within the range of 35%-55%, not in the 26%-35% range. Furthermore, it should be noted that the conifer proportion within the UFMP communities is heavily dominated by native conifer species. Out of all the conifers identified in all plot types, non-native conifers account for 0.85% of conifer trees.

Figure 4.4 The conifer composition proportion throughout the ten UFMP communities.

Within the iTree-Eco dataset that characterizes the ten UFMP communities' conifer density, the data can be delineated into urban plots and woodland plots; the threshold/distinction between plots was decided by those in charge of the data collection – David Foster and Dr. Peter Duinker. It was found that in nine of the ten communities, more plots fell into the urban plot category; in these nine communities, there were considerably more urban plots than woodland plots. However, Beaver Bank is an anomaly as it has more woodland plots than urban plots. The distribution of plots can be seen in Table 4.2.

Table 4.2 The distribution of urban and woodland plots in each of the ten UFMP communities.

Community	Woodland Plots No. Plots	Urban Plots No. Plots
Ashburn/Armdale	4	16
Beaver Bank	11	9
Bedford	7	13
Cole Harbour	3	17
Dartmouth	5	15
Eastern Passage	6	14
FBLT	4	16
Halifax Peninsula	2	18
Sackville	8	12
Spryfield	7	13
Total	**57**	**143**

The woodland plots have a substantially higher conifer density than the urban plots (Figure 4.5). Out of the ten communities, Beaver Bank and the Halifax Peninsula have the largest range in conifer density between their urban plots and their woodland plots. Beaver Bank generated 19 conifers per hectare in its urban plots and 1306 conifers per hectare in its woodland plots while the Halifax Peninsula has 4 conifers per hectare in its urban plots and 1061 in its woodland plots. Within the Halifax Peninsula, there were only two woodland plots and 18 urban plots– the largest spread in plots throughout all ten communities. The two woodland plots on the Halifax Peninsula were both in Point Pleasant Park.

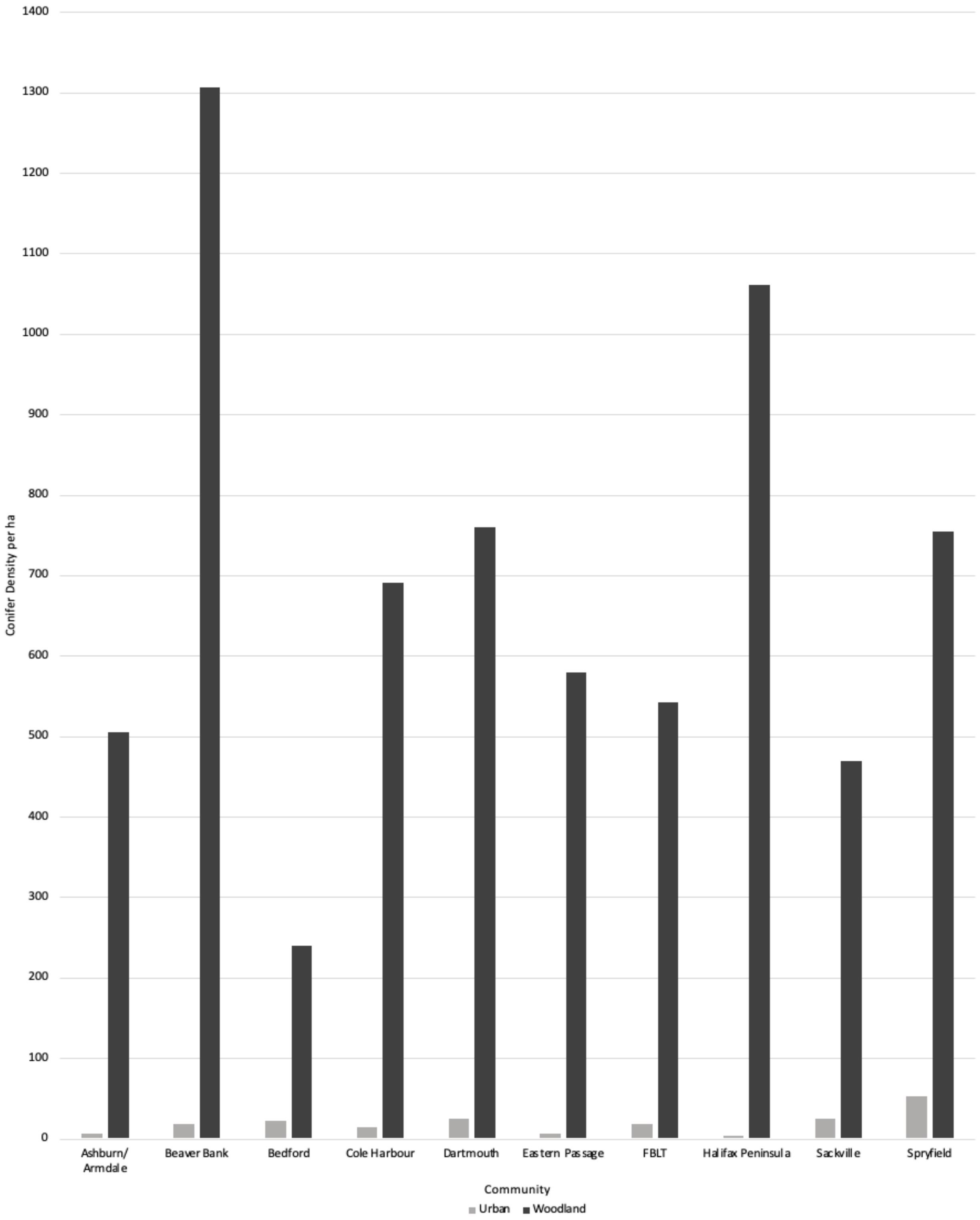

Figure 4.5 The comparison of urban plot conifer densities to the conifer densities of woodland plots in each of the ten UFMP communities.

4.2.1 Surrounding Communities' Urban Plots

The conifer density within the UFMP communities' urban plots is consistently low except for spikes in the Spryfield community (Figure 4.5). This consistency can be seen in Figure 4.6, where it becomes evident that there is a correlation between spatial location of the community and conifer density in the urban plots. The conifer density in the urban plots does increase in moving away from the urban core. However, Beaver Bank, being the furthest away from the urban centre, only has an urban conifer composition of 19 conifers per hectare, effectively showing that this trend isn't consistent. Additionally, it can be seen through Table 4.2 and Figure 6 that the communities with the most urban plots – the communities with the most urbanization, are those that have the lowest conifer densities: Ashburn/Armdale, Eastern Passage and the Halifax Peninsula.

Figure 4.6 The conifer density (per ha) in the urban plots of the UFMP communities.

The conifer density in the UFMP communities' urban plots is substantially higher than the conifer densities in the eight neighbourhoods on the Halifax Peninsula (Figure 4.7). The only exception is the North-West Arm neighbourhood on the Halifax Peninsula - it has a higher conifer density per hectare than Ashburn/Armdale, Eastern Passage, and Halifax Peninsula communities.

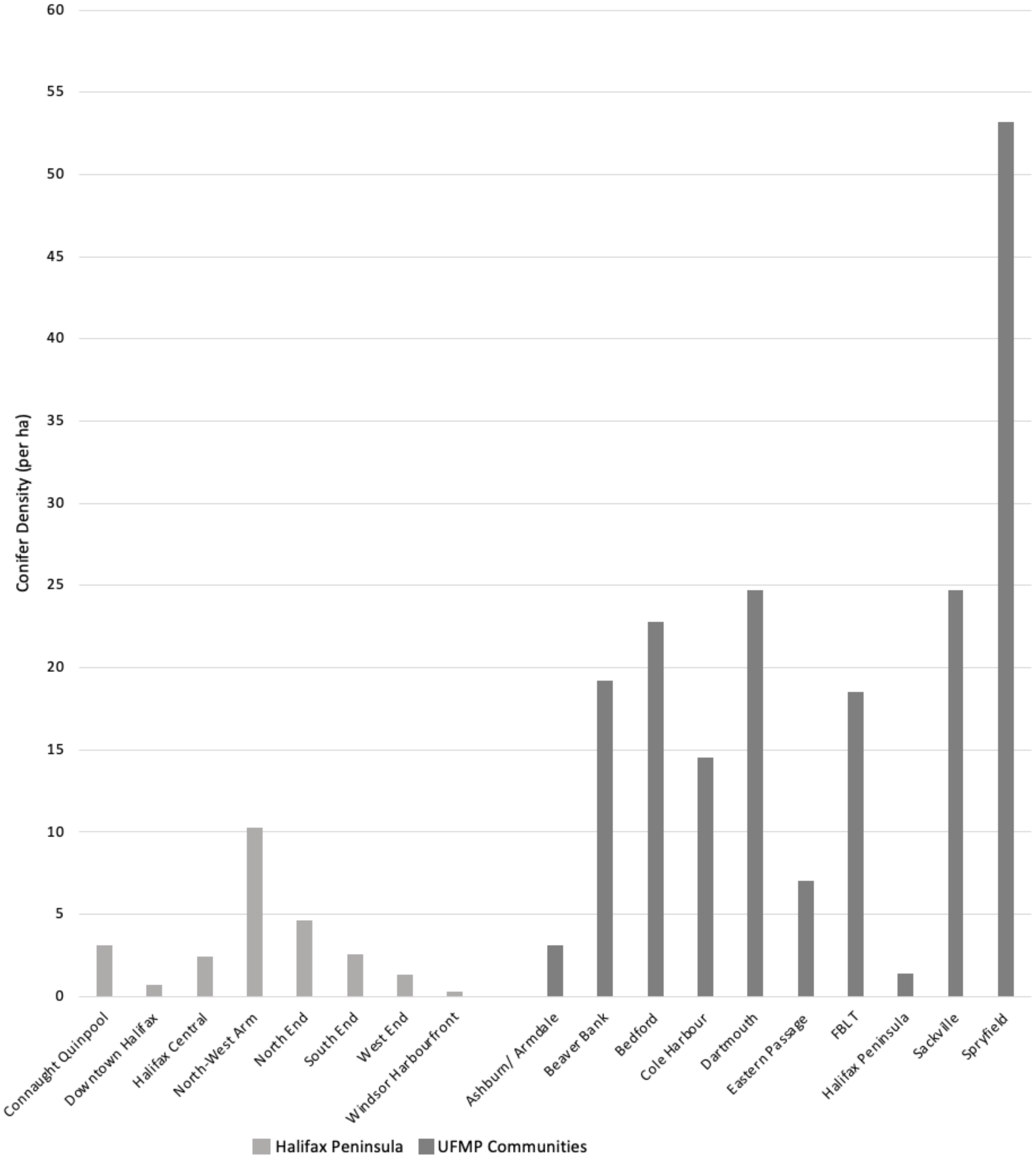

Figure 4.7 The conifer densities in the eight neighbourhoods on the Halifax Peninsula versus the conifer densities in the urban plots in each of the ten UFMP communities; the collection in the eight neighbourhoods did not include Point Pleasant Park.

