Adaptive Planning for Emerald Ash Borer Invasion

Includes:

Final Report

By

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Completed for: Nature Areas Stewardship Advisory Committee

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Emerald Ash Borer (EAB) Impact Remediation
Final Report - First Draft

Trent University's Symons Campus March 25th, 2016

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PREFACE

This report was authored by Kaitlyn Fike, Alex Fisher, and Adam Fyfe, as a component of the Community Based Research Project for use by the Nature Areas Stewardship Advisory Committee (NASAC) of Trent University in Ontario, Canada. Its purpose is to provide a review of the current status of Emerald Ash Borer (EAB) throughout North America with an emphasis on Southern Ontario. This report also includes an analysis of the impacts associated with the impending EAB infested ash (*Fraxinus*) trees at the Symons Campus of Trent University. Most predominantly, this report offers a range of options and dynamics to consider in regards to the management and mitigation of EAB, to be used at the discretion of the NASAC.

DISCLAIMER

The information compiled in this report has been collected from reviews of literature and research papers, extensive consultations with municipalities and conservation authorities, as well as forestry experts, scientists, and others. The template and layout of this report mirrors that of the York Region Emerald Ash Borer Management Plan, which was developed in 2011.

It should be noted that while there is substantial literature based on the biology and other important characteristic of EAB, there is a lack of information available in regards to the ecological impacts across a range of temporal and spatial scales. Given this predicament, leniency with respect to predicting EAB impacts and the overall effectiveness of the client's management option of choice. The information and recommendations contained in this report are based on the most current scientific knowledge and regulatory requirements as of March 25, 2016.

ACKNOWLEDGEMENTS

We would like to thank Tom Whillans and Robert Loney for their continuous guidance and support throughout every stage in the creation of our final report. We would also like to thank the numerous individuals and municipalities who have contributed to this report through extensive consultations in their multidisciplinary professions. Their willingness to provide information regarding several of our questions and requests towards the formation of this report is greatly appreciated. We would also like to thank everyone at the City of Peterborough GIS department for granting us access to their recently developed aerial imagery.

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EXCUTIVE SUMMARY

Ash Borer in North America

The Emerald Ash Borer (Agrilus planipennis) is an invasive wood-boring insect originating from Asia. The species was first detected in 2002 in the Detroit-Windsor area. The Emerald Ash Borer (EAB) has exponentially reproduced; and the distribution has spread throughout North America. The invader was assessed and reported as a severe pest of quarantine significance by the Canadian Food Inspection Agency within the same detection year. The EAB is now present in most of southern Ontario, eastern Quebec, and more than 20 American States. The economic and ecological impacts associated with the introduction of EAB are considered severe, with an estimated one hundred million ash trees decimated throughout North America within the first decade of introduction (GRCA, 2014). It has been identified that an additional ten billion trees at risk (GRCA, 2014).

Trent - The Need for Intervention

As a higher learning institution situated in a forested environment, the environmental focus of Trent's curriculum provides a strong commitment to preserving and promoting the ecological integrity of the surrounding natural landscape. Habitats which make up Trent's Nature Areas (TNAs), core campus and endowment lands encompass ecologically significant areas with natural heritage functions that are crucial to the both environment within the university and the surrounding Peterborough/ Douro community.

Pre-existing Bio-blitz data has indicated that a large portion of the TNA's tree composition are ash trees. Ash mortality caused by the inevitable EAB invasion is already expected to reach over 10,000 trees on the property; significantly altering the near-natural and managed lands of the Symons Campus. These areas are also socially significant as they are largely used by the university community, external organizations and the general public for educational, research and recreational use. Therefore, it is in the best interest of the university to adhere to the commitment of responsible and sustainable stewardship in preparing for the inevitable EAB invasion of the TNA's. Management plans have already been developed and implemented throughout other regions in Ontario in accordance with this issue, and it is in excellent foresight for Trent to follow suit. The overall goal of this study was to identify stand characteristics and vital community components within high density ash stands that would be most affected by the infestation of EAB.

Field Work: Methods and Findings

Generalized descriptions of habitat and ecosystem characteristics were compiled for each of the TNAs. Forest characterization data was acquired in order to develop an understanding of forest species composition, levels of succession, and intensity of invasive establishment within the forested areas of the campus. Field data was collected by using a line transect method placed through priority zones (characterized by greater densities of ash trees). The locations of these transect areas were selected by randomly choosing a coordinates start and end point within the map depicting the campus areas with high counts of ash stands. Transect sections were placed through each zone in 20m sections, and species inventory was recorded within a meter distance of each side of the transect. Using a GPS, this process was continued until a coordinate end point was reached. All species within the recording zone of one meter on either side of the transect line were incorporated into our data, and multiple levels of species growth/establishment were presented including, seedlings, super seedling, saplings, super saplings, and full grown mature trees. The data shows that in many priority zones of the nature areas, ash and buckthorn are significantly the two most abundant species. This has implications for predicting invasive gap succession if no human intervention occurs. Furthermore, the data has allowed a further understanding of other species that are succeeding in these ecosystems, and will assist in the selection of species if a replacement planting strategy is implemented.

Suggestions for Management

Our suggestions for EAB have been acquired through reviews of scientific literature and previously constructed EAB remediation plans of municipalities across the United States and Canada. Most municipalities have conducted a full clearing operation for all ash trees. Due to the large property encompassed by the TNAs, full scale ash extraction would be a costly endeavour in both finances and resources. We hereby recommend that ash only be removed in areas where trees are already encountering pre-existing stresses. These stresses could be caused by exposure, land degradation and fragmentation. On the TNAs these conditions are observed on the side of frequently used trails, roads and field boundaries. For the security of ash in this area we recommend a harvest of trees 50m on either side of these landscape features. This barrier would further contribute to an ash-free buffer to slow the spread process. For trees of aesthetic/intrinsic value there is opportunity for chemical inoculation to be conducted through use of TreeAzin chemical. Inoculation comes at a high cost, and is inefficient for large-scale operation. Upon the removal of ash we recommend that the niche be filled with a combination of forbs, shrubs and trees which will contribute elements of biodiversity and ecosystem stability to the region. The species used will be determinate of the landscape's geology, topography, saturation and level of succession.

As per Canada Food Inspection agency guidelines, we recommend that harvested ash trees stay within the boundaries of the City of Peterborough in order to prevent the further spread of EAB. Following the recommendations of municipal EAB projects, all actively infested wood and brush should be incinerated or heavily mulched. Uninfected wood could be chipped for use in buckthorn remediation, TNA trail maintenance, campus upkeep or sale to the Peterborough community. Observations of restoration projects have also seen value in using ash for habitat mounds for forest restoration initiatives.

Buckthorn is currently the most prominent invasive species on the TNAs. Results have determined that buckthorn appears to be the fastest spreading invasive species; and is the apparent species which will fill the gap left behind by harvested/dead ash. We recommend that a combination of hand pulling, cover suppression and glyphosate treatments be used to suppress buckthorn until which time a vegetative community can be established that will outcompete buckthorn. Due to the abundant seed dispersal and intricate root network of buckthorn, elimination may not be an option. Suppression is a realistic goal that can contribute to the formation of a community which can outcompete buckthorn.

1. INTRODUCTION AND BACKGROUND

1.1. Discovery in North America

The Emerald Ash Borer (*Agrilus planipennis*) is an insect that was first detected in North America in 2002, around the Detroit-Windsor area. The Canadian Food Inspection Agency conducted a pest risk assessment (PRA) in 2002 and reported that EAB had definite potential to be a serious and detrimental pest of quarantine significance in North America. The insect has excelled in reproduction and distribution in North America, and is now present throughout much of southern Ontario, eastern Quebec, and more than 20 American states (GRCA, 2014). Originating from Asia, it is speculated that the Emerald Ash Borer (EAB) arrived on the continent a decade before its recorded discovery, and has continued to spread to new areas with considerable economic and ecological impacts (NRC, 2015). The EAB is an invasive exotic insect that is generally acknowledged as the most destructive pest that has invaded North America.

1.2. Dispersal and Establishment

This wood-boring insect has become severely problematic in Southern Ontario as the larval stage of this species tends to cause widespread decimation of Ash (*Fraxinus spp.*). The economic and ecological impacts associated with the introduction of EAB are considered severe, with an estimated one hundred million ash trees decimated throughout North America and the United States within the first decade of introduction and an additional ten billion trees at risk (GRCA, 2014). EAB can expand their range through flight, but are often transported undetected through the movement of infested wood. This includes firewood, logs, and infested nursery stock. The current methods of detection include visual signs and symptoms of attack (Groot et al, 2008). Without many effective natural enemies or ash trees with viable defense mechanisms, the EAB population is becoming abundant and dramatically spreading in range.

1.3. Biology and Lifecycle

The adult body of the EAB ranges from copper to an emerald green with a metallic glint. The male EAB has long silvery-white setae on the front of the thorax and the inner femora (Wang et al. 2010). Additionally, the female EAB have setae located in the same region but they are much more short and sparse. Another characteristic that indicates female sex is the width of the body, which often exceeds that of the male (Wang et al. 2010). Adult EAB may mate multiple times with preference given to the leaf surface but can be found on the trunk of a tree at times. One female can accommodate two males simultaneously with coupling lasting between 25-30 minutes (Wang et al. 2010). Approximately 10 days after mating, egg maturation has reached its peak. Individual eggs are deposited by the female onto the outer bark of the host tree, though at times clusters of eggs (max of 7) are laid together but these are speculated to be from various females (Wang et al. 2010). After 12-19 days, newly hatched instars immediately tunnel through the bark into the cambium layer where the phloem and outer xylem is consumed. Serpentine, frass-packed galleries that impede translocation of water, nutrients, and photosynthate cause girdling of the tree. Most individuals complete their life cycle in 1 year, though a proportion of the population requires 2 years to complete development (Wang et al. 2010). The EAB emerges as an adult in North America in the late May through early September (Wang et al. 2010). The emergence of EAB can be indicated by a 3.0-4.5 mm in length and 2.0-3.0 mm in width D-shaped exit hole, which provides evidence to researchers of infestation (Wang et al. 2010). Frass from both consumption and emergence is packed into the pupal cells (Wang et al. 2010). In locations with higher sunlight exposure, growth and emergence of EAB is much more rapid (Wang et al. 2010). Leaves of neighbouring ash trees and host tree are consumed by adults for nutrition following emergence, though damage is relatively insufficient. Research into mitigation strategies for EAB is predominantly directed towards biological control efforts. Predation, host-tree resistance, pathogenic microorganisms, and parasitism of both native and introduced species have been under study since efforts to suppress EAB populations first began. Further studies are currently underway, but a quick and easy solution to the EAB problem is not likely to be uncovered immediately due to the temporal and spatial environmental factors intrinsically associated with the biological characteristics of invasion.

1.4. Hosts

All ash species in eastern North America are susceptible to EAB, including white (*Fraxinus americana*), green (*Fraxinus pennsylvanica*), black (*Fraxinus nigra*), and blue ash (*Fraxinus quadrangulata*). The EAB will colonize ash trees ranging from saplings to mature aged specimens. However, trees with very smooth bark, young trees of DBH less than 3 cm, or new shoots are far less susceptible to infestation (Wang et al, 2010). The female EAB lays her eggs in the crevices of the ash tree, which eventually hatch and feed on the phloem and xylem. The feeding tunnels created throughout the cambium layer girdles the tree causing death within a 1-4 year time period (Rebek et al. 2008). Studies have indicated that the ash species within Asia are more resistant to EAB infestations than ash species in North America due to the coevolutionary relationship between EAB and Asian ash species (Rebek et al. 2008). The EAB is relatively rare within its native range and largely suppressed by the chemical resistance of the ash tree, as well as predator abundance. In North America, it is difficult to detect EAB infestations at low population levels in ash trees. The visual survey method—looking for signs and symptoms of attacks—is often used to survey for the insect. However, in the early stages of an infestation, signs and symptoms (i.e. epicormic shoots, canopy dieback, and bark cracks over larval galleries) are not readily apparent until trees are heavily infested. This makes infestations hard to notice until numerous heavily infested dead and dying ash trees become evident (NRC, 2015). For this reason, regulatory efforts such as early detection, quarantine, and removal of infested ash trees have proven to be ineffective for containing the spread of EAB.

The ability of Canada's ash trees to overcome EAB devastation and restore the natural balance of forest communities through successional stages is very unlikely. The viability of ash seeds are very limited, and evidence suggests that natural seed banks in heavily infested areas will soon be depleted, limiting the ability of ash to rebound and recover its former prominence (Simcoe County, 2014). With the impending loss of ash, EAB populations are expected to sharply decline. For this reason, future outbreaks of EAB are likely to be far less damaging. However, EAB populations are expected to persist and increase with the recovery of ash in future years. The emergence of biological control agents such as pathogens, predators, and natural selection of resistant ash species may achieve normalization of affected ash communities over time. Further studies are currently underway, but a quick and easy solution to the EAB problem is not likely to be uncovered immediately due to the temporal and spatial environmental factors intrinsically associated with the biological characteristics of invasion. Thus, immediate action is required in order to ensure ecosystem processes are intact following ash devastation.