4.2.2 Surrounding Communities' Woodland Plots

As per Figure 4.8, Beaver Bank and the Halifax Peninsula have the highest conifer densities in their respective woodland plots and Bedford has the lowest conifer density in its woodland plots. There are no trends identified from the woodland plots.

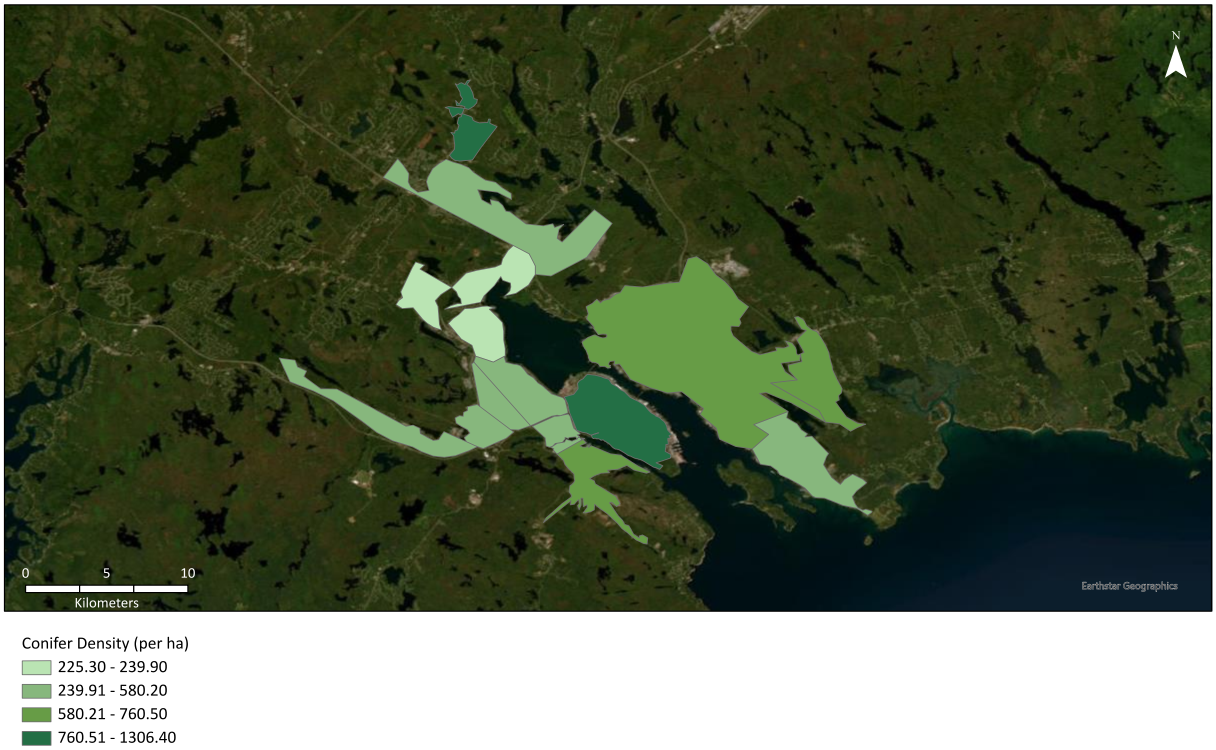

Figure 4.8 The conifer density (per ha) in the woodland plots of the UFMP communities.

It is apparent that there is a difference between the conifer densities in the eight neighbourhoods on the Halifax Peninsula and in the woodland plots of the UFMP communities (Figure 4.9). In looking at the conifer density that exists in the eight neighbourhoods of the peninsula and the density that exists in the woodland plots in the Halifax community, it is evident that the density from the i-Tree dataset (woodland plots) is substantially higher.

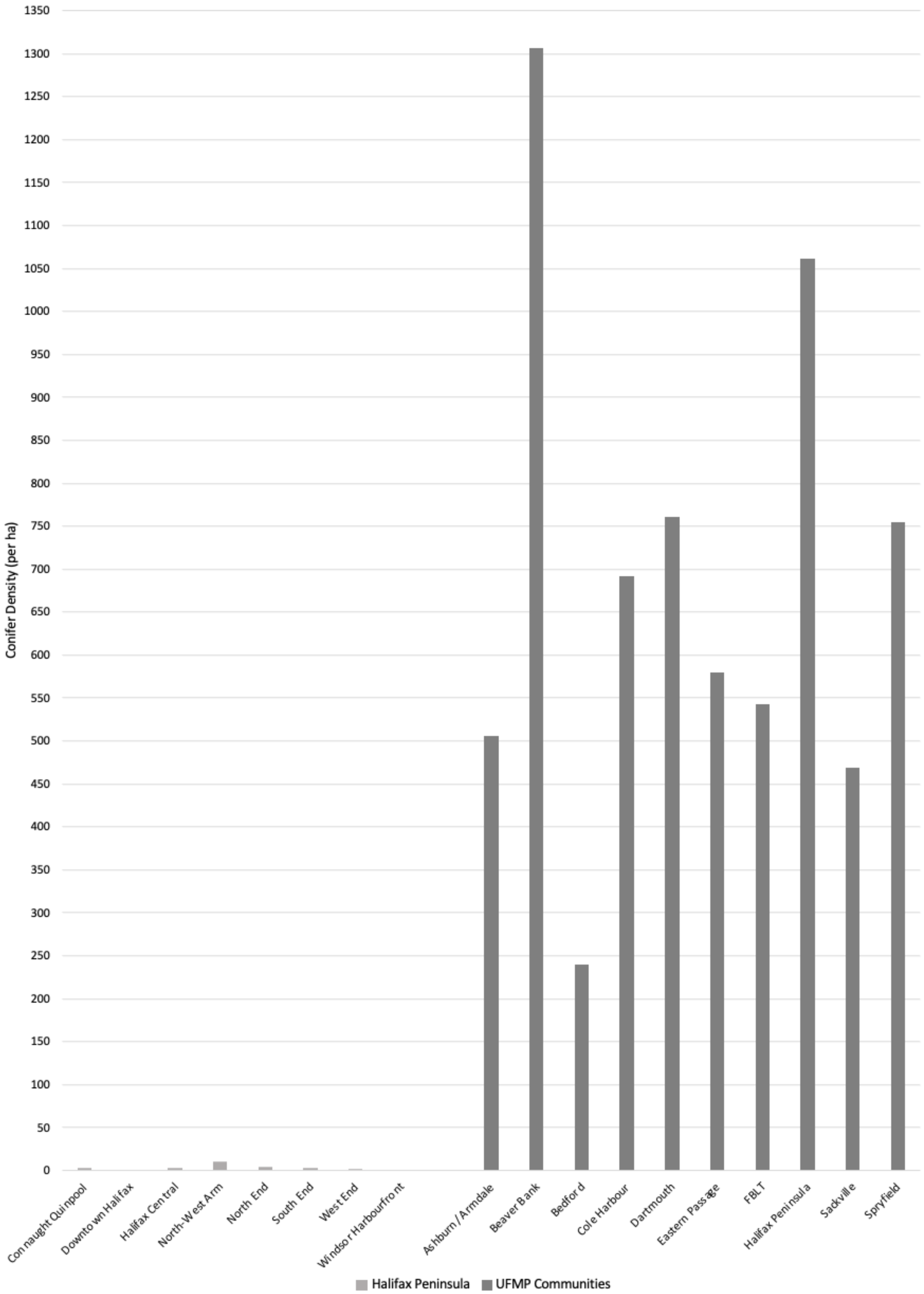

Figure 4.9 The conifer densities in the woodland plots of the ten UFMP communities compared to the eight neighbourhoods on the Halifax Peninsula; the sampling in the eight neighbourhoods did not include Point Pleasant Park.

4.2.3 Surrounding Communities' Combined Data

From Figure 4.10, the combined data from the urban plots and the woodland plots has considerably higher conifer densities than the sampled neighbourhoods on the Halifax Peninsula. Evidently, the combined densities for the UFMP communities are considerably lower than the woodland density.

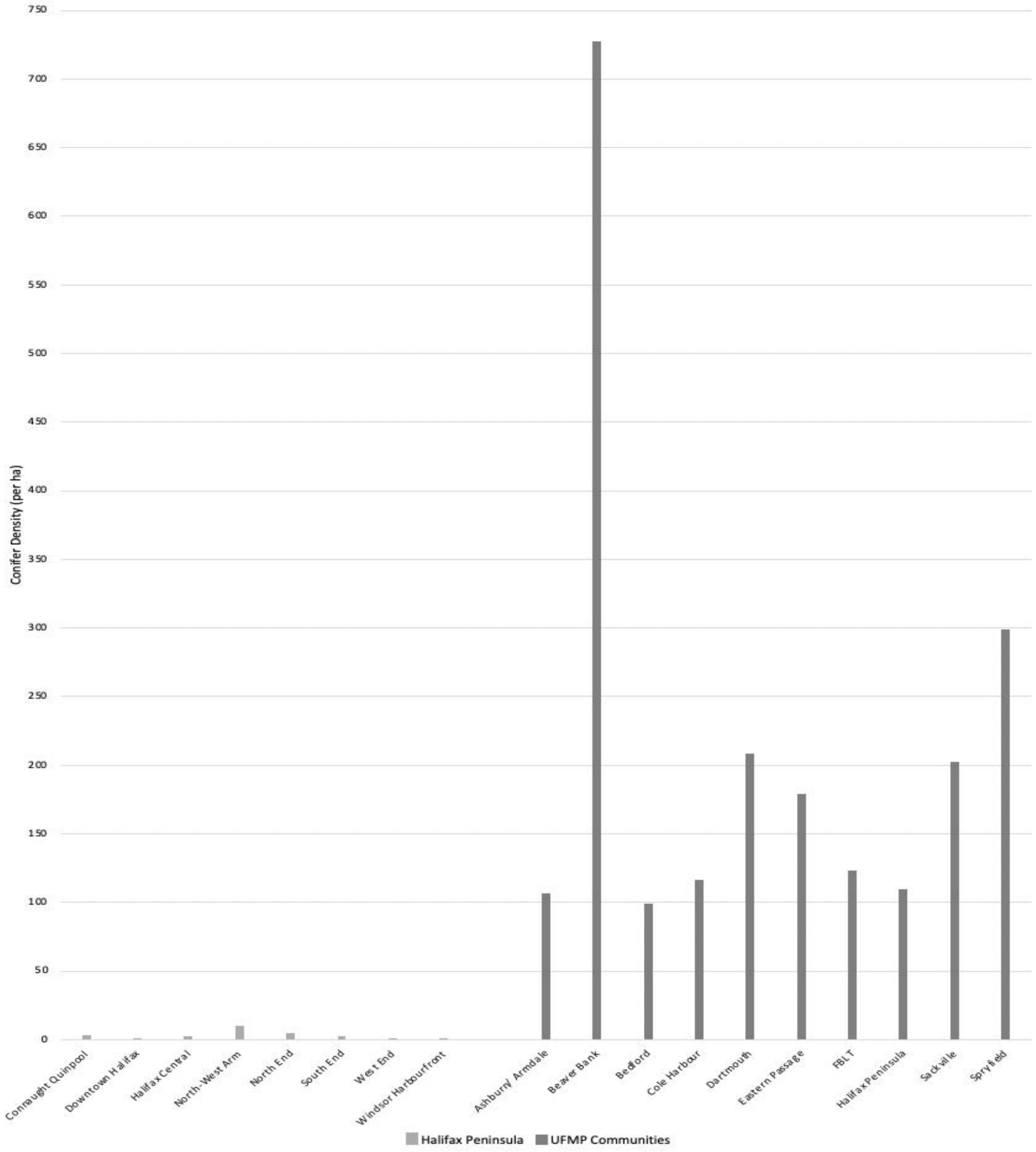

Figure 4.10 The combined density of the urban and woodland plots in the ten UFMP communities compared to the conifer density in the eight neighbourhoods on the Halifax Peninsula – the data in the eight neighbourhoods does not include Point Pleasant Park.

It is clear that the conifer density data obtained from the i-Tree Eco dataset for the Halifax Peninsula is lower than the average for the other communities (Figure 4.11). As mentioned, the elevated conifer density in the woodland plots is a result of the plots being placed in Point Pleasant Park. Within the urban plots, the Halifax Peninsula is substantially lower than the average of the other UFMP communities. Overall, the Halifax Peninsula holds a lower conifer density than the average of the other nine UFMP communities.

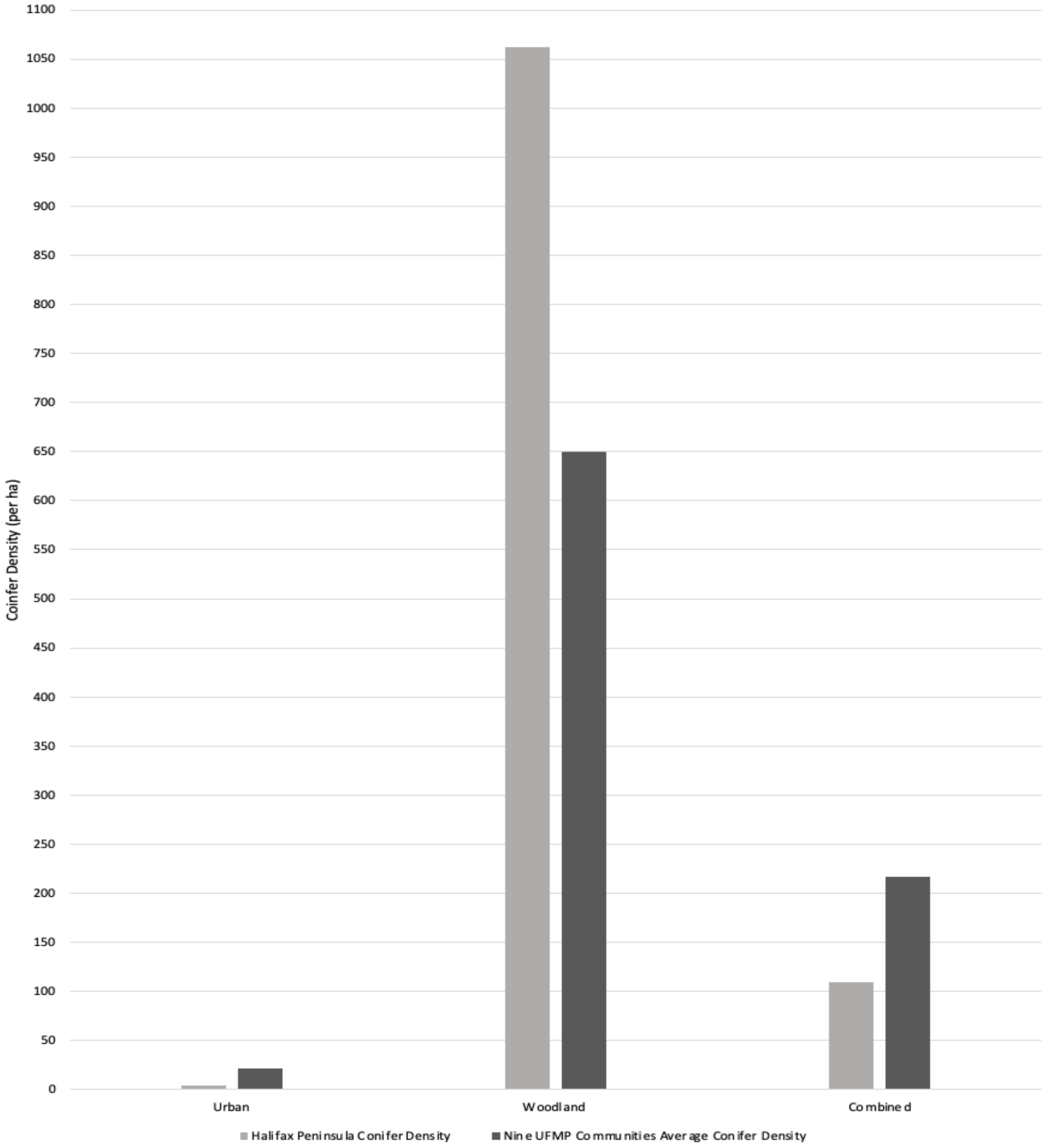

Figure 4.11 The conifer density of the Halifax Peninsula community (extracted from the iTree-Eco dataset) compared to the average conifer density for the other nine UFMP communities. The data are delineated into three categories: Urban, Woodland, and Combined.

4.3 Hinterlands of the Halifax Regional Municipality

Through the assessment of the provincial forest inventory, it became clear that conifers dominate the canopy in the hinterlands of the Halifax Regional Municipality. The proportion of conifers in both Halifax West and Halifax East is distinct. The proportion of conifers in Halifax East was calculated to be 76%, and 61% in Halifax West. This difference in proportion is large enough to warrant keeping the two areas separate for this analysis.

As seen in Figure 4.12, the conifer proportions in the hinterlands are relatively similar to the woodland plots in the UFMP communities. Among the ten communities, Bedford is the only community to have a conifer proportion under 40%; the other nine communities are similar with conifer proportions ranging between 43% and 69%. This indicates that the composition in the woodlands of the peri-urban area (UFMP communities) is fairly similar to the conifer proportion in the woodland forests of the HRM.

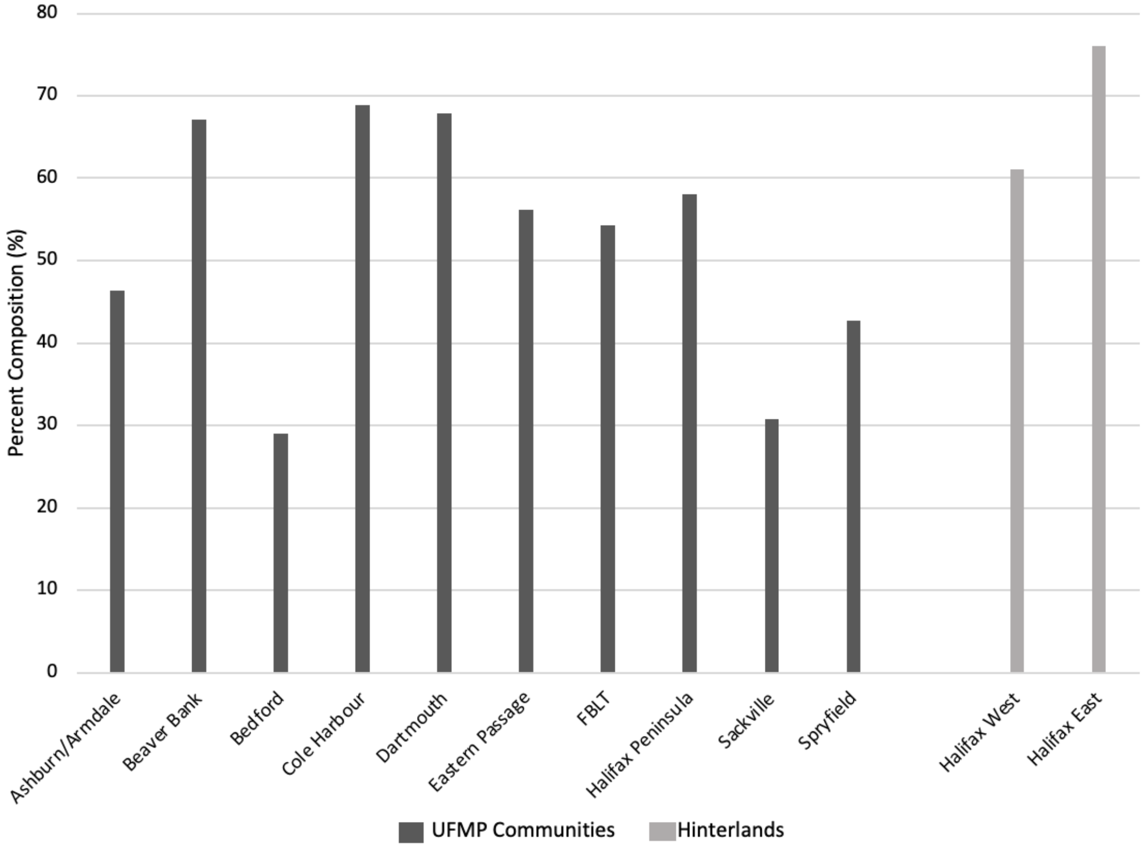

Figure 4.12 A comparison of the conifer proportion in the ten UFMP communities' woodland plots and the conifer proportion in the hinterlands of the Halifax Regional Municipality.