2. ECONOMIC IMPACTS

Researchers of the Great Lakes Forestry Centre (GLFC) estimate a cost of approximately $524 million in street tree mortality from EAB over a 30-year time span in Canadian municipalities (McKenney and Pedlar, 2013). An additional cost of $366 million is expected for backyard trees (McKenney and Pedlar, 2013). The estimated overall cost of treatment, removal, and replacement of ash trees subject to invasion in Canadian municipalities are projected to reach $2 billion within the 30 years time span (NRC, 2015). The costs to restore ecological impacts related to ash tree mortality in regards to the deterioration of ecosystem function and structure are of great concern. A depletion in air quality, water quality, soil structure, food and shelter for wildlife, and the moderation of climate extremes are direct consequences of ecosystem function and structure deterioration. Considering the heavy reliance on these factors is dependant on the health or quality of ecological components, the costs of restoration is expected to be extreme.

3. ECOLOGICAL IMPACTS

3.1. Ash Mortality in North America

In the face of human disturbance and a changing climate, forests are continually impacted by disturbances occurring in a diverse range of spatial and temporal scales. As a result, forest ecosystems have developed processes that create stability within the environment in the form of resistance or resilience to disturbance events (Harrison, 1979). Invasions by exotic insect pests have been devastating North American forests for decades, where disturbances such as canopy gap formation due to emerald ash borer induced ash mortality alter the availability of resources including light, water, and mineral nutrients, which potentially resulting in shifts in plant community composition (Klooster, 2012).

Species within forest ecosystems have life history behaviours adapted to the prevalent abiotic and biotic conditions of the local environment (Lavorel & Garnier 2002). One way forests achieve stability is through the functional redundancy of its species, referring to multiple species performing similar services, creating a system that is not defined or limited by a specific web of species (Laliberté et al. 2010). Greater functional redundancy allows for greater resilience because if one species is eliminated, another can continue the important biological processes, thus more diverse forests often have greater resistance or resilience to disturbance as more species increase the level of functional redundancy (Halpern, 1988).

Disturbance caused by invasive/exotic species have caused declines in many native tree species populations (Lovett et al. 2006). Due to a lack of co-evolutionary history, North American tree species are found to be susceptible to mortality by exotic insect pests (Gandhi and Herms 2010). Typically, in a co-evolved system an equilibrium is reached between the success of the pest species and the defense of the host species: however, when an exotic species is introduced into a more novel environment, the inexperienced host species are biologically naive and consequently lack necessary defenses. This scenario explains the greater susceptibility of North American ash species to emerald ash borer (EAB) compared to ash species native to Asia (Rebek et al. 2008). It also explains the response of native birch trees to bronze birch borer (Agrilus anxius) (Nielsen et al. 2011); and beech tree mortality due to beech scale (Cryptococcus fagisuga) and its associated pathogenic fungus (Gandhi and Herms 2010).

3.2. Ash Mortality in Peterborough

Ash trees are a significant component of Peterborough's urban forests and private landscapes, representing about 10% of the total City-owned tree canopy with numerous individuals dispersed throughout private properties within the City (City of Peterborough, 2013). There are roughly 2600 ash trees along the streets in Peterborough, with an estimated 4500 additional trees residing in the City's parks and open spaces (City of Peterborough, 2013). An EAB Management Plan was developed in 2013 by the City of Peterborough in anticipation of invasion. In the summer of 2013, EAB was detected in the Fenelon Falls area and the north shore of Rice Lake, and by the late summer of 2014 it was detected in Peterborough in the south and southeast of the city (Peterborough, 2014). Ash trees that were found to be heavily infested were removed from Park Street in the summer of 2015 by city officials. Visual surveys are on-going and monitoring has included increased use of pheromone traps and further branch sampling (Peterborough, 2014). While infestation has not yet heavily impacted Trent University in the North end of the city, there is evidence that EAB is steadily rising in numbers within the area. A minority of affected ash trees now stand devoid of their canopy with bore holes apparent in the bark and the tunneled cambium layer exposed, an indication of EAB presence.

The Symons Campus of Trent University consists of approximately 591 hectares of land which are categorized into three broad land use designations: Core Campus, Nature Area and Endowment Land. The ash trees comprise a significant portion of Trent's Nature Areas (see Appendix A, Figure 1). It is expected that the loss of the ash tree populations within most of these high density areas would open the microecosystems to unforeseeable alterations. It has been suggested that pre-emptively removing the ash trees may be the best viable solution, as revenues from the lumber would generate feasible proceeds for restoration and stewardship.

Particular ash trees on Trent's Symons campus have been identified as socially significant to the overall appearance of the campus and have been subject to limited inoculation in areas of prominent view in the core of the campus. Areas where inoculation has occurred or is planned to occur includes off of West Bank Drive, East Bank Drive and Nassau Mills Road.

3.3. Invasive Species Concerns

Invasive plants may outcompete native plants for space and resources (Tilman 2004; Davis et al. 2005), due to increased growth rates or higher reproductive rates of invasive species compared to native species. These invasive plant species are very persistent, can spread easily, and tend to crowd out native plant species and prevent forest regeneration. The theory that the presence of invasive species can facilitate further invasions has been termed 'invasional meltdown' (Simberloff 2006), and has been supported by multiple studies (Dorning and Cipollini 2006; Belote and Jones 2009). Further invasion due to the presence of European buckthorn is an additional challenge on top of the invasion of EAB, where there is concern about this species dominating the gaps left behind by fallen ash.

The invasive plants on the grounds of Trent University have been an issue for some time, but are coming to the forefront of stewardship priorities due to their ecosystem dominance. Most prevalent is European buckthorn (*Rhamus cathartica*), which has the potential to cause serious ecological damage to TNAs by aggressively displacing native vegetation. European buckthorn is a non-native plant species that was deliberately introduced to North America as an ornamental hedge plant in the early 1800s by European colonists. It was selected for ornamental purposes, shelterbelts and/or hedges in a variety of locations stretching from Nova Scotia to Saskatchewan. European buckthorn was valued for its compact structure with many spiny branches, ease of propagation, hardiness, and ability to tolerate a variety of soils and site conditions. It has since escaped cultivation and has propagated a high-density range expansion into foreign habitats. After successful establishment in a new habitat, European buckthorn efficiently dominates the area through rapid and abundant reproduction and dispersal. Other mechanisms that perpetuate successful invasion include (though not limited to) the ability to alter nitrogen levels in the soil, a lack of co-evolved predators or competitors, and allelopathy. Thus, there is cause for concern that European Buckthorn would take over and dominate any rejuvenating forest stand with young saplings within the high density ash areas that are expected to be subject to severe ecological alterations with the EAB invasion throughout the Symons Campus of Trent University

4. TRENT UNIVERSITY ASH ASSESSMENT

4.1. Project Overview

Trent University is recognized as a higher learning institution with a strong commitment to preserving and promoting the ecological integrity of the natural landscape and habitats which make up Trent's Nature Areas (TNAs), Core Campus and Endowment Lands. The 590 ha (1450 acres) of Trent's Symons Campus largely encompasses ecologically significant areas with natural heritage characteristics and functions that are crucial to the natural environment within and surrounding the university boundaries. A large portion of the landscape is composed of ash tree communities. Ash mortality caused by the inevitable EAB invasion is already expected to reach over 10,000 trees on the property, significantly altering the near-natural and managed lands of the Symons Campus. These areas are also socially significant, as they are largely used by the university community, external organizations and the general public for educational, research and recreational use. Therefore, it is in the best interests of the university to be adhere to the commitment of responsible and sustainable stewardship of TNAs and endowment lands throughout the Symons Campus in regards to the inevitable EAB invasion. Management plans have been developed and implemented throughout other regions in accordance with this issue. Thus, the overall goal of this study was to identify stand characteristics and vital community components within high density ash stands that will be most affected by the onslaught of EAB. This study is expected to provide insight into the best approach of responding to the future infestation, while taking into account ecological, social, and economic needs and considerations.

4.2. Study Purpose and Objectives

Forest measurement techniques were conducted to collect data in order to establish forest stand characteristics for each zone delegated within Trent University's Symons Campus boundaries. Forest measurement techniques were conducted to collect data in order to establish forest stand characteristics for each zone delegated within Trent University's Symons campus boundaries. The data collected will identify forest succession, species tolerance, stand diversity and other components of the ecosystem. This data will be used in the creation of Trent University's Emerald Ash Borer Remediation Plan.

Forest stand structure and composition are significant attributes of forested ecosystems. A study of the stand composition and dynamics of forest communities in high density ash stands (i.e. priorities areas) can provide a reference for sustainable forest management and restoration of the inevitable EAB degraded forest communities. The management of these highly dense ash areas are crucial to ensuring the appropriate management protocol of affected forest stand structure to protect and maintain biological diversity while sustaining forest productivity.

The aim of research was to study and assess the forest stand dynamics in order to determine appropriate strategies and objectives of forest restoration following EAB devastation. This will be established by comparing basal area, weighted diameter, and volume of high-density ash area within the variable microecosystems throughout the Symons Campus. Special consideration was also given to the exotic plant species that have become aggressive invaders in the area. Reiteratively, European buckthorn, which has existed in Peterborough for nearly 40 years.

4.3. Study Area

Field inventories were completed utilizing a strip cruise/transect sampling method with the aid of GPS (See Appendix A, Table 1) to fix the field sample plots throughout the Symons Campus. The inventory plots (zones) were selected based on areas containing the most abundant ash densities (i.e. high priority areas; see Appendix A, Figure 1). The strip cruise/transect sampling line was positioned along an axis that centered between the most dense ash clusters per sample area. Each zone varied in length, which was largely based on the ash coverage of individual sample areas. Strips that progressed through different forest types were subdivided into respective sections. The composition of woody plants were classified into 5 categories:

1. Tree - A woody plant with a diameter at breast height (dbh)(outside bark) greater than or equal to 10.2cm
2. Sapling - A woody plant with a dbh (outside bark) less than 10.2cm but greater than or equal to 2.5cm

3. Super Seedling - A woody plant of either a shrub or tree species that is less than 91.4cm tall, but is less than 2.5cm in dbh
4. Seedling - A woody plant of either a shrub or tree species that is less than 91.4cm tall

Within each zone, recordings were made on tree species and diameters at breast height. Due to seasonal restraints, the herbaceous layer and canopy cover was unable to accurately be documented and was excluded from data collection. The forest stand was characterized by computing the abundance of woody plants, basal area, weighted diameter, and density.

4.4. Zone Characteristics (Nature Areas)

4.4.1. Wildlife Sanctuary

The Wildlife Sanctuary (WSNA) encompasses 164 ha of land in the southeast corner of Trent's Symons Campus (See Appendix B, Figure 2). The WSNA is one of the most socially and ecologically significant areas on the Symons Campus, with extensive recreational and educational use. Habitats vary from upland indistinct drumlins, wetlands, immature forests and mature forests. Both upland and some lowland areas contain soils belonging to the Otonabee series, which are medium in texture, and moderately stony with good to excessive drainage (Jones et al. 2002). Other lowland soils are characterized as being Foxboro Series, which is coarse in texture, stone free and has poor to very poor drainage (Jones et al. 2002).

The upland portion of WSNAs are mature field communities of grasses, perennial vegetation, and light to moderate cover of shrubs and young trees, which are in a secondary successional stage (Jones et al. 2002). Lowland forest stands are bordered by moderate to dense seedlings of Eastern white cedar and deciduous tree saplings (i.e. trembling aspen)(Jones et al. 2002). The seasonally flooded wetland vegetation consists primarily of deciduous trees such as silver maple, red ash, white cedar, and trembling aspen.

Concerns in regards to ecological integrity within the area are associated with the overabundance of Eastern white cedar, which have the capability to entirely dominate ecosystems with the formation of dense stands. The situation can be quite severe, as the allelopathy and rapid reproduction of Eastern white cedar can restrict the establishment of other tree species. It is possible that cedars will dominate these locations for a significant length of time and potentially other locations throughout the WSNAs in future decades (Jones et al. 2002). There are also invasives present within this area including, but not limited to, lilacs (*Syringa vulgaris*), periwinkle (*Vinca minor*), dog strangling vine (*Cynanchum rossicum*), and European buckthorn.

4.4.2. The Lady Eaton Drumlin

The LEDNA covers an area of 31 hectares, bordering highway 28, and adjacent to wetlands on the east side, the upland soils are well drained and composed of stony glacial till (Jones et al. 2002). For vegetation, field-thicket, deciduous woodlands and conifer plantations are the dominant components of this nature area. European buckthorn is an established invader along the forest margin. Immature deciduous trees comprise most of the lowland woods north of the hydro corridor, with white ash being dominant. The drumlin experience fairly regular recreational and educational use, and there is concern that buckthorn will invade other areas as it has established itself where lighting is favourable.