In contrast to the woodland plots, there is a considerable difference in the conifer proportion from the urban plots to the conifer proportion in the hinterlands. As per Figure 4.13, the majority of communities have urban plots with conifer compositions of less than 40% with two communities that exceed this mark. This is consistent with the idea that the conifer density/proportion will increase as one moves from the urban setting to the woodland setting. The Halifax Peninsula has the lowest conifer proportion within its urban plots (6% of all trees are conifers); this further supports the notion that conifers are less prominent in urban areas than in naturalized woodlands.

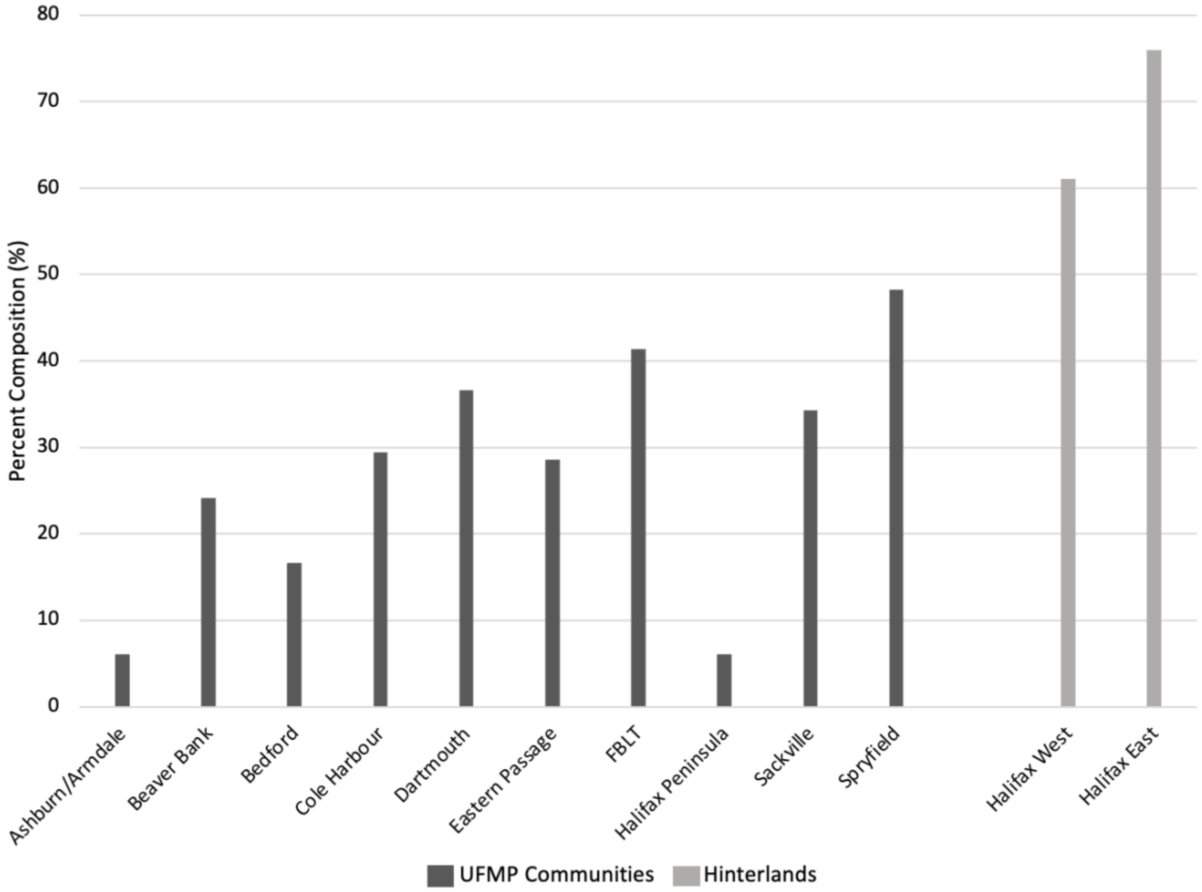

Figure 4.13 A comparison between the conifer proportion in the urban plots of the ten UFMP communities and the conifer proportion in the hinterlands of the Halifax Regional Municipality.

4.4 UFMP of other Canadian Cities

Supplementary analysis of 37 other Canadian cities' UFMPs was conducted to compare the conifer abundance in the Halifax urban forest to other cities across the country. Of the 37 UFMPs, only 15 were identified to have conifers in relatively high abundance in their urban tree inventories. Across these 15 UFMPs, the respective conifer proportions in most were relatively low - only three had an urban forest species composition with more than 20% of the trees being conifers. These cities were Edmonton AB, Kamloops BC, and Toronto ON. Each of these cities had a unique species that was the most abundant.

In the 15 tree inventories that included conifers, the lowest confer proportion was found in Burlington ON, with seven percent of their tree inventory being conifer genera. Contrasting Burlington is Edmonton AB, with 25% of its tree inventory being coniferous. Within these 15 cities, out of the five identified conifer genera, spruce was the most abundant in eight of the cities; followed by cedar in four and pine in three (Figure 4.14). Both fir and larch were limited in their abundance in all 15 cities. These findings were mostly consistent with the species composition in the Halifax urban forest.

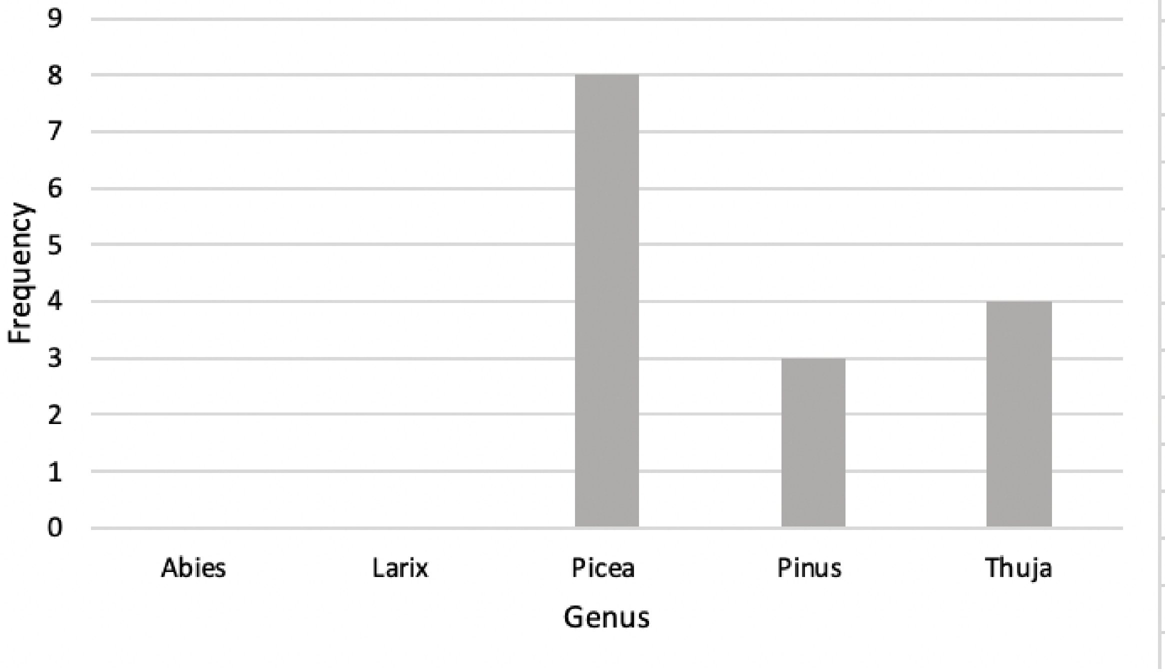

Figure 4.14 The most abundant conifer genera across the other cities UFMPs.

Chapter V: Discussion

The conifer density on the Halifax Peninsula was determined to be lower than in the other UFMP communities and in the hinterlands of the HRM. The conifer density in the eight neighbourhoods is relatively low across the entire peninsula (Figure 4.1). In seven of eight neighbourhoods, the conifer density was less than or equal to 4.6 conifer trees per hectare. However, among the low conifer densities is one outlier, the North-West Arm, with a conifer density of 10.28 conifers per hectare. Though this is still a relatively low conifer density, it is more than twice the density of the next highest neighbourhood, the North End. The elevated conifer density in the North-West Arm neighbourhood can be attributed to its lower housing density. The housing in this neighbourhood was developed with fewer homes on large lots (Wagner, 2007). Thus, with fewer houses, there is more green space in the neighbourhood. The combination of a lower housing density and more green space allowed for considerable amounts of natural succession to take place here. Evidently, the succession that took place favoured the regeneration of conifer species leading to the elevated conifer density. In addition to the natural regeneration in this neighbourhood, the elevated conifer density may in part be a result of residential plantings favouring conifer species. Contrasting the North-West Arm are the Windsor/Harbourfront and the Downtown Halifax neighbourhoods; these neighbourhoods have conifer densities of 0.26 and 0.75 conifers per hectare (Figure 4.2). Both areas have relatively low conifer densities due to the dense built infrastructure that occupies the space. It is predictable that the Windsor/Harbourfront neighbourhood would have the lowest conifer density among the eight neighbourhoods; it consists of industrial and commercial buildings on large lots (e.g., car dealerships and shipyards) where one would not expect to see an abundance of any kinds of trees. This study cannot directly compare the conifer density to the overall tree population in the Windsor/ Harbourfront, as the non-conifer population was not identified; therefore, it is somewhat unknown if this neighbourhood has a low conifer density or has a low tree population as a whole.

In the sampled blocks in each of the eight neighbourhoods on the Halifax Peninsula, six coniferous genera were identified (Figure 4.3). Among these genera, the spruce (*Picea)* and pine (*Pinus)* genera were the most abundant (Figure 4.3). Within the pine genus, 677 trees were identified, with eastern white pine being the most abundant species with 338 trees, followed by Austrian pine (*Pinus nigra* Arnold.) with 201 trees. The elevated count of eastern white pine is what one would predict. This pine species is native to the Halifax region; thus, it naturally grows in this area (Loo & Ives, 2003). Additionally, the conducted sampling of conifer species in the eight neighbourhoods was focused on private property; therefore, most of the eastern white pines identified were located within people's yards rather than alongside the street. If the sampling were focused on trees that are more exposed to urban stressors, there would be substantially fewer eastern white pine trees as they are vulnerable to soil salinity, basic soils, soil compaction, and air pollution (Barlett Tree Experts n.d; Fraedrich, n.d). In more-urbanized areas – i.e., locations where trees were closer to roads and larger infrastructure – Austrian pines were the prominent pine species. The ability of Austrian pines to tolerate the variety of external stressors that the urban environment perpetuates (Cregg et al., 2001; Sawidis et al., 2011; Iowa State University, 2023) makes this species a favoured choice for urban plantings, thus explaining the relatively high frequency of occurrence of this species across the Halifax Peninsula.