4.4.3. South Drumlin

The South Drumlin Nature Area (SDNA) is approximately 14 ha in size, with a distinct drumlin rising roughly 15 to 20 m from the canal (Jones et al. 2002). The stoss (north) slope and sides are steep, and the lee (south) slope is gently inclining to the Thompson Creek lowland. The east and west side of the drumlin is bordered by flat terrain. The soil type is classified as being a part of the Emily Series, which is characterized by being medium in texture, moderately stony and imperfectly drained (Jones et al. 2002).

The SDNA covers a large area supporting mixed deciduous forests, dominated by sugar maple, white ash, basswood and American beech. There are also partially wooded habitats, which have been subject to disturbance that have left openings in the canopy. Within these areas exist patches of tree, sapling, and shrub cover, notably black cherry trees and large sumacs. European buckthorn is not a major concern within this area, although it is quite prevalent in less mature wooded and open communities.

The SDNA is a feature valuable to both the Trent community and the general public for aesthetic and recreational reasons. The SDNA is also used by environmental science classes for educational purposes, as well as research conducted by external organizations.

4.4.4. Canal Area

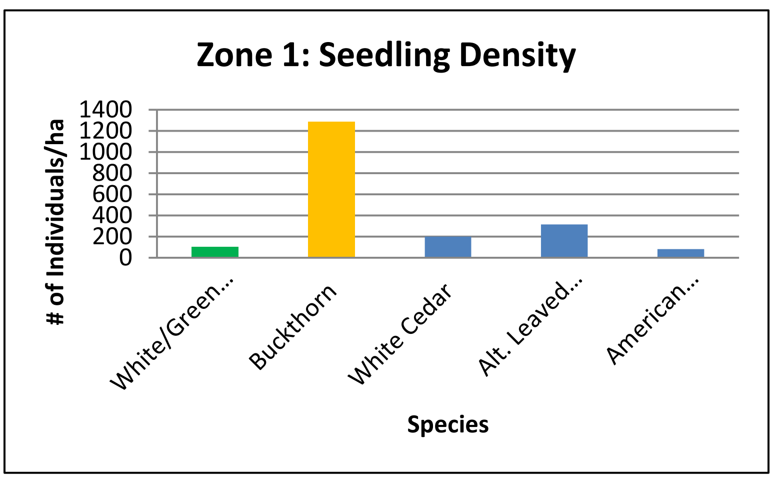
The CNA is 37 hectares in size, consisting of 3 separate wetlands this area shows primarily vegetation in various levels of secondary succession (Jones et al. 2002). Host to primarily black locust and Eastern white cedar. Within the wetlands the dominant species are trembling aspen, balsam poplar, red/black ash, and primarily understory cedar. The land is seasonally flooded and as with many other areas, the encroachment of European buckthorn is a current pressure.

4.5. Field Results

Priority Areas

Zone 1 (South Drumlin Nature Area):

Seedling growth in zone 1 was predominantly composed of high densities of buckthorn while ash maintained a minor role acting as the least abundant variety of tree sapling. Alternate leaf dogwood was most commonly found in areas of high moisture. Super seedling growth was largely dominated by buckthorn while ash formed the least common variety. Serviceberry and alternate leaf dogwood showed a high abundance in areas with greater soil moisture content. The most common variety of sapling was ironwood followed by American beech. Buckthorn was the least common variety of sapling. The most common variety of mature tree was American beech and basswood, with many American beech showing signs of deteriorating bark.



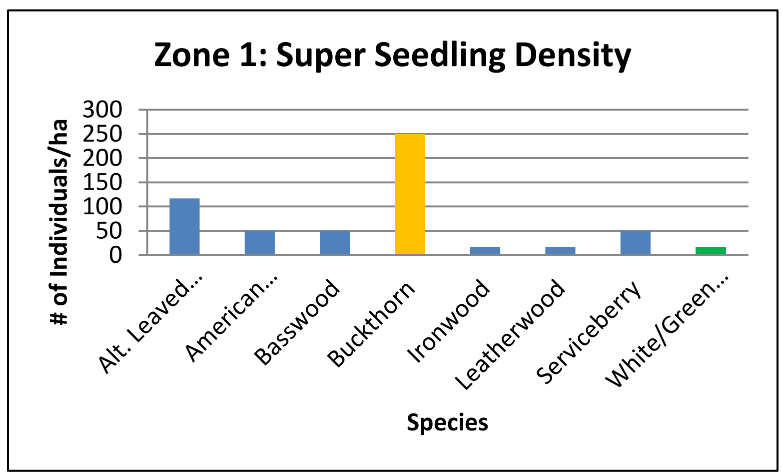
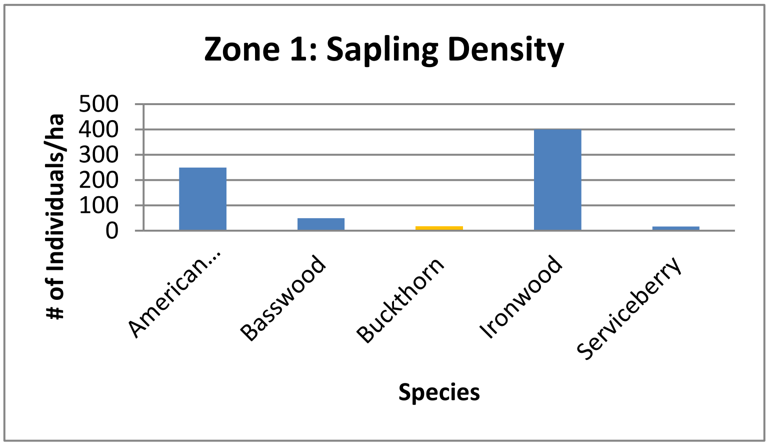


Figure.1. Overall seedling density per species present per 1 ha for zone 1 *(buckthorn shaded yellow, ash shaded green)*. **Figure.2.**Overall super seedling density per species present per 1 ha for zone 1 *(buckthorn shaded yellow, ash shaded green).*



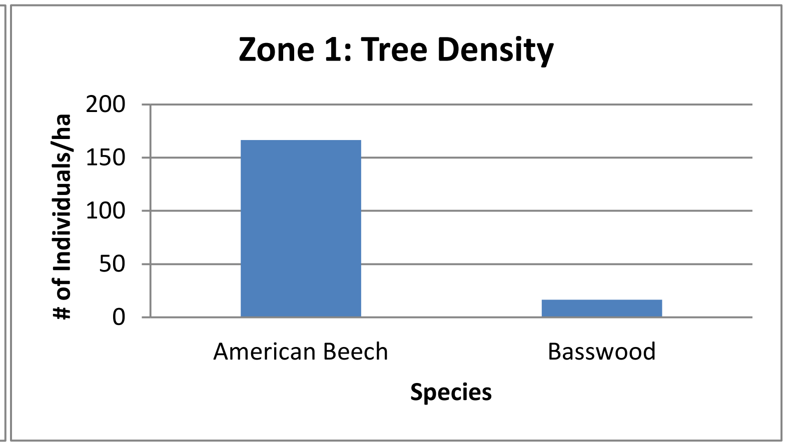


Figure.3. Overall sapling density per species present per 1 ha for zone 1 *(buckthorn shaded yellow, ash shaded green)*.**Figure.4.** Overall tree density per species present per 1 ha for zone 1 *(ash shaded green)*.

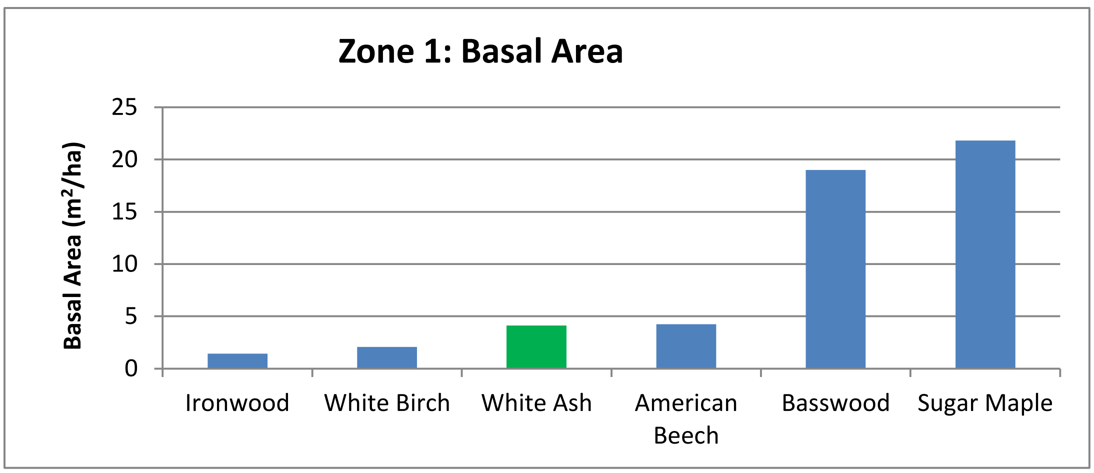
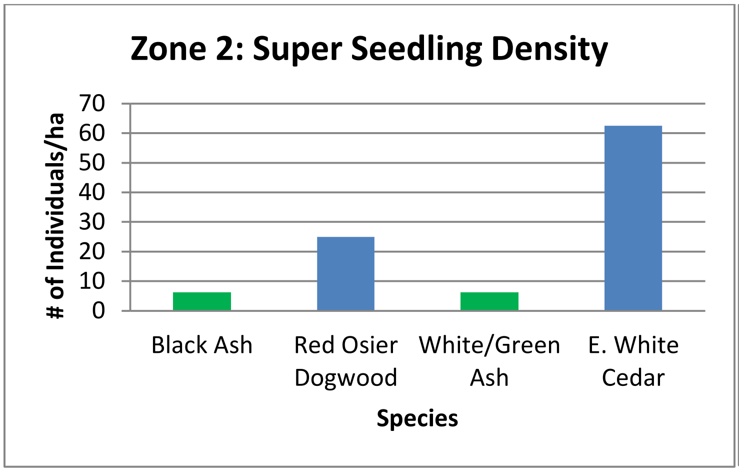


Figure.5. The Basal area in square metres/ha of zone one.

With reference to figure 5, it is apparent that basswood and sugar maple tress dominate zone 1 in terms of their cross sectional area at breast height. Basswood and sugar maples hold the most mature portion of this zone while ironwood, white birch, and white ash compose less than 5 m^2 of breast height girth per ha.

Zone 2 (Southern Nature Area, East of the Trent Canal):

Zone 2 showed only sporadically dispersed eastern white cedar seedlings in low density. Eastern white cedar and red osier dogwood were the most abundant and densely concentrated super seedlings. Eastern white cedar significantly showed the highest sapling density followed by black ash. The most common variety of mature tree was black ash. Both eastern white cedar and black ash were found growing most commonly in areas of standing water.



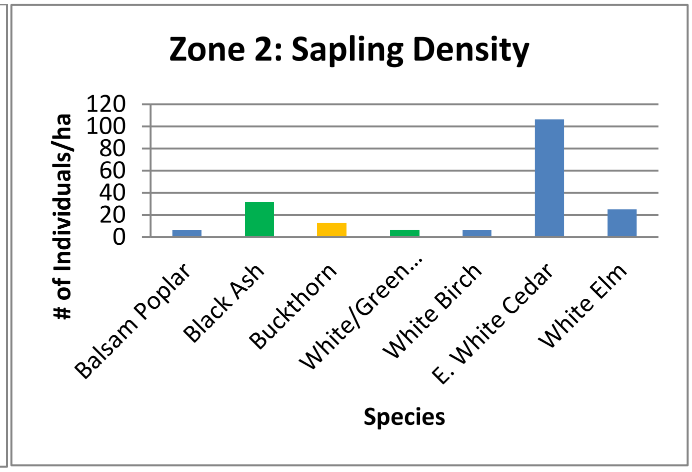
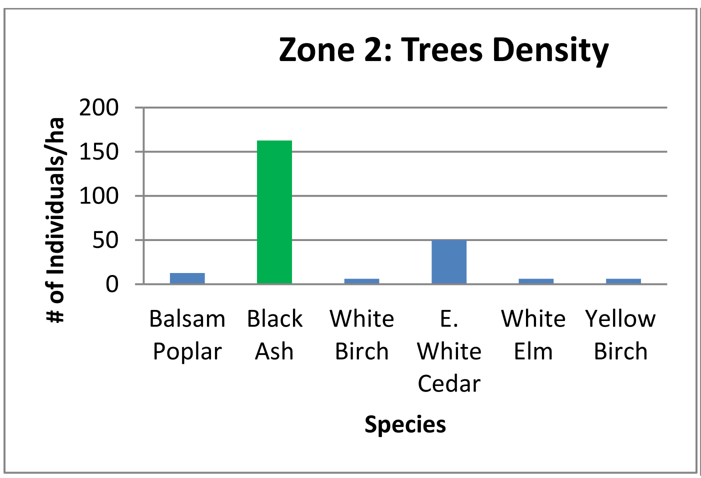


Figure.6. Overall super seedling density per species present per 1 ha for zone 2 (*ash shaded green).***Figure.7.** Overall sapling density per species present per 1 ha for zone 2 *(buckthorn shaded yellow, ash shaded green).*



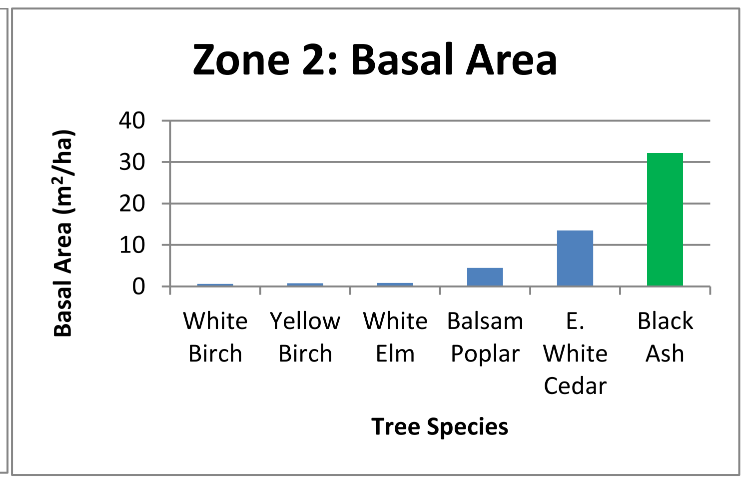
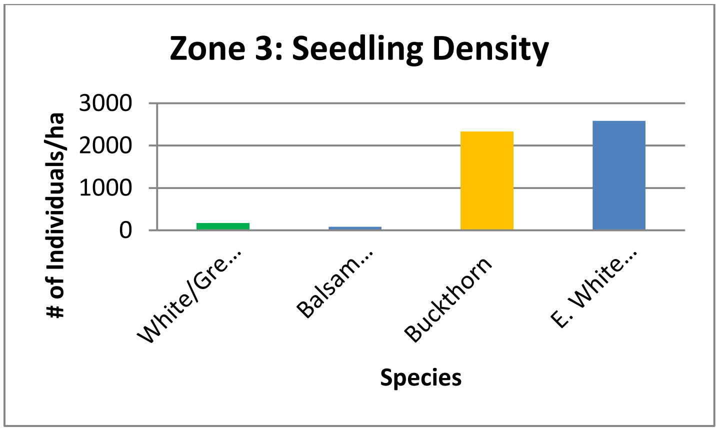


Figure.8. Overall tree density per species present per 1 ha for zone 2 (*ash shaded green*). **Figure.9.** The basal area in square metres per ha for zone 2.

In zone two it is apparent that for mature tree abundance black ash holds the greatest basal area with more than 30 m^2 within one ha, followed by eastern white cedar as the second most dominant. White birch, yellow birch and white elm compose the least trunk girth per ha.

Zone 3 (Border of Wildlife Sanctuary and Southern Nature Area):

Buckthorn and eastern white cedar were relatively close in competing for the highest density of seedlings in zone 3. Black ash with balsam poplar seedlings were the least densely populated varieties. Ash and buckthorn were the most common super seedlings. Observations showed ash seedlings and super seedlings appeared brittle showing missing/deteriorating buds. Green/white ash and white birch showed the highest density of saplings. Eastern white cedar was the highest density mature tree, with a strong presence of white birch and green/white ash.



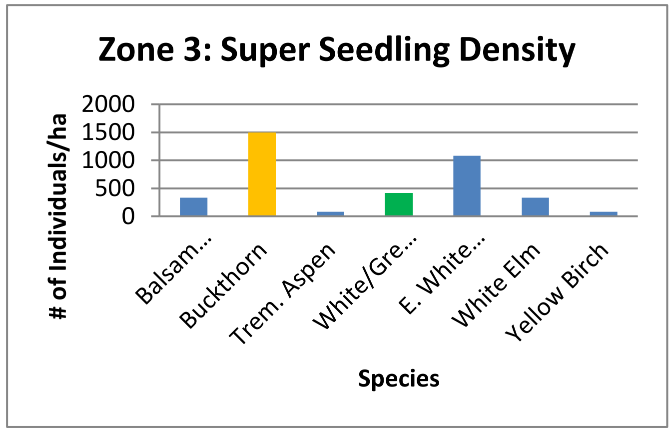
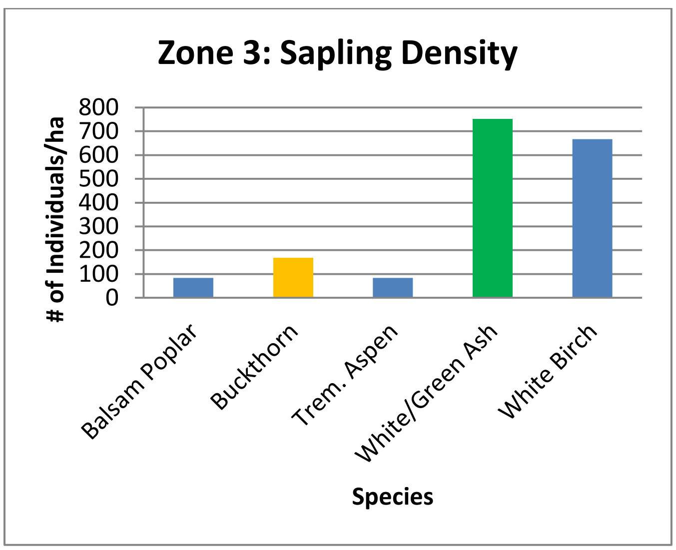


Figure.10. Overall seedling density per species present per 1 ha for zone 3 *(buckthorn shaded yellow, ash shaded green)*. **Figure.11.** Overall super seedling density per species present per 1 ha for zone 3 *(buckthorn shaded yellow, ash shaded green).*



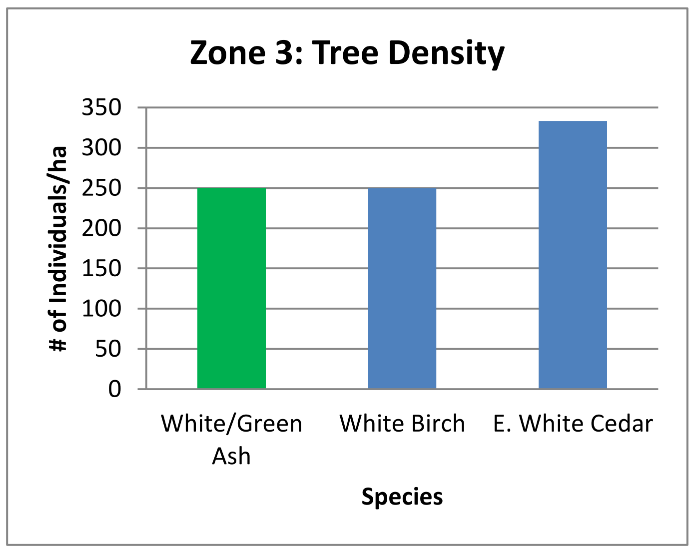


Figure.12. Overall sapling density per species present per 1 ha for zone 3 *(buckthorn shaded yellow, ash shaded green).* **Figure.13.** Overall tree density per species present per 1 ha for zone 3 *(ash shaded green).*

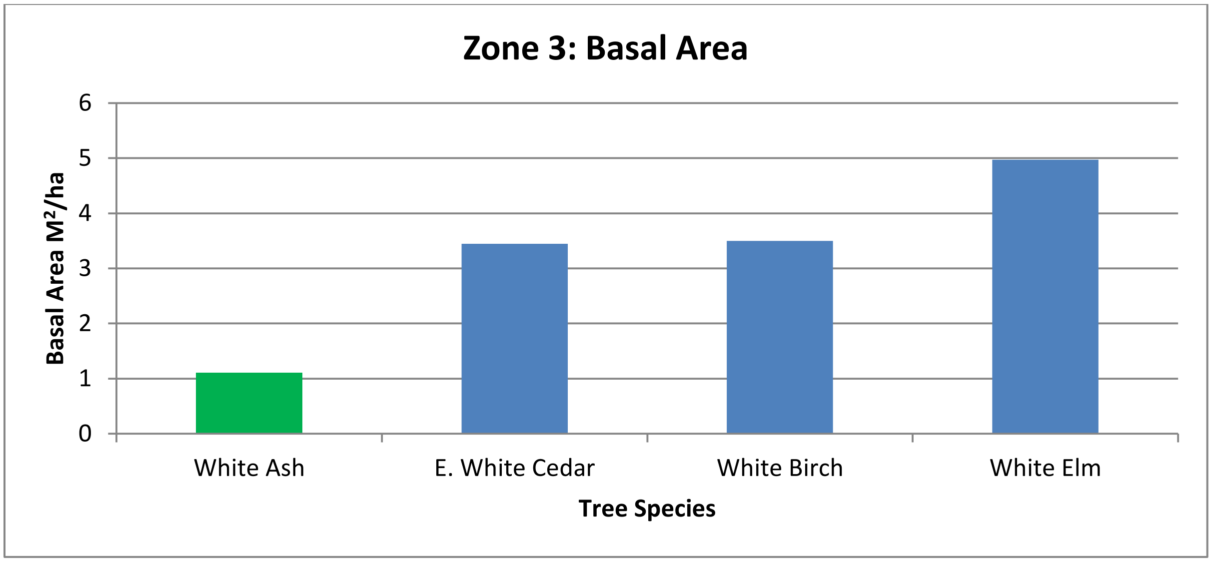
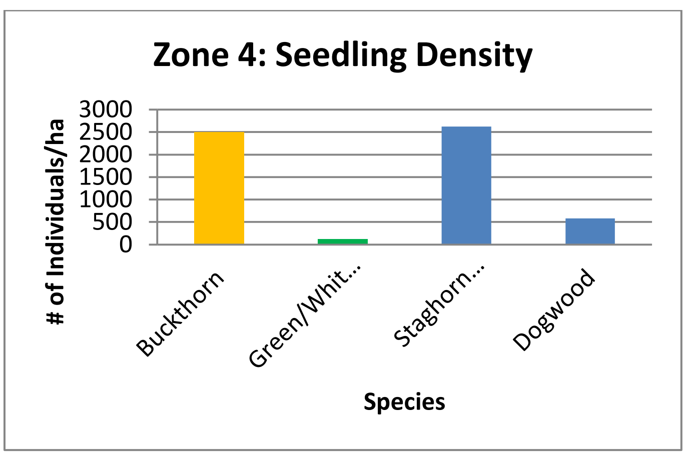


Figure.14. The basal area in square metres per ha for zone 3.

Tree species in zone 3 found a lower overall basal area, with white elm taking up slightly more trunk girth compared to the other species. Ash species in this area take up very little of the basal area.

Zone 4 (West Wildlife Sanctuary Nature Area):

Buckthorn and staghorn sumac maintained the highest seedling, super seedling and sapling density. Ash showed the lowest seedling and super seedling density. Ash however formed the third highest sapling density and the second highest mature tree density. Manitoba maple formed the highest mature tree density. Manitoba maples in the zone were only present at the mature tree stage of growth.