In the spruce genus, 920 trees were identified. During the data collection process, the spruce genus was only identified to the genus level, as differentiating between red spruce, white spruce *(Picea glauca* (Moench) Voss), black spruce (*Pinus mariana* (Mill.) BSP), and Norway spruce (*Picea abies* (L.) Karst.) is difficult from a distance. In assessing the distribution of spruce trees, it was consistent across the eight neighbourhoods except for one anomaly, the North End, which had a sampled species composition of 82% spruce trees (Table 4.1). Similar to the eastern white pine, the elevated count of spruce species might be attributed to the fact that red spruce, black spruce, and white spruce are all native species. However, as the identification was only to the genus level, and Norway spruce is a non-native species, the elevated count may also be attributed to the planting of spruce species. Furthermore, their ability to tolerate certain urban stressors such as salt spray (Dirr, 1976; Equiza et al., 2016) allows them to persist in more exposed areas. Opposite to the pine and spruce genera, the *Abies* and *Larix* genera were the least abundant with 20 trees independently identified (Figure 4.3).

When assessing the conifer proportion of the ten UFMP communities, it is evident that the conifer composition is higher in areas that are further away from the Halifax Peninsula (Figure 4.4). It can be seen from Figure 4.4 that communities such as Beaver Bank, Cole Harbour, and the distal parts of Dartmouth that are further away from the Halifax Peninsula have conifer proportions in the highest range (55%-65%). The Halifax Peninsula itself generated an elevated conifer proportion due to the location of two of its i-Tree Eco plots. Two plots were located in Point Pleasant Park. This large, naturalized park has high densities of conifer trees (Steenberg & Duinker, 2010). The natural regeneration of species in Point Pleasant Park following Hurricane Juan (2003) included an abundance of conifers such as red spruce, eastern white pine, white spruce, eastern hemlock, and balsam-fir (Steenberg & Duinker, 2010). Individually, these species have characteristics that allow them to thrive post disturbance events, and together are all native tree species in the Acadian/ Wabanaki Forest region (Loo & Ives, 2003). Ultimately, the data revealing that the Halifax Peninsula has a conifer proportion of 44% is not a result of the Peninsula being dominated by conifers but rather the location of two plots in the regenerating woodland of Point Pleasant Park. This study decided include the plots found in Point Pleasant Park to ensure that all 20 plots across the ten UFMP communities underwent analysis.

Furthermore, throughout all ten UFMP communities and among all the conifer trees that were identified in both urban and woodland plots, the composition of conifer species was dominated by native conifer species; only 0.85% of the registered conifers were non-native species. The dominance of native species aligns with a study conducted by Nitoslawski et al. (2016) which determined that woodland plots are dominated by native tree species. As the majority of conifers were identified within woodland plots, this strengthens the reasoning for the limited abundance of non-native conifers and the dominance of native conifer species.

Within the UFMP communities, the i-Tree Eco data were separated into two plot types: urban and woodland. As per Table 4.2, it is evident that urban tree plots were more abundant than woodland tree plots. This is true for all the communities except for Beaver Bank; this community had nine urban plots and eleven woodland plots. The other nine communities all had considerably fewer woodland plots than urban plots. In assessing the urban plots within the ten UFMP communities, it is apparent (Figures 4.6 and 4.7) that the Spryfield community has a substantially higher conifer density than the other UFMP communities. This dominance can be explained by comparing Figure 4.7 and Table 4.2, where it appears that there is a relationship between the number of urban plots and the urban conifer density. Communities such as Spryfield and Sackville that have a more even ratio of urban to woodland plots tend to exhibit higher conifer densities in their urban plots. However, communities such as the Halifax Peninsula and Ashburn/Armdale that have more urban plots have lower conifer densities overall.

Furthermore, in comparing the conifer density of urban plots in the ten UFMP communities to the conifer density in the eight neighbourhoods on the Halifax Peninsula (Figure 4.7), it is evident that the urban plots in the other UFMP communities have higher conifer densities; therefore, there is a clear trend of increasing conifer density with distance from the Halifax Peninsula. However, this trend includes two outliers, the North End and the North-West Arm, which have higher densities than the Halifax Peninsula and Ashburn/Armdale communities (Figure 4.7). Seemingly, it is logical that the conifer densities in the urban plots on the Halifax Peninsula are relatively close to the conifer densities in the eight neighbourhoods; the target sample area is effectively the same, leading to similar conifer densities. Additionally, the low conifer density in the Ashburn/Armdale community strengthens the notion that the conifer density increases in moving away from the Halifax Peninsula; this community is adjacent to the urban centre (Figure 4.6) and thus has a lower conifer density as expected.

Moreover, the lack of conifers on the Halifax Peninsula (both in the urban plots and in the neighbourhoods) could in part be due to tree availability (Conway et al., 2015). Nurseries obviously would grow species that are in high demand, so if conifers are seldomly chosen by urban foresters and consumers (Almas et al., 2016; Conway et al., 2015), there will be limited selection of conifers to begin with. Residents may be more familiar with the services that non-conifers provide, such as an elevated canopy that can create ample shade for their property, prompting them to plant non-coniferous species. In 2016, Aven et al., assessed a tree planting program in Pittsburgh and found that once volunteers gained knowledge about conifers and their benefits, they became highly motivated to incorporate conifer species into their own yards. Therefore, the low conifer density in the eight neighbourhoods and in the urban plots on the Halifax Peninsula could partially be related to a lack of consumer knowledge.

Although the UFMP communities may show a trend of having more urban plots than woodland plots (Table 4.2), Figure 4.5 shows that the conifer densities in the woodland plots are much higher. The abundance of conifers in the woodland plots is associated with the forest type in the Halifax region. Per Neily et al. (2017), the Halifax region – where the ten UFMP communities are located – is composed of well to imperfectly drained soils with most sites dominated by red spruce, black spruce, eastern larch, and red maple forest stands. Historically the urban plots were the same as the woodland plots and shared the same soil composition and thus, similar tree compositions (Gartzia-Bengoetxea et al., 2016). However, the environment (the built infrastructure and daily human activity) that surrounds the urban plots changed the chemistry and composition of the soil (Ferreira et al., 2018; McDonnell & Pickett, 1990). Thus, the species composition within these plots may be different from the woodland plots because of the immediate surrounding environment and urbanization. Overall, the species composition that exists within the urban plots is ultimately a result of management decisions, as the species composition in the urban forest is controlled by urban foresters. Unlike the urban plots, the woodland plots haven't been altered due to urbanization and thus have a species composition that corresponds to the hinterlands of the HRM (Figure 4.12).

Overall, there is a prominent increase in conifer density with distance away from the urban core. Per Figure 4.9, the highest conifer density on the Halifax Peninsula is the North-West Arm with 10.28 conifers per hectare, compared to Bedford, the UFMP community with lowest conifer density, with 240 conifers per hectare. One can visually identify that the conifer density is considerably higher in the UFMP woodland plots compared to the eight neighbourhoods on the Halifax Peninsula (Figure 4.1 and Figure 4.8). As expected, the urban setting generated a substantially lower conifer density than the naturalized setting. This trend continued when comparing the average density of the urban and woodland plots to the neighbourhoods on the Halifax Peninsula (Figure 4.10).

Within the provincial forest inventory dataset (FID), the HRM is split into two areas: Halifax East and Halifax West. It was determined that the conifer proportion for Halifax East was 76% whereas it was 61% for the Halifax West region. In comparing these conifer proportions to the conifer proportions in the woodland plots of the ten UFMP communities, it was determined that the two are similar. The correspondence between the conifer proportions suggests that the woodland plots in the ten UFMP communities are well representative of the conifer abundances that exist in the woodlands of the HRM; indicating that the woodland plots haven't been affected by urbanization in the UFMP communities.

Unlike the woodland plots (Figure 4.12), the urban plots in the ten UFMP communities (Figure 4.13) had substantially lower conifer proportions than the hinterlands of the HRM. Of the ten UFMP communities, Spryfield has the largest conifer proportion with 48%, which is somewhat lower than the conifer proportion in the Halifax West region. As expected, the urban plots' conifer proportion is the lowest in the Halifax Peninsula community. The low conifer proportions in the urban core were expected (Almas et al., 2016; Aven et al., 2016), as identifying the right place for conifers in the urban forest takes substantial consideration (MacPherson et al., 1997). Evidently, this consideration must acknowledge the concerns that are associated with conifers (Almas et al., 2016): susceptibility to needle burn from salt spray from major transportation (e.g., near an underpass), vulnerability to air pollution, shallow rooting behaviour (increased blow down potential), and potentially limiting visibility due to their low crown (Saebo et al., 2003; Nackley et al., 2014; Aven et al., 2016; Wendel & Smith, n.d). However, these concerns are not applicable to all species of conifer trees nor are these stressors always prevalent. Thus, through proper selection of species, these concerns can be negated. Foster et al. (2015) analyzed the species composition of the Halifax waterfront. The results found that Austrian pine was the most abundant species, with red spruce also being prominent in the area. Further analysis on these species concluded that they could maintain a healthy canopy while thriving in the area. These results suggest that these species can tolerate the stress of the urban environment (Konijnwndijk et al., 2005). More specifically, they can tolerate frequent and significant doses of salt spray from the harbour, substantial soil compaction, and high wind speeds (Foster et al., 2015). Much like the concerns associated with conifers, the advantages must also be considered. This could begin with their ability to act as microclimate regulators – regulating stormwater, controlling the UHI effect, and reducing emissions (Hounshell, 2020; Clapp et al., 2014; Berland et al., 2017). Aside from acting as microclimate regulators, they can attract and host native bird species in the urban forest (Fontana et al., 2011; McKinney, 2002; Jokimaki et al., 1999) as well as provide canopy-dependent services year-round, such as noise and wind buffering and the urban aesthetic (Sulaiman et al., 2016; Clapp et al., 2014).

In the complementary analysis of the other Canadian cities, four cities exhibited cedar as their most abundant conifer genus, further assessment was required. This assessment focused on Toronto as it had the largest percentage of cedar species in its tree inventory: 15.1% (Nowak et al., 2013). In Nowak et al.'s (2013) report on Toronto's' urban forest, i-Tree Eco was used to create the city's tree inventory. The USDA Forest Service is the home of the i-Tree Eco program that is used to analyze ecosystem services from urban tree inventories (Hirabayashi et al., 2011). There are concerns surrounding the accuracy of this inventory approach when it comes to identifying particular genera and conducting diameter at breast height (DBH) measurements (Roman et al., 2017). Stated in Nowak et al.'s (2013) assessment of the Toronto urban forest, the i-Tree program included cedar shrubs (mostly in groomed hedges) that had a DBH of greater than 2.5 cm. Therefore, the dominance of eastern white cedar (*Thuja occidentalis* L.) in the tree inventory, based on stem count, could result from the inventory including these cedar shrubs as trees. In all four cities where cedar was the most abundant conifer (i.e., Langley BC, Richmond Hill ON, Surrey BC, and Toronto ON), the i-Tree Eco program was used to design the UFMP tree inventory. As the species composition in the urban plots within the ten UFMP communities relied on the i-Tree Eco program, this issue could extend to the accuracy of these plots. The abundance of cedar trees in the urban plots is unknown in this study, however, the data collection in the urban forest on the Halifax Peninsula found that cedar was the third most abundant conifer genera (Figure 4.3). Therefore, it is possible that the conifer abundance in the urban plots on the Halifax Peninsula could be skewed due to cedar shrubs being counted.

In determining whether the species composition of the Halifax urban forest is similar to other Canadian cities, the analysis relied on the conifer proportions in the urban plots. These values were used as the values reported in the other Canadian cities were reported as proportions; thus, using the conifer density for the Halifax Peninsula wouldn't be sufficient for this analysis. Among the 18 urban plots on the Halifax Peninsula, 6% of all trees in all plots were conifers. In the 15 cities that held conifers in their inventories, the average conifer proportion was 13%, which is more than double that of Halifax. Therefore, the Halifax urban forest has considerably fewer conifers in its urban forest than other Canadian cities.

An important limitation to this study, is the ocular estimates that were used for collecting conifer data on the Halifax Peninsula. As mentioned in the methods, ocular estimates allow for potential error while taking observations due to different identification skills, different height, and different eyesight among the team members. For future data collection, the use of drone imagery could reduce potential error. With the technology that drones are equipped with, data collection on private property could become more accurate. However, there is the ethical concern that drones are intrusive and invade one's privacy. To reduce the concern of privacy invasion, collecting the data from the highest possible elevation may be a solution. Although, more research is required in determining the legality of this data collection method.

Another limitation to the study, is knowing only the conifer density on the Halifax Peninsula (conifer inventory). Only knowing the density limits the study from identifying the overall tree population per block/ neighbourhood, or if there is an abundance of non-conifers and a lack of conifers. Thus, knowing the conifer proportion for the Halifax Peninsula could improve our understanding of the conifer population in the urban forest.

Chapter VI: Conclusion

By assessing the Halifax Peninsula, the other nine UFMP/surrounding communities, and the hinterlands of the HRM, this study determined that there is an existing conifer density gradient from the urban setting to the woodland environment. The results indicated that the conifer density increases substantially from the urban core to the natural woodlands. The increase in the conifer abundance from the urban core to the naturalized environment is what I hypothesized. Visually, it is evident that non-coniferous trees dominate the Halifax Peninsula, and that conifer species are relatively more abundant in the natural environment outside of the city boundaries.

Prior to this study, the density of conifers on the Halifax Peninsula was not directly identified. Moreover, limited research directly identified the role and importance associated with conifers in the urban environment. This study acts as a starting place for local research on conifers to reduce the knowledge gap that surrounds conifers and the urban environment. Future research on conifer survival in the urban environment could prove to be useful; monitoring the success of the conifers in the urban forest could reduce the existing ambiguity surrounding conifers’ ability to thrive in the urban setting. Such research would enable a comparison between conifer and non-conifer tolerance to urban stressors, which would be vital for future management. Additional research that focuses on the societal implications of conifers could be helpful; understanding peoples’ opinions and preference of tree species is important to know, as the urban forest serves in many ways to benefit the human population.

Knowing the density of conifers may be useful for urban forest managers and researchers. Understanding the contrast in conifer densities among the Halifax Peninsula, surrounding communities, and the hinterlands can allow future urban forest managers to assess whether the benefits associated with conifers have enough merit for their explicit consideration in future UFMPs. Through this study, the advantages that conifers provide were discussed together with the concept that conifer species do belong in the urban forest given proper consideration, especially for appropriate locations. It was determined that with proper selection of conifer species given their surrounding environment, they can thrive in the urban setting and provide services that non-conifers cannot. This can include selecting hardy species such as Austrian pine or Norway spruce that are more tolerant to stress in areas that are more exposed to the urban environment (Foster & Duinker, 2016), while selecting species such as eastern white pine or a native species of spruce in areas that have less-harsh urban conditions (e.g., greenways, parks, and non-major roadways).

One way to incorporate more conifers into the urban forest, may be through tree giveaways. If the HRM implements tree give aways in the future, including native conifer species would be one way to increase the conifer presence in the urban forest. This would allow these conifer species to be planted in yards, where they are more than likely sheltered from the harsh conditions of the urban environment.

Overall, this study has directly addressed conifers in the urban environment and generated insights that point toward the merits of planting more conifers in the urban forest.

REFERENCES

Achim, A & Nicoll, B. C. (2009). Modelling the anchorage of shallow-rooted trees. *Forestry (London)*, *82*(3), 273–284. https://doi.org/10.1093/forestry/cpp004

Almas, A, & Conway, T. M. (2016). The role of native species in urban forest planning and practice: A case study of Carolinian Canada. *Urban Forestry & Urban Greening*, *17*, 54–62. https://doi.org/10.1016/j.ufug.2016.01.015

Alvey, A. A. (2006). Promoting and preserving biodiversity in the urban forest. *Urban Forestry & Urban Greening*, *5*(4), 195-201. https://doi: 10.1016/j.ufug.2006.09.003

Aven, N., Erb, M., Bicha, F., Ramirez, F. F, Smith, J.P., & Bassuk, N. 2016. SMA Roundtable: Conifers in the Urban Forest. City Trees, pp. 24-33. Society of Municipal Arborists, Chums Vista, CA. https://www.urban-forestry.com/assets/documents/roundtables/roundtable%20fall%20planting.pdf

Barlett Tree Experts. (n.d). Eastern White Pine. Plant Healthcare Report. https://www.bartlett.com/resources/eastern%20white%20pine.pdf

Bentrup, G. (2009). *Creatively communicating conservation complexity*. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/84688/NAAC2009-Bentrup.pdf?sequence=1&isAllowed=y

Blakely, E. (2007). *Urban planning for climate change*. Lincoln Institute of Land Policy. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/united-states/gulf-coast/louisiana/Blakely.-2007.-New-Orleans-Urban-Planning-for-CC.pdf

Bluegreen. (2015). *How trees act as sound barriers in urban environments*. https://greenblue.com/na/trees-as-sound-barriers/

Berland, A., Shiflett, S. A., Shuster, W. D., Garmestani, A. S., Goddard, H. C., Herrmann, D. L., & Hopton, M. E. (2017). The role of trees in urban stormwater management. *Landscape and Urban Planning*, *162*, 167–177. https://doi.org/10.1016/j.landurbplan.2017.02.017

Blood, A., Starr, G., Escobedo, F., Chappelka, A., & Staudhammer, C. (2016). How do urban forests compare? Tree diversity in urban and peri urban forests of the southeastern US. *Forests*, *7*(6), 120–120. https://doi.org/10.3390/f7060120

Bolund,P., & Hunhammer, S. (1999). Ecosystem services in urban areas. *Ecological Economics, 29*(1), 293-301. https://doi.org/10.1016/S0921-8009(99)00013-0

Bowyer, J., Bratkovich,S., Fernholz, K., Howe, J., Groot, H., & Pepke, E. (2016). The human health and social benefits of urban forests. Dovetail partners. https://infta.net/files/references/Benefits%20of%20urban%20forests%202016.pdf

Cao, Z., Wu, X., Wang, T., Zhao, Y., Zhao, Y., Wang, D., Chang, Y., Wei, Y., Yan, G., Fan, Y., Yue, C., Duan, J., & Xi, B. (2022). Characteristics of airborne particles retained on conifer needles across China in winter and preliminary evaluation of the capacity of trees in haze mitigation. *The Science of the Total Environment*, *806*(2), 150704–150704. https://doi.org/10.1016/j.scitotenv.2021.150704

Chen, L., Liu, C., Zhang, L., Zou, R., & Zhang, Z. (2017). Variation in Tree Species Ability to Capture and Retain Airborne Fine Particulate Matter (PM 2.5). *Scientific Reports*, *7*(1), 3206–3211. https://doi.org/10.1038/s41598-017-03360-1

Clapp, J., Ryan, D., Harper, R., & Bloniarz, D. (2014). Rationale for increased use of conifers as functional green infrastructure: A literature review and synthesis. *Arboricultural Journal, 36*(3), 161-178. https://doi.org/10.1080/03071375.2014.950861

Clark, E. (2017, January 13). Conifers Provide Urban Forests Many Benefits. *Wisconsin DNR Forestry News.* https://forestrynews.blogs.govdelivery.com/2017/01/13/conifers-provide-urban-forests-many-benefits/

Conway, T. M., & Vander Vecht, J. (2015). Growing a diverse urban forest: Species selection decisions by practitioners planting and supplying trees. *Landscape and Urban Planning*, *138*, 1–10. https://doi.org/10.1016/j.landurbplan.2015.01.007

Cregg, B. M & Dix, M. (2001). Tree Moisture Stress and Insect Damage in Urban Areas in Relation to Heat Island Effects. *Arboriculture & Urban Forestry*, *27*(1), 8–17. https://doi.org/10.48044/jauf.2001.002

Czaja, M., Kołton, A., & Muras, P. (2020). The Complex Issue of Urban Trees—Stress Factor Accumulation and Ecological Service Possibilities. *Forests*, *11*(9), 932. https://doi.org/10.3390/f11090932

Davey Resource Group. (2011). *Urban forest management plan. https://www.thunderbay.ca/en/city-hall/resources/Documents/Urban-Forest-Management-Plan.pdf*