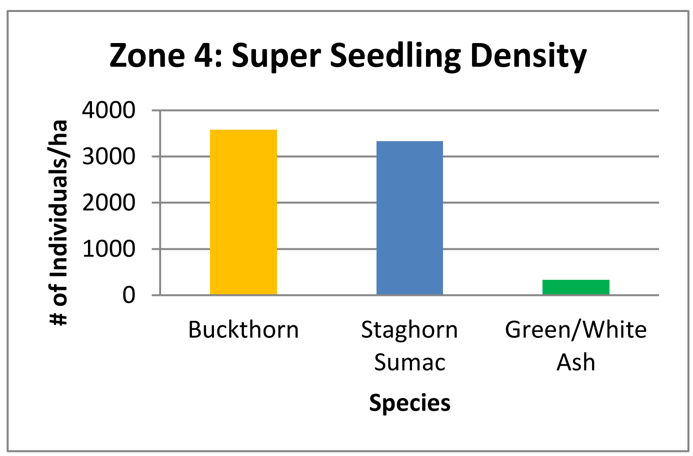
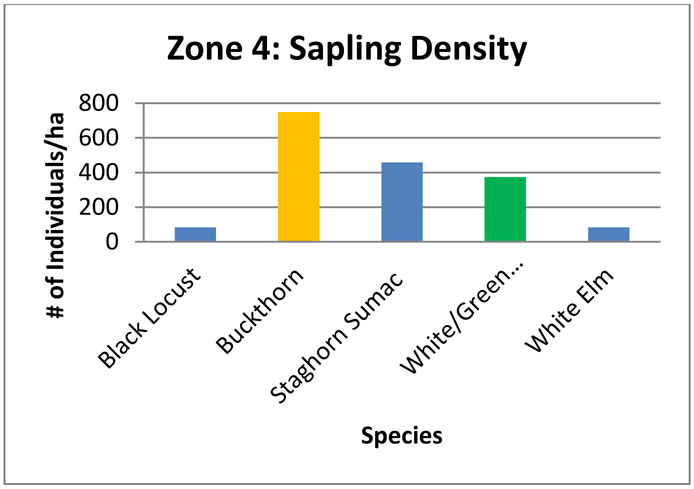


Figure.15. Overall seedling density per species present per 1 ha for Zone 4 *(buckthorn shaded yellow, ash shaded green)*. **Figure.16.** Overall super seedling density per species present per 1 ha for zone 4 *(buckthorn shaded yellow, ash shaded green).*



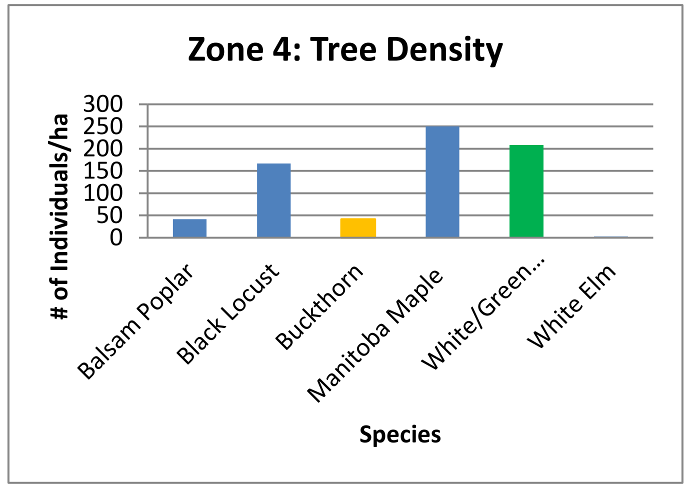


Figure.17. Overall sapling density per species present per 1 ha for zone 4 *(buckthorn shaded yellow, ash shaded green).***Figure.18.** Overall tree density per species present per 1 ha for zone 4 *(buckthorn shaded yellow, ash shaded green).*

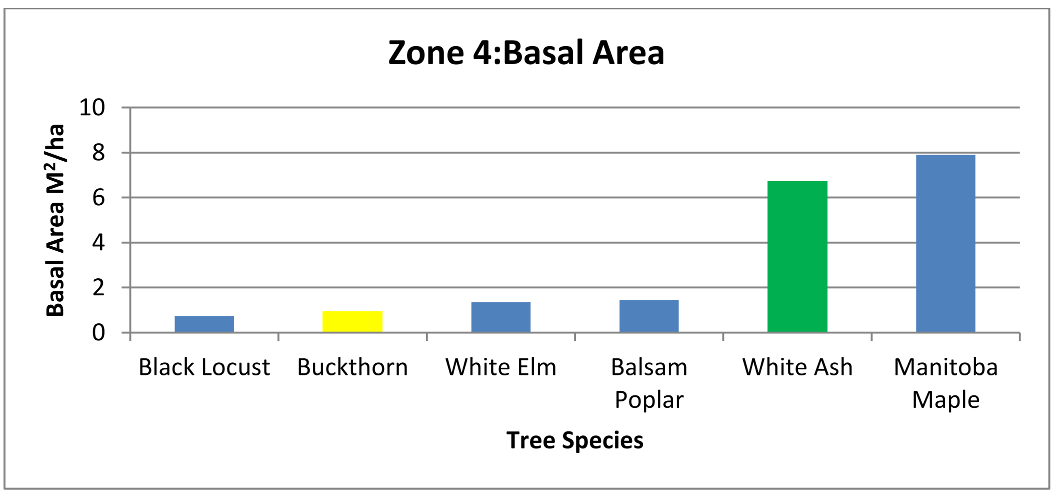
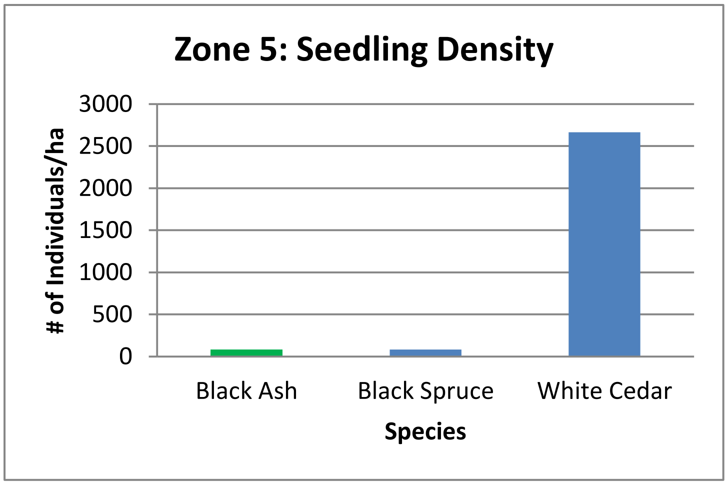


Figure.19. The basal area in square metres per ha for zone 4.

In zone four it is apparent that much of the basal area is comprised of Manitoba maples and white ash, while the remaining species contribute substantially less basal area.

Zone 5 (NW Wildlife):

Zone 5 showed a large density of eastern white cedar seedlings and also formed the highest species density for super seedlings and saplings. Black ash was the species with the lowest density in seedling and super seedling stages of growth. Black ash formed the highest density of species of mature trees surpassing the eastern white cedar. Buckthorn maintained a minor density presence only at the sapling stage of growth. Black ash and eastern white cedar were found growing in standing water throughout zone 5, while buckthorn was only found to be present in soils free from submersion.



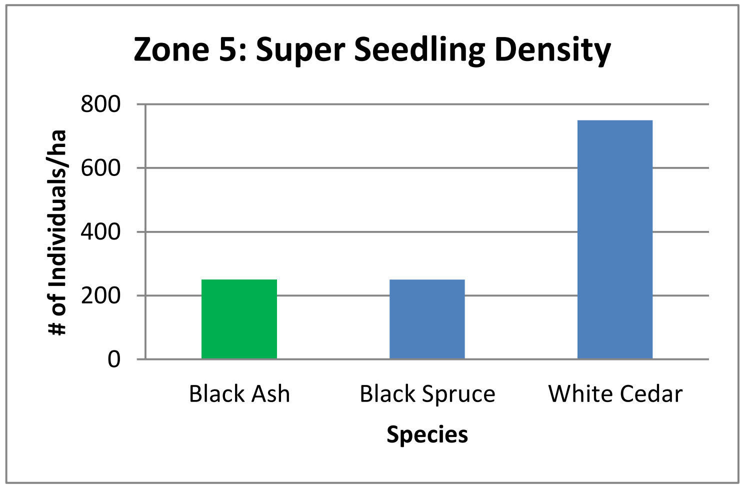
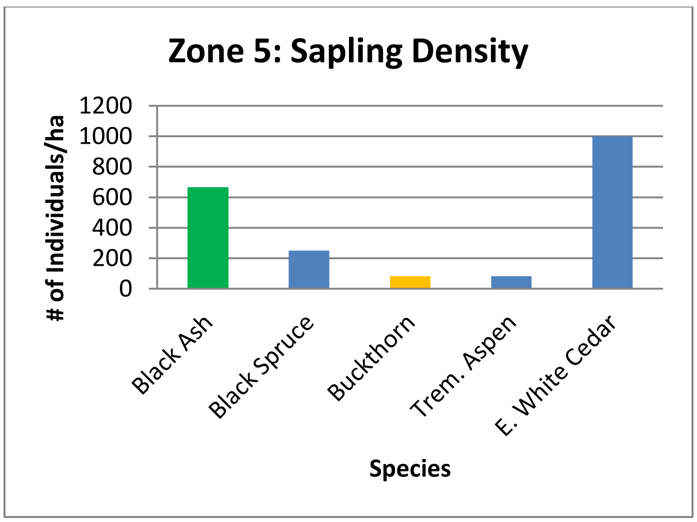


Figure.20. Overall seedling density per species present per 1 ha for Zone 5 *(ash shaded green)*.
Figure.21. Overall super seedling density per species present per 1 ha for zone 5 *(ash shaded green)*.



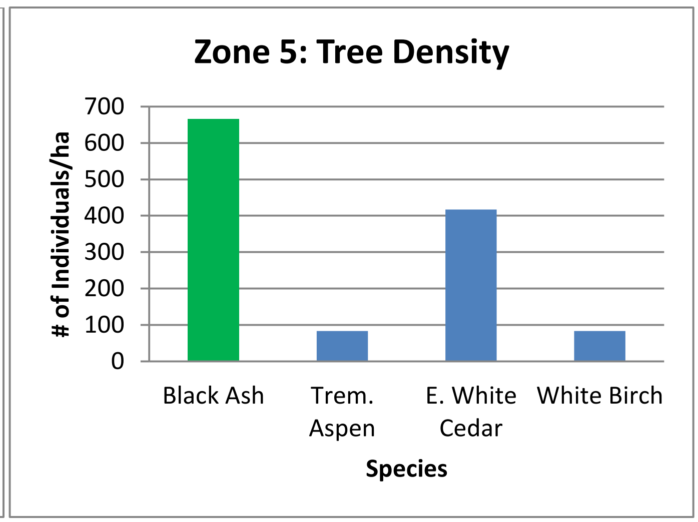


Figure.22. Overall sapling density per species present per 1 ha for zone 5 *(buckthorn shaded yellow, ash shaded green).* **Figure.23.** Overall tree density per species present per 1 ha for zone 5 *(ash shaded green).*

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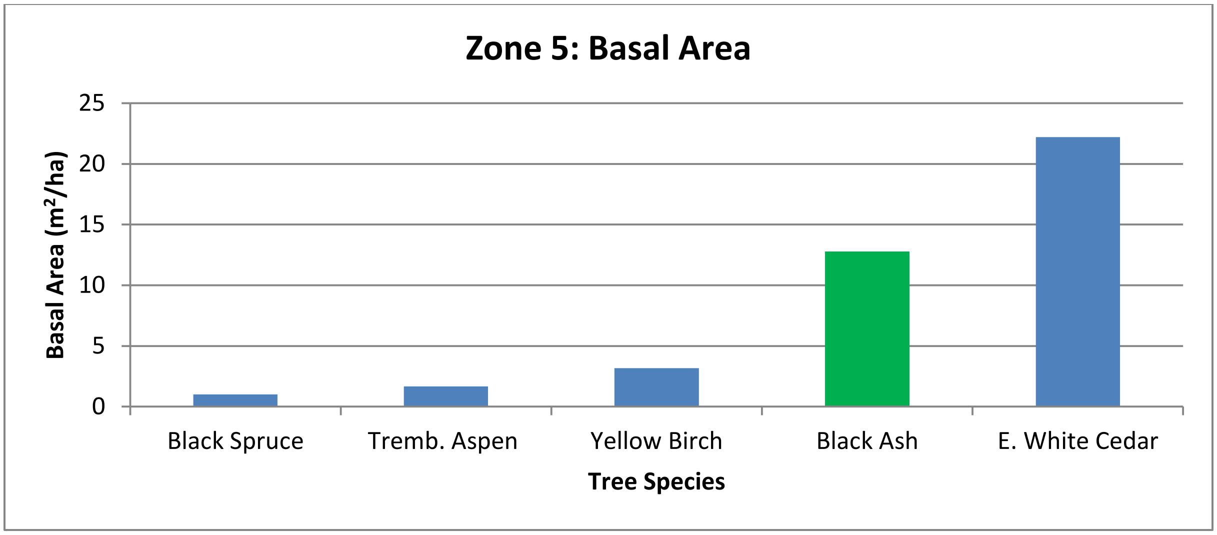


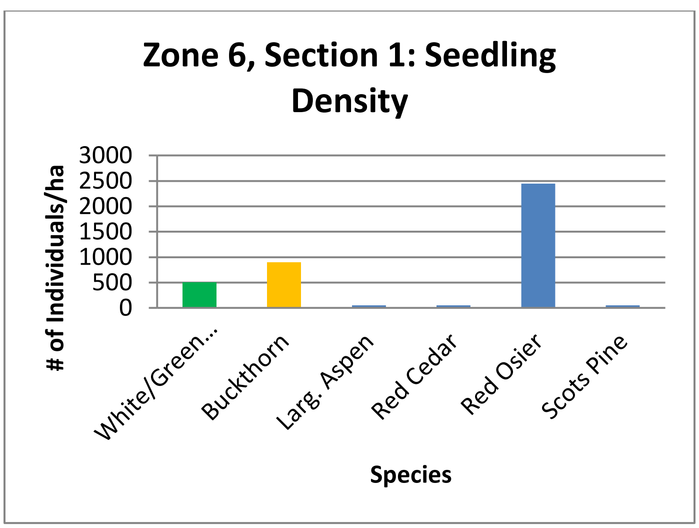
Figure.24. The basal area in square metres per ha for zone 5.

In zone 5 eastern white cedar and black ash dominate the basal area while the other three tree species found were only established in smaller abundances

Zone 6 (South-West Corner of Wildlife Sanctuary Nature Area):

Section 1:

High densities of red osier dogwood were present in zone 6, section 1, with a secondary presence of buckthorn seedlings. Ash formed the highest tree density in both super seedling and sapling stages of growth, while buckthorn was the only other species observed in these stages. There were no mature trees observed in this section of zone 6.



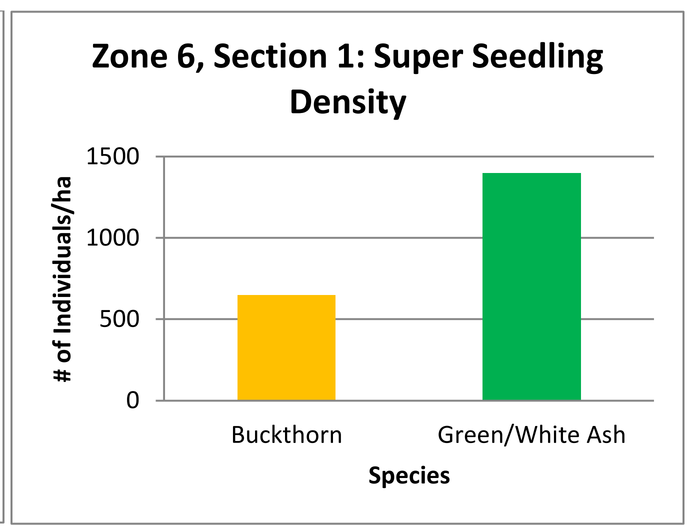
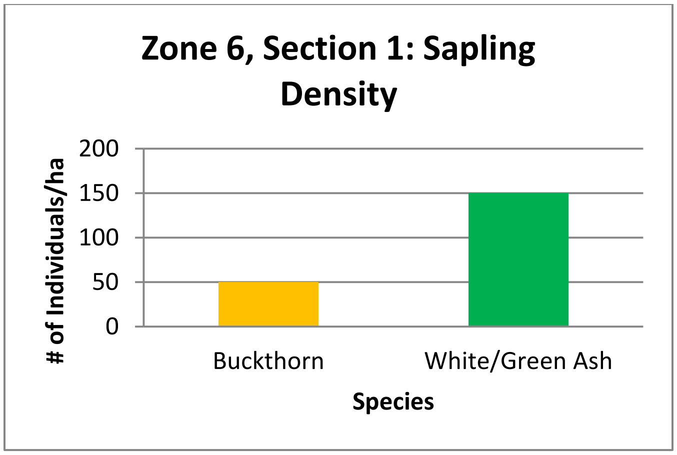


Figure.25. Overall seedling density per species present per 1 ha for Zone 6, section 1 *(buckthorn shaded yellow, ash shaded green)*. **Figure.26.** Overall super seedling density per species present per 1 ha for zone 6, section 1 *(buckthorn shaded yellow, ash shaded green).*



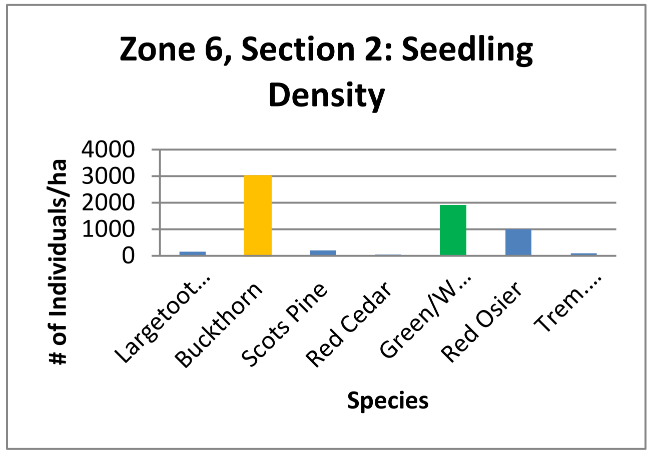
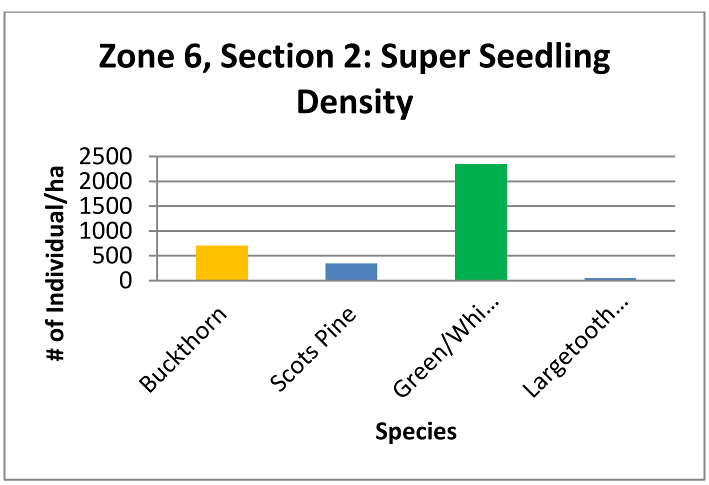


Figure.27. Overall sapling density per species present per 1 ha for zone 6, section 1 *(buckthorn shaded yellow, ash shaded green).* **Figure.28.** Overall seedling density per species present per 1 ha for Zone 6, section 2 *(buckthorn shaded yellow, ash shaded green).*

Section 2:

Buckthorn presented the greatest density of seedlings for zone 6, section 2 with ash maintaining the next highest density. Ash showed the greatest density for super seedlings, saplings and mature trees throughout the rest of the section. This section showed the greatest overall density of ash anywhere in the Trent Nature Areas.



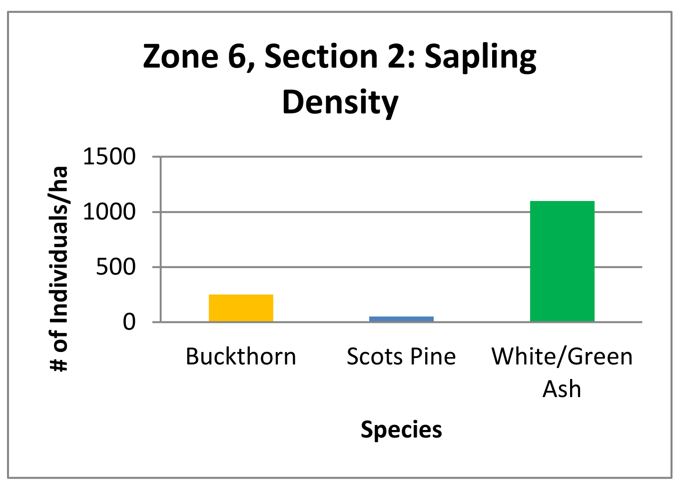
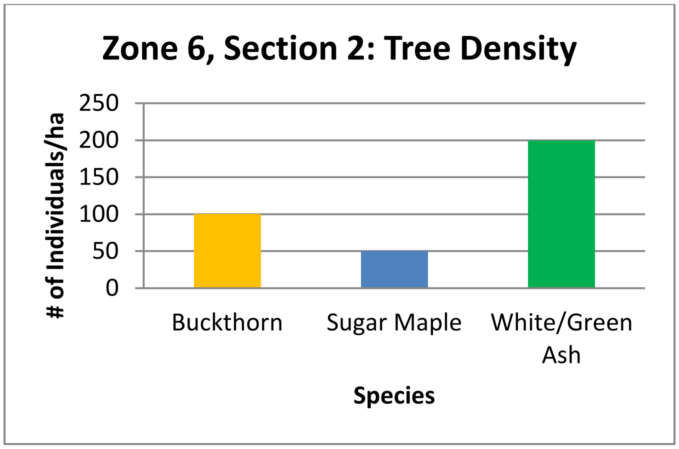


Figure.29. Overall super seedling density per species present per 1 ha for zone 6, section 2 *(buckthorn shaded yellow, ash shaded green).* **Figure.30.** Overall sapling density per species present per 1 ha for zone 6, section 2 *(buckthorn shaded yellow, ash shaded green).*



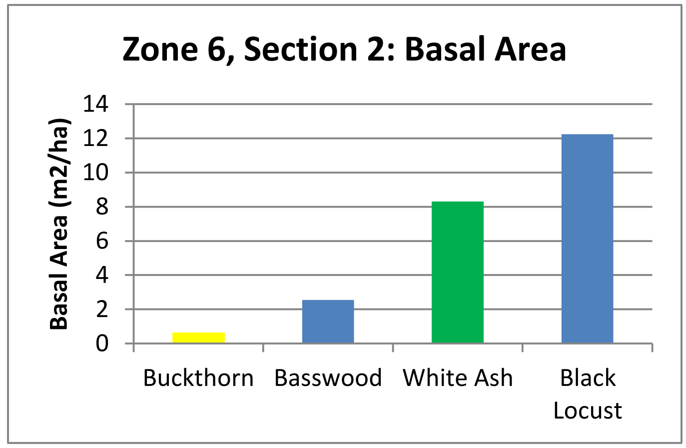
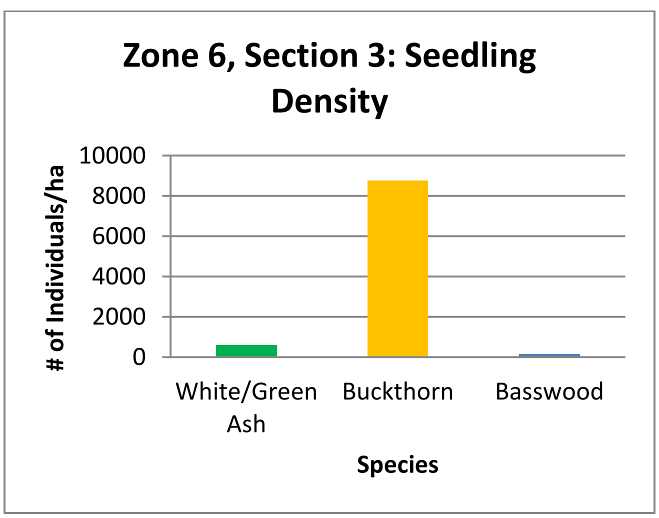


Figure.31. Overall tree density per species present per 1 ha for zone 6, section 2 *(buckthorn shaded yellow, ash shaded green).* **Figure.32.** The basal area in square metres per ha for zone 6.

The second section of zone six shows a dominant basal area of black locust followed by black ash, while basswood and buckthorn comprise little basal area.

Section 3:

Buckthorn made up the highest density of seedlings and super seedlings found in zone 6, section 3. Ash formed the highest density of saplings as well the second highest density of mature trees. Black locust was the most common mature tree present, however many specimens appeared to be highly weathered nearing the label of standing deadwood.



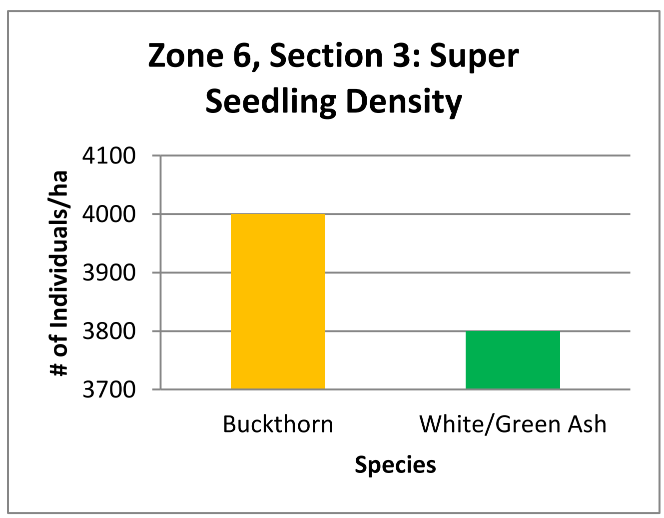
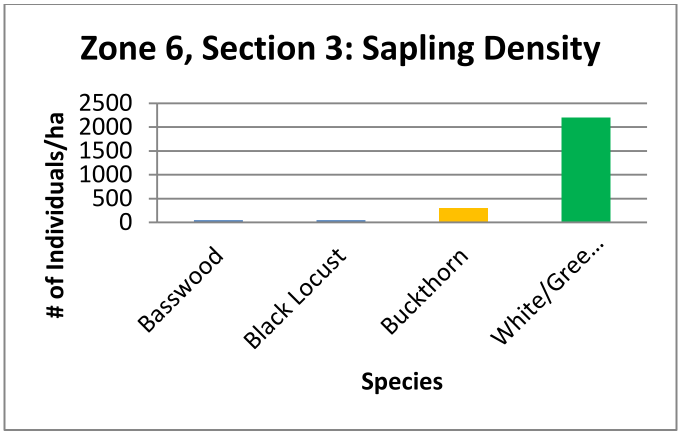


Figure.33. Overall seedling density per species present per 1 ha for zone 6, section 3 *(buckthorn shaded yellow, ash shaded green)*. **Figure.34.** Overall super seedling density per species present per 1 ha for zone 6, section 3 *(buckthorn shaded yellow, ash shaded green).*