DeWolfe, K., Simard, I., & Coon, D. (2005). Our Acadian Forest in Danger. Conservation council of New Brunswick. https://www.conservationcouncil.ca/wp-content/uploads/2013/02/Acadian_Forest_in_Danger_final.pdf

Dirr, M. A. (1976). Selection of Trees for Tolerance to Salt Injury. *Arboriculture & Urban Forestry*, *2*(11), 209–216. https://doi.org/10.48044/jauf.1976.053

Dobrowolska, D. (2015). Forest regeneration in northeastern poland following a catastrophic blowdown. *Canadian Journal of Forest Research*, *45*(9), 1172–1182. https://doi.org/10.1139/cjfr-2014-0507

Dong, X., Guo, H., & Zeng, S. (2017). Enhancing future resilience in urban drainage system: Green versus grey infrastructure. *Water Research*, *124*, 280-289. https://doi.org/10.1016/j.watres.2017.07.038

Duinker, P., Ordóñez, C., Steenberg, J., Miller, K., Toni, S., & Nitoslawski, S. (2015). Trees in Canadian Cities: Indispensable Life Form for Urban Sustainability. *Sustainability, 7*(6), 7379–7396. https://doi.org/10.3390/su7067379

Dwyer. J., Nowak, D., & Noble, H. (2003). Sustaining urban forests. *Journal of Arboriculture, 29*(1), 49-55. https://www.nrs.fs.usda.gov/pubs/jrnl/2003/nc_2003_dwyer_001.pdf

Ederny, T. (2018). Strategically growing our urban forest will improve our world. *Nature Communications*, *9*(1160). https://doi.org/10.1038/s41467-018-03622-0

Ellis, N., Smith, S. J., & Pitcher, C. R. (2012). Gradient forests: calculating importance gradients on physical predictors. *Ecology*, *93*(1), 156–168. https://doi.org/10.1890/11-0252.1

Esperon-Rodriguez, M., Ordonez, C., van Doorn, N. S., Hirons, A., & Messier, C. (2022). Using climate analogues and vulnerability metrics to inform urban tree species selection in a changing climate: The case for Canadian cities. *Landscape and Urban Planning*, *228*, 104578. https://doi.org/10.1016/j.landurbplan.2022.104578

Equiza, Calvo-Polanco, M., Cirelli, D., Señorans, J., Wartenbe, M., Saunders, C., & Zwiazek, J. J. (2017). Long-term impact of road salt (NaCl) on soil and urban trees in Edmonton, Canada. *Urban Forestry & Urban Greening*, *21*, 16–28. https://doi.org/10.1016/j.ufug.2016.11.003

Ferreira, C. S. S., Walsh, R. P. D., & Ferreira, A. J. D. (2018). Degradation in urban areas. *Current Opinion in Environmental Science & Health*, *5*, 19–25. https://doi.org/10.1016/j.coesh.2018.04.001

Ferenc, M., Sedláček, O., & Fuchs, R. (2014). How to improve urban greenspace for woodland birds: site and local-scale determinants of bird species richness. *Urban Ecosystems*, *17*(2), 625–640. https://doi.org/10.1007/s11252-013-0328-x

Fernandez-Juricic, E., Poston, R., De Collibus, K., Morgan, T., Bastain, B., Martin, C., Jones, K., & Treminio, R. (2005). cU.S. *Urban Habitats*, *3*(1). https://estebanfj.bio.purdue.edu/papers/finch_pdf.pdf

Filazzola, A., Shrestha, N., & MacIvor, J. S. (2019). The contribution of constructed green infrastructure to urban biodiversity: A synthesis and meta-analysis. *Journal of Applied Ecology*, *56*(9), 2131-2143. https://doi.org/10.1111/1365-2664.13475

Fontana, S., Sattler, T., Bontadina, F., & Moretti, M. (2011). How to manage the urban green to improve bird diversity and community structure. *Landscape and Urban Planning*, *101*(3), 278–285.
https://doi.org/10.1016/j.landurbplan.2011.02.033

Food and Agriculture Organization of the United Nations. (2016). *Guidelines on urban and peri-urban forestry*. https://www.fao.org/3/i6210e/i6210e.pdf

Foster, D. E., Margetts, W., & Saunders, S. (2015). At the waters edge: an inventory of trees on the Halifax waterfront.
http://DOI:10.13140/RG.2.2.25643.13606

Foster, D. & Duinker, P. (2017). *The HRM urban forest in 2016*. School for Resource and Environmental Studies, Dalhousie University. https://www.itreetools.org/documents/319/FosterDuinker_2017_iTreeEcoForHalifax_Feb2017.pdf

Foster, D. (2016). Halifax i-Tree Eco inventory [Data Set]. Restricted Access [Retrieved, March 10, 2023].

Fraedrich, B, R. (n.d). Eastern White Pine. Bartlett Tree Experts. https://www.bartlett.com/resources/eastern-white-pine-cultural-problems.pdf

Gartzia-Bengoetxea, N., Kandeler, E., Martínez de Arano, I., & Arias-González, A. (2016). Soil microbial functional activity is governed by a combination of tree species composition and soil properties in temperate forests. *Applied Soil Ecology : a Section of Agriculture, Ecosystems & Environment*, *100*, 57–64. https://doi.org/10.1016/j.apsoil.2015.11.013

Garschagen, M., & Romero-Lankao, P. (2015). Exploring the relationship between urbanization trends and climate change vulnerability. *Climate Change*, (133), 37-52. https://doi.org/10.1007/s10584-013-0812-6

Gerstenberg, T., & Hofmann, M. (2015). Perception and preference of trees: A psychological contribution to tree species selection in urban areas. *Urban forestry & Urban Greening, 1*(15), 103-11.https://doi.org/10.1016/j.ufug.2015.12.004

Ghirardo, A., Blande, J. D., Ruehr, N. K., Balestrini, R., & Külheim, C. (2022). Editorial: Adaptation of Trees to Climate Change: Mechanisms Behind Physiological and Ecological Resilience and Vulnerability. *Frontiers in Forests and Global Change, 4*. https://doi.org/10.3389/ffgc.2021.831701

Gill, S. E., Handley, J. F., Ennos, A. R, & Pauleit, S. (2007). Adapting Cities for Climate Change: The Role of the Green Infrastructure. *Built Environment*, *33*(1), 115–133. https://doi.org/10.2148/benv.33.1.115

Government of Nova Scotia. (2010). *Forest ecosystem classification of Nova Scotia*. https://novascotia.ca/natr/forestry/veg-types/mw/pdf/mw-full.pdf

Gower, S. T., & Richards, J. (1990). Larches: deciduous conifers in an evergreen world. *Bioscience*, *40*(11), 818–826. https://doi.org/10.2307/1311484

Halifax Regional Municipality. (2023). *Zoning Boundaries* [Map]. https://catalogue-hrm.opendata.arcgis.com/datasets/11adc4e1e52a45b5b9f6bc63ef6e0883_0/explore?location=44.645036%2C-63.584285%2C15.06

Halifax Regional Municipality. (2013). *Urban Forest Master Plan.* https://cdn.halifax.ca/sites/default/files/documents/transportation/streets-sidewalks/HALREG%201246%20UrbanForestReport_HighRes_SINGLEPAGE_Mon20_Combined.pdf

Hale, D., Pugh, T., Sadler, J., Boyko, C. T., Brown, J., Caputo, S., Caserio, S., Coles, R., Farmani, R., Hales, C., Horsey, R., Hunt, D. V. L., Leach, J., Rogers, C., & MacKenzie, A. (2015). Delivering a multi-functional resilient urban forest. *Sustainability*, *7*(4), 4600-40624.
https://doi.org/10.3390/su7044600

Hounshell, T. (2020). Ecosystem services of urban tree canopy for the mitigation of climate change: Measuring carbon sequestration and understory temperature reduction of Knoxville’s urban forest. *The Journal of Undergraduate Research at the University of Tennessee*, *10*(1).
https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1397&context=pursuit

Handyani, N., & Mardikannigish, R. (2022). Urban Forest: The role of improving the quality of the urban environment. Bulletin of Science and Technology, *1*(1), 25-29. https://inti.ejournalmeta.com/index.php/inti/article/view/7

Hirabayashi, S., Nowak, D., Endreny, T. A., Kroll, C., & Maco, S. (2011, December). i-Tree: Tools to assess and manage structure, function, and value of community forests. In *AGU Fall Meeting Abstracts* (Vol. 2011, pp. B21B-0263).

Iowa State University. (2023). Austrian Pine. Natural Resource Stewardship. https://naturalresources.extension.iastate.edu/forestry/iowa_trees/trees/austrian_pine.html

Janeczko, E., Bielinis, E., Wójcik, R., Woźnicka, M., Kędziora, W., Łukowski, A., Elsadek, M., Szyc, K., & Janeczko, K. (2020). When Urban Environment Is Restorative: The Effect of Walking in Suburbs and Forests on Psychological and Physiological Relaxation of Young Polish Adults. *Forests*, *11*(5), 591. https://doi.org/10.3390/f11050591

Jim, C., & Chen, W. (2009). Ecosystem services and valuation of urban forests in China. *Cities*, *26*(4), 187-194. https://doi.org/10.1016/j.cities.2009.03.003

Jokimäki, J., & Suhonen, J. (1998). Distribution and habitat selection of wintering birds in urban environments. *Landscape and Urban Planning*, *39*(4), 253–263. https://doi.org/10.1016/S0169-2046(97)00089-3

Konijnwndijk, C., Randrup., Nilsson, K., & Schipperijn. (2005). *Urban Forests and Trees*. Springer. https://doi.org/10.1007/3-540-27684-X

Konijnendijk, C., Ricard, R. M., Kenney, A., & Randrup, T. B. (2006). Defining urban forestry – A comparative perspective of North America and Europe. *Urban Forestry & Urban Greening*, *4*(3), 93–103. https://doi.org/10.1016/j.ufug.2005.11.003

Kielbaso, J, J. (2008). Management of urban forests in the United States. *Ecology, Planning, and Management of Urban Forests*, 240-258. https://link.springer.com/chapter/10.1007/978-0-387-71425-7_15

Liu, Q., Wang, X., Liu, J., An, C., Liu, Y., Fan, X., & Hu, Y. (2021). Physiological and Psychological Effects of Nature Experiences in Different Forests on Young People. *Forests*, *12*(10), 1391–. https://doi.org/10.3390/f12101391

Loo, J., & Ives, N. (2003). The Acadian Forest: historical condition and human impacts. *The Forestry Chronicle*, *79*(3). https://pubs.cif-ifc.org/doi/pdf/10.5558/tfc79462-3