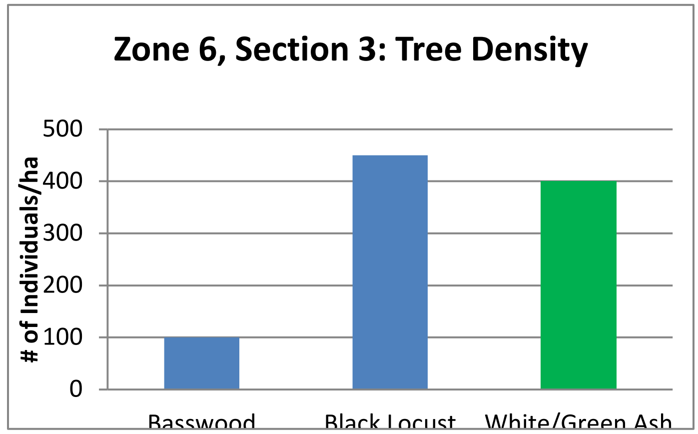
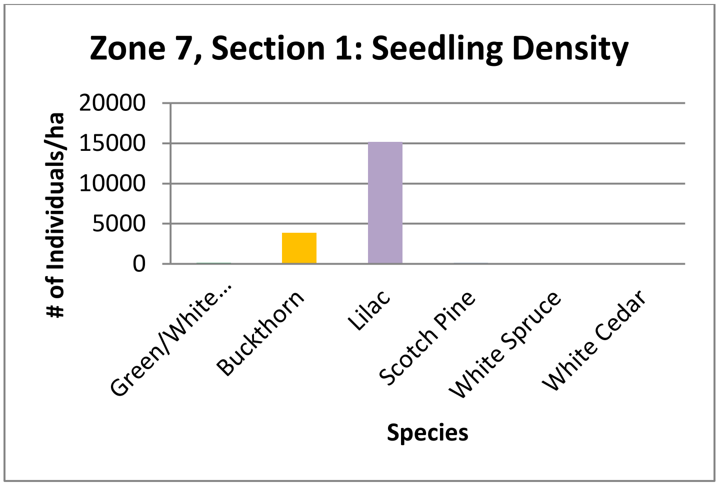


Figure.35. Overall sapling density per species present per 1 ha for zone 6, section 3 *(buckthorn shaded yellow, ash shaded green).* **Figure.36.** Overall tree density per species present per 1 ha for zone 6, section 3 *(ash shaded green).*

<u>Zone 7 (North West Edge of Lady Eaton Drumlin Nature Area):</u>

Section 1:

Lilac formed the greatest density of seedlings and super seedlings in zone 7, section 1. Buckthorn had a lesser presence at these stages of growth. Buckthorn followed by ash formed the greatest densities of saplings. Ash saplings appeared weathered and brittle. Lilac, Manitoba maple and scots pine shared approximate equal density for presence of mature trees. The overall density of mature trees was very low.



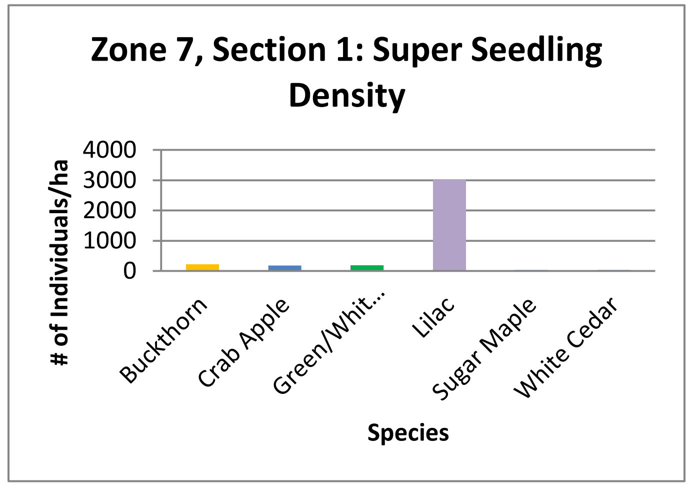
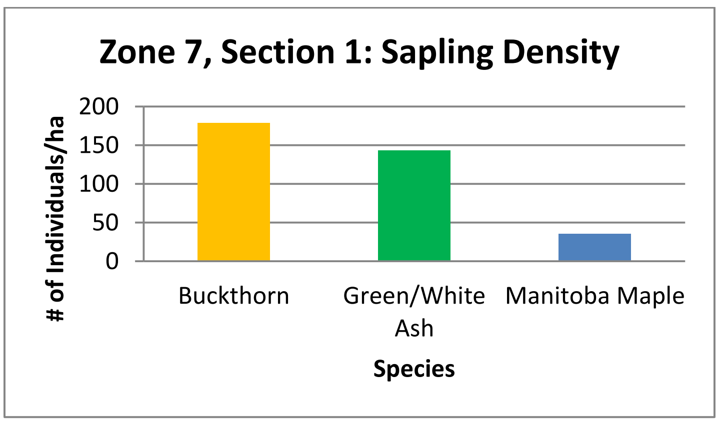


Figure.37. Overall seedling density per species present per 1 ha for zone 7, section 1 *(buckthorn shaded yellow, ash shaded green, lilac shaded purple).* **Figure.38.** Overall super seedling density per species present per 1 ha for zone 7, section 1 *(buckthorn shaded yellow, ash shaded green, lilac shaded purple).*



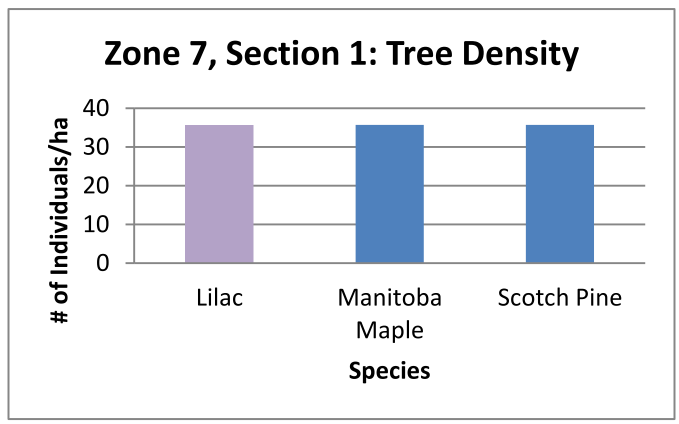
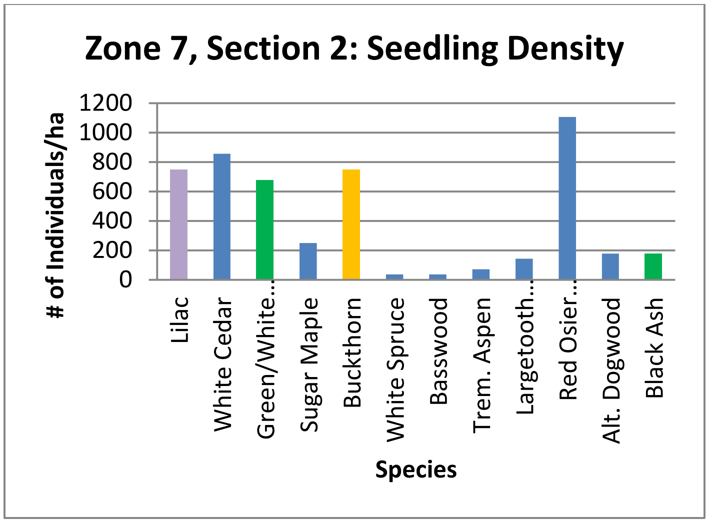


Figure.39. Overall sapling density per species present per 1 ha for zone 7, section 1 *(buckthorn shaded yellow, ash shaded green).* **Figure.40.** Overall tree density per species present per 1 ha for zone 7 section 1 *(lilac shaded purple).*

Section 2:

Red osier dogwood and Eastern white cedar formed the highest density of seedlings in zone 7, section 2, growing in the areas of saturated soils and standing water. Buckthorn and lilac were found in the highest densities growing on areas of land that weren’t submersed. Ash formed the highest density of super seedlings and mature trees. Ironwood was found in highest density in areas with less soil saturation as opposed to the species such as white elm and black ash found present in/adjacent to standing water.



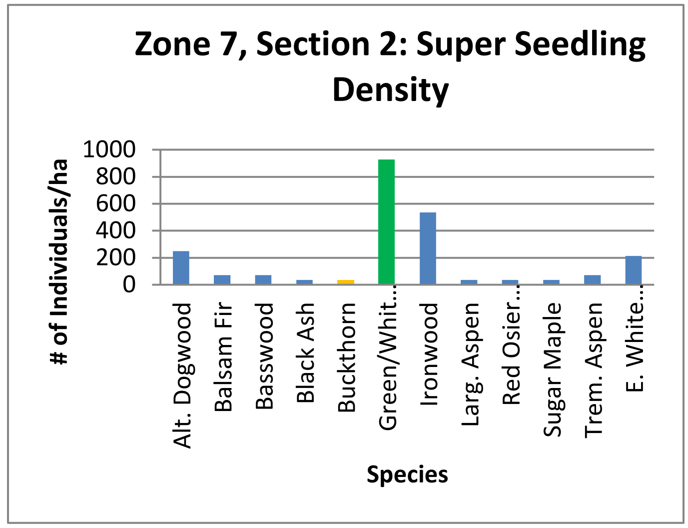
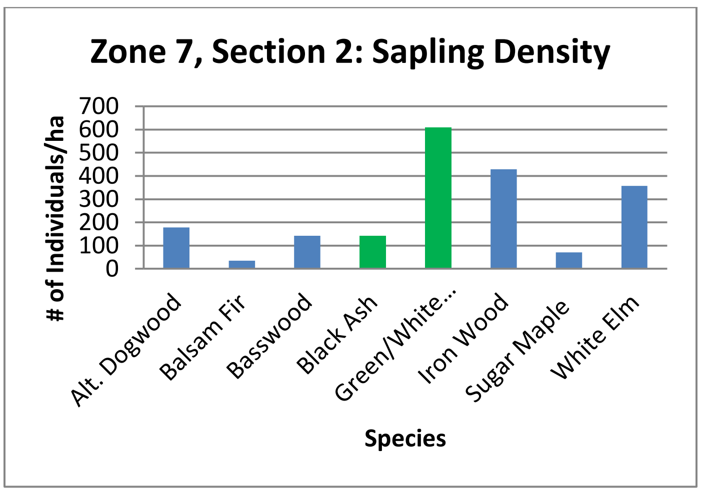


Figure.41. Overall seedling density per species present per 1 ha for zone 7, section 2 *(buckthorn shaded yellow, ash shaded green, lilac shaded purple)*. **Figure.42.** Overall super seedling density per species present per 1 ha for zone 7, section 2 *(ash shaded green)*



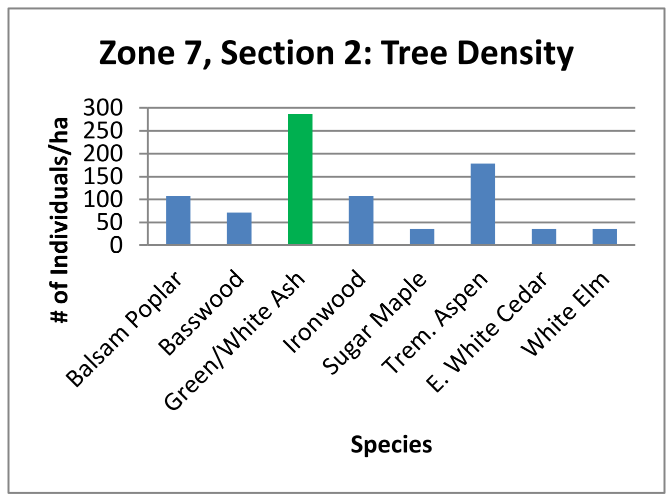


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Figure.43. Overall sapling density per species present per 1 ha for zone 7, section 2 *(ash shaded green).*
Figure.44. Overall tree density per species present per 1 ha for zone 7, section 2*(ash shaded green).*

A combination of ash and trembling aspen make up much of the girth in the zone seven section 2, while hardwoods such as ironwoods and maple are also fairly well established. The white elm and cedar make up only a small portion of the basal area.