Lüttge,U & Buckeridge, M. (2023). Trees: structure and function and the challenges of urbanization. *Trees (Berlin, West)*, *37*(1), 9–16. https://doi.org/10.1007/s00468-020-01964-1

McPherson, Nowak, D., Heisler, G., Grimmond, S., Souch, C., Grant, R., & Rowntree, R. (1997). Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. *Urban Ecosystems*, *1*(1), 49–61. https://doi.org/10.1023/A:1014350822458

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health*, *8*, 14. https://doi.org/10.3389/fpubh.2020.00014

McClellan, R. O. (2002). Setting ambient air quality standards for particulate matter. *Toxicology*, *181*, 329-347. https://doi.org/10.1016/S0300-483X(02)00459-6

McDonnell, M. J & Pickett, S. T. A. (1990). Ecosystem structure and function along urban-rural gradients: An unexploited opportunity for ecology. *Ecology*, *71*(4), 1232–1237. https://doi.org/10.2307/1938259

McKinney, M. L. (2002) Urbanization, biodiversity, and conservation: The impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *Bioscience*, *52*(10), 883–890. https://doi.org/10.1043/0006-3568(2002)052(0883:UBAC)2.0.CO;2

Mori, J. (2018). Air pollution mitigation by urban greening. *Italus Hortus*, *25*, 13. https://doi.org/10.26353/j.itahort/2018.1.1322

Nackley, L. L., Barnes, C., & Oki, L. R. (2015). Investigating the impacts of recycled water on long-lived conifers. *AoB Plants*, *7*. https://doi.org/10.1093/aobpla/plv035

Nature Conservancy Canada. (2022). *Acadian Forest*. https://www.natureconservancy.ca/en/what-we-do/resource-centre/forests-101/acadian-forest.html#:~:text=The%20Acadian%20forest%20region%20boasts,and%20supports%20breeding%20bird%20populations.

Neily, P., Basquill, S., Quigley, E., Keys, K. (2017). Ecological Land Classification for Nova Scotia. Nova Scotia Department of Natural Resources. https://novascotia.ca/natr/forestry/ecological/pdf/Ecological-Land-Classification-guide.pdf

Nitoslawski, S. A., & Duinker, P. N. (2016). Managing tree diversity: A comparison of suburban development in two Canadian cities. *Forests*, *7*(6), 119. https://doi.org/10.3390/f7060119

Nowak, D & Dwyer, J. F. (1998.). Understanding the Benefits and Costs of Urban Forest Ecosystems. In *Urban and Community Forestry in the Northeast*. Springer. https://doi.org/10.1007/978-1-4020-4289-8_2

Nowak, D. J., Noble, M. H., Sisinni, S. M., & Dwyer, J. F. (2001). People and trees: assessing the US urban forest resource. *Journal of Forestry*, *99*(3), 37-42. https://doi.org/10.1093/jof/99.3.37

Nowak, D., & Crane, D. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, *116*(3), 381-389. https://doi.org/10.1016/S0269-7491(01)00214-7

Nowak, D, J., Hoehn, R, E., Bodine, A. R., Greenfield, E, J., Ellis, A., Endreny, T, A., Yang, Y., Zhou, T., & Henry, R. (2013). Assessing urban forest effects and values: Toronto's urban forest. https://www.nrs.fs.usda.gov/pubs/rb/rb_nrs79.pdf

Nova Scotia Department of Resources and Renewables. (2022). *Forest inventory-geographic information systems* [Data Set]. https://novascotia.ca/natr/forestry/gis/dl_forestry.asp

O'Briena, L. E., Urbaneka, R. E., & Gregory, J. D. (2022). Ecological functions and human benefits of urban forests. *Urban Forestry & Urban Greening*, *75.* https://doi.org/10.1016/j.ufug.2022.127707

Ozdemir, H. (2019). Mitigation impact of roadside trees on fine particulate pollution. *Science of the Total Environment*, *659,*1176-1185. https://doi.org/10.1016/j.scitotenv.2018.12.262

Pataki, D. E., Alberti, M., Cadenasso, M. L., Felson, A. J., McDonnell, M. J., Pincetl, S., Pouyat, R. V., Setälä, H., & Whitlow, T. H. (2021). The benefits and limits of urban tree planting for environmental and human health. *Frontiers in Ecology and Evolution, 9*. https://doi.org/10.3389/fevo.2021.603757

Peters, E. B., McFadden, J. P., & Montgomery, R. A. (2010). Biological and environmental controls on tree transpiration in a suburban landscape. *Journal of Geophysical Research, 115*(G4). https://doi.org/10.1029/2009JG001266

Roman, L. A., Scharenbroch, B. C., Östberg, J. P. A., Mueller, L. S., Henning, J. G., Koeser, A. K., Sanders, J. R., Betz, D. R., & Jordan, R. C. (2017). Data quality in citizen science urban tree inventories. *Urban Forestry & Urban Greening*, *22*, 124–135. https://doi.org/10.1016/j.ufug.2017.02.001

Russo, A. & Cirella, G. (2021). Urban ecosystem services: current knowledge, gaps, and future research. *Land*, *10*(8), 811.
https://doi.org/10.3390/land10080811

Sæbø, A., Benedikz, T., & Randrup, T. B. (2003). Selection of trees for urban forestry in the Nordic countries. *Urban Forestry & Urban Greening*, *2*(2), 101–114. https://doi.org/10.1078/1618-8667-00027

Sawidis, T., Breuste, J., Mitrovic, M., Pavlovic, P., & Tsigaridas, K. (2011). Trees as bioindicator of heavy metal pollution in three European cities. *Environmental Pollution*, *159*(12), 3560–3570. https://doi.org/10.1016/j.envpol.2011.08.008

Seto, L. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences - PNAS*, *109*(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109

Sjöman, H., & Nielsen, A. B. (2010). Selecting trees for urban paved sites in Scandinavia–A review of information on stress tolerance and its relation to the requirements of tree planners. *Urban Forestry & Urban Greening*, *9*(4), 281-293.

https://doi.org/10.1016/j.ufug.2010.04.001

Sjoman, H., Ostberg, J., & Buhler, O. (2012). Diversity and distribution of the urban tree population in ten major Nordic cities. *Urban Forestry & Urban Greening*, *11*(1), 31–39. https://doi.org/10.1016/j.ufug.2011.09.004

Speak, A., Montagnani, L., Wellstein, C., & Zerbe, S. (2020). The influence of tree traits on urban ground surface shade cooling. *Landscape and Urban Planning*, *197*, 103748. https://doi.org/10.1016/j.landurbplan.2020.103748

Steenberg, J. & Duinker, P. (2010). Post-Hurricane Coniferous Regeneration in Point Pleasant Park. Nova Scotian Institute of Science. 45(2), 26-54. https://static1.squarespace.com/static/5b3babac70e802454aede034/t/5d07ec2f66b84200010d8002/1560800432145/3985-6092-1-SM.pdf

Steenberg, J. W. N., Millward, A. A., Nowak, D. J., & Robinson, P. J. (2017). A conceptual framework of urban forest ecosystem vulnerability. *Environmental Reviews*, *25*(1), 115–126. https://doi.org/10.1139/er-2016-0022

Straigyté, L. & Vaidleys, T. (2012). Inventory of green space and woody plants in the urban landscape in Ariogala. *Southeast European Forestry*, *3*(2), 115-121. https://doi.org/10.15177/seefor.12-13

Sulaiman, F., Hasan, R., Jamaluddin, E. (2016). The mature trees in creation areas and its role in enhancing the quality of life. *Procedia- Social and Behavioural Science.* 234, 289-298. http://doi: 10.1016/j.sbspro.2016.10.245

Tepley, A. J., Thompson, J. R., Epstein, H. E., & Anderson-Teixeira, K. J. (2017). Vulnerability to forest loss through altered postfire recovery dynamics in a warming climate in the Klamath Mountains. *Global Change Biology*, *23*(10), 4117–4132. https://doi.org/10.1111/gcb.13704

Tesler, R., Endevelt, R., & Plaut, P. (2022). Urban Forest Health Intervention Program to promote physical activity, healthy eating, self-efficacy and life satisfaction: impact on Israeli at-risk youth. *Health Promotion International*, *37*(2). https://doi.org/10.1093/heapro/daab145

Tree Canada. (2019). *Compendium of best urban forest management practices*. https://treecanada.ca/resources/canadian-urban-forest-compendium/

Tree Canada. (2022). *Benefits of urban forests.* https://treecanada.ca/resources/canadian-urban-forest-compendium/3-benefits-of-urban-forests/

United Nations. (2018). 68% of the world population projected to live in urban areas by 2050, says UN. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html#:~:text=Today%2C%2055%25%20of%20the%20world's,increase%20to%2068%25%20by%202050.

University of Maine. (2017). Tolerance of trees and shrubs to salt in soils. Maine Gardner Manual. https://extension.umaine.edu/gardening/manual/tolerance-trees-shrubs-salts-soil/

Wagner, J. (2007). *Design proposal for the Halifax urban greenway*. [Undergraduate Honours thesis, Dalhousie University]. http://www.halifaxurbangreenway.ca/reports/wagner_thesis_1.pdf

Wendel, G. W., Smith, C. H., (n.d). Eastern White Pine. USDA. https://www.srs.fs.usda.gov/pubs/misc/ag_654/volume_1/pinus/strobus.htm

Wilby, R. L. (2007). A Review of Climate Change Impacts on the Built Environment. *Built Environment*, *33*(1), 31–45. https://doi.org/10.2148/benv.33.1.31

Wood, S. L. R., & Dupras, J. (2021). Increasing functional diversity of the urban canopy for climate resilience: Potential tradeoffs with ecosystem services? *Urban Forestry & Urban Greening*, *58*. https://doi.org/10.1016/j.ufug.2020.126972

Wyatt, G. (2020). *Selecting trees and shrubs for wind breaks*. University of Minnesota. https://extension.umn.edu/agroforestry/trees-shrubs-windbreaks#conifer-trees-1740463

Xing, Y., & Brimblecombe, P. (2020). Traffic-derived noise, air pollution and urban park design. *Journal of Urban Design*, *25*(5), 590–606. https://doi.org/10.1080/13574809.2020.1720503

Zhou, W., Cao, F., & Wang, G. (2019). Effects of spatial pattern of forest vegetation on urban cooling in a compact megacity. *Forests*, *10*(3), 282. https://doi.org/10.3390/f10030282