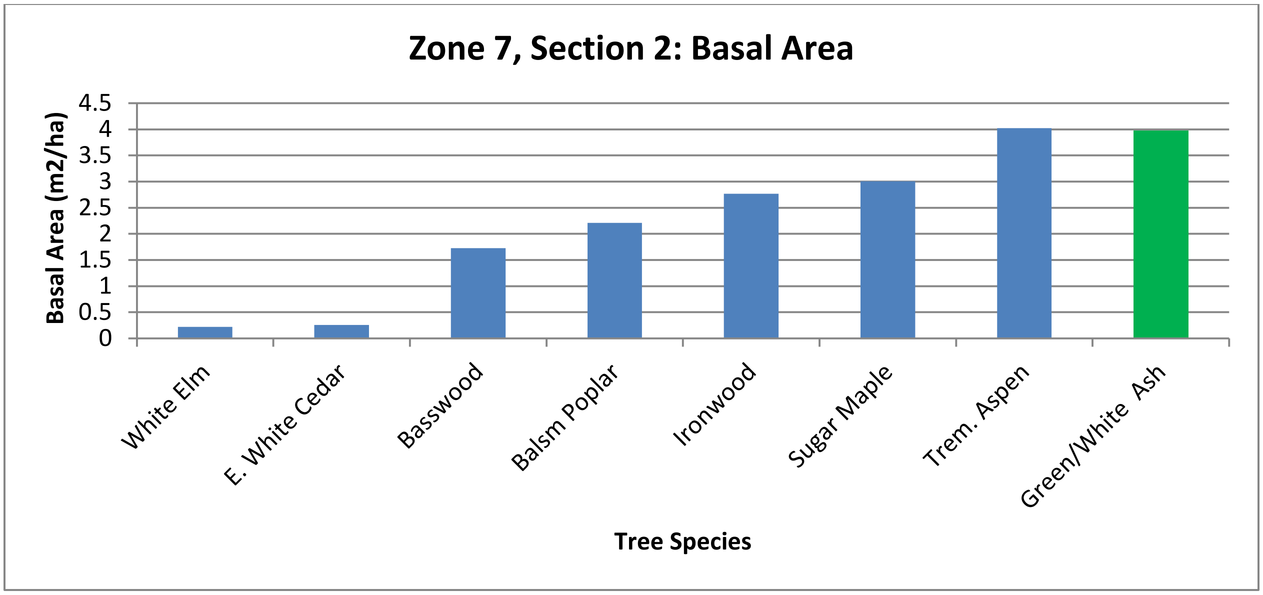
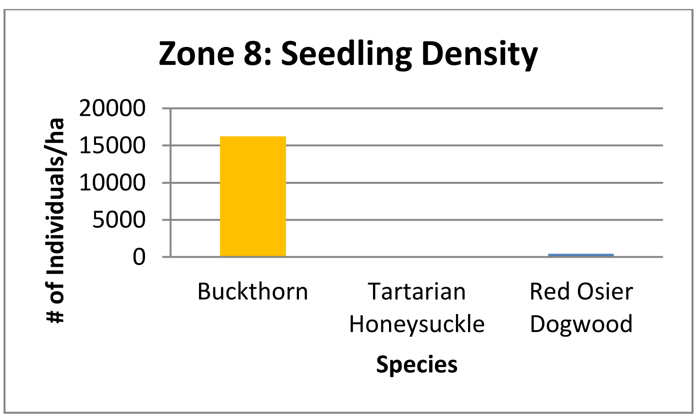


Figure.45. The basal area in square metres per ha for zone 6.

<u>Zone 8 (Core Campus AC - BATA):</u>

Buckthorn was the species with the highest density of seedlings and super seedlings in zone 8, and there was no ash present at these stages of growth. There was low overall sapling growth in this zone. Ash and white pine formed the highest densities of mature trees. Zone 8 was the zone with the highest deciduous tree density of areas sampled.



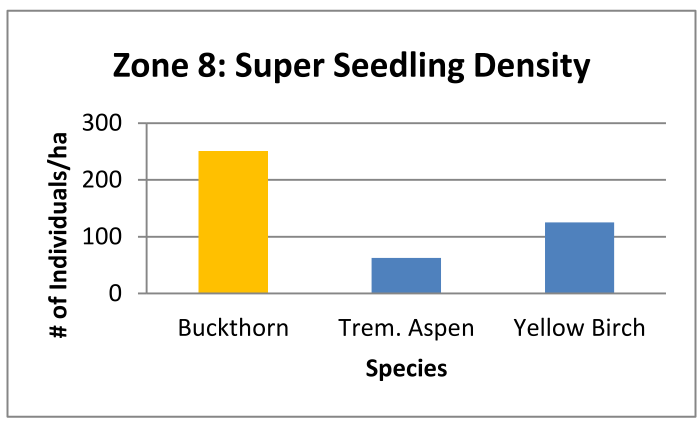
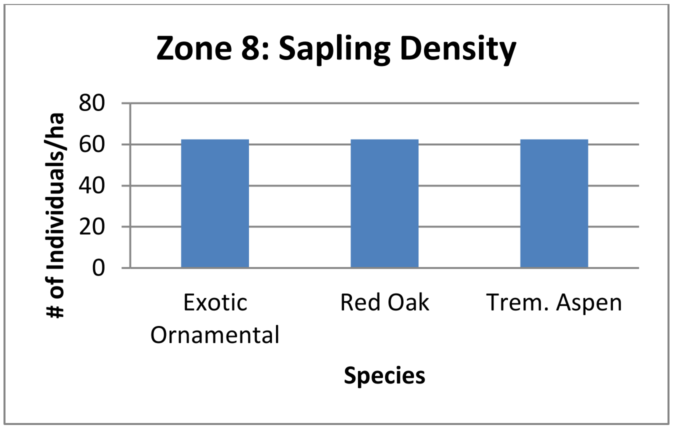


Figure.46. Overall seedling density per species present per 1 ha for zone 8 *(buckthorn shaded yellow).*
Figure.47. Overall super seedling density per species present per 1 ha for zone 8 *(buckthorn shaded yellow).*



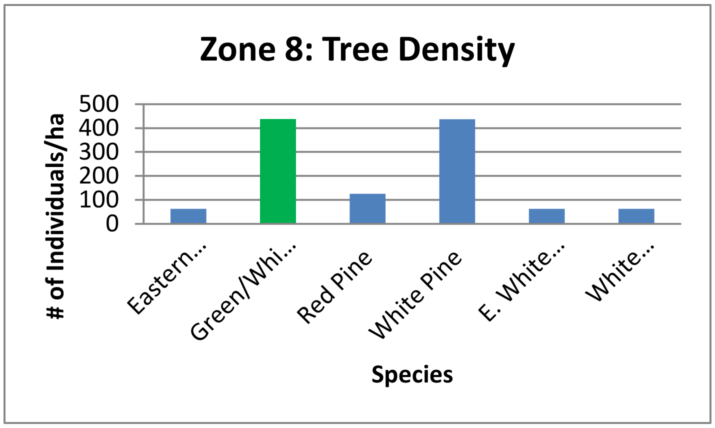


Figure.48. Overall sapling density per species present per 1 ha for zone 8. **Figure.49.** Overall tree density per species present per 1 ha for zone 8 *(ash shaded green).*

White pine makes up a large portion of the basal area of trees for zone 8, while white spruce and both green/white ash compete for the mid-range of mature establishment. White cedar, hemlock, and rep pine remain less established in the variety of mature trees.

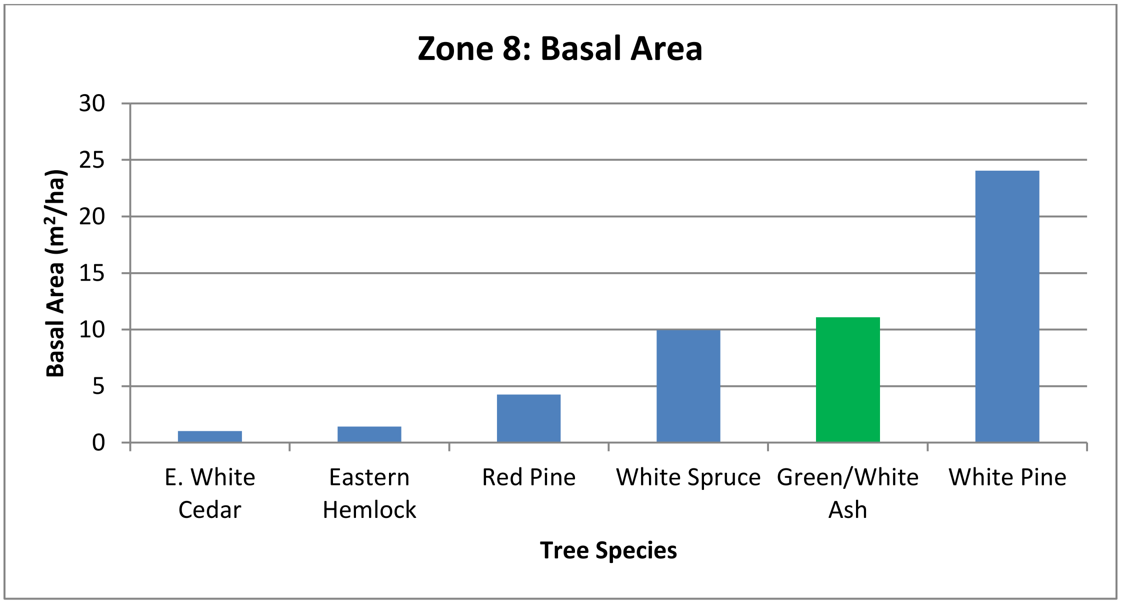
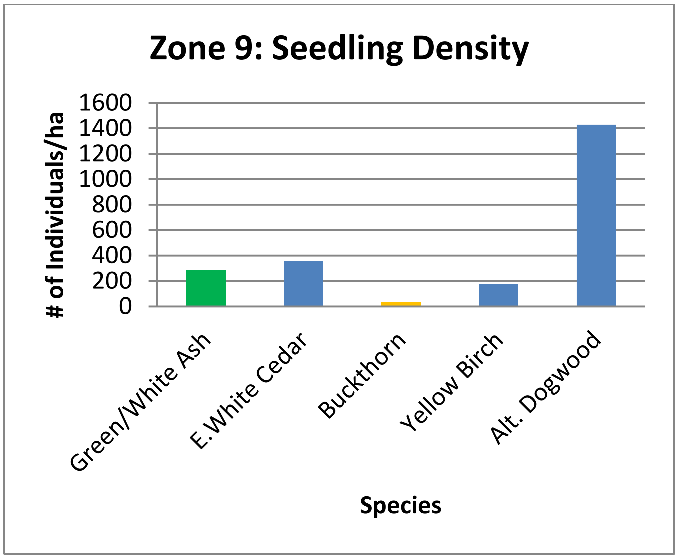


Figure.50. The basal area in square metres per ha for zone 6**.**

Zone 9 (East-Central Wildlife Sanctuary Nature Area):

Alternate dogwood formed the highest density of seedlings in zone 9. Buckthorn formed the lowest seedling and super seedling density. Buckthorn formed a high density of saplings that extensively covers the zone. Mature trees were of relatively low overall density in this zone.



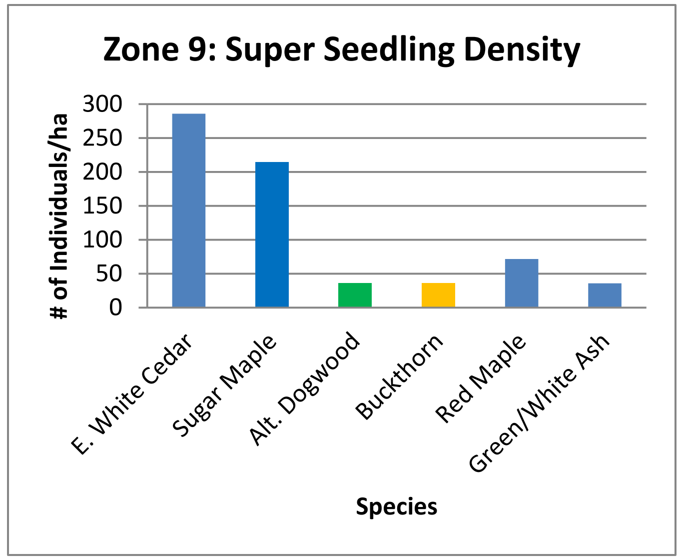
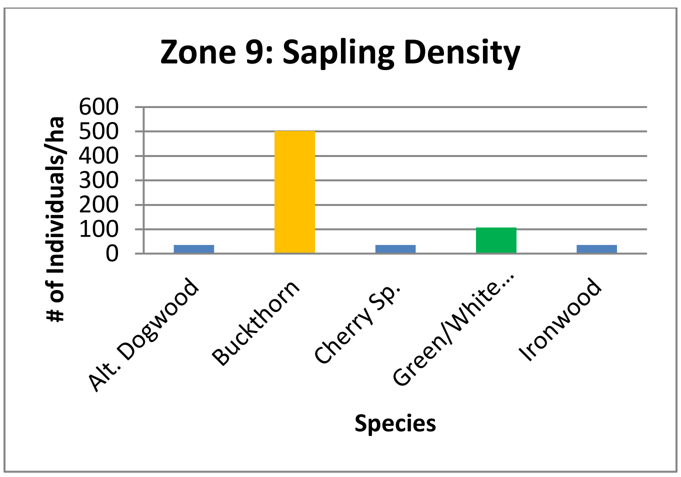


Figure.51. Overall seedling density per species present per 1 ha for zone 9 *(buckthorn shaded yellow, ash shaded green).* **Figure.52.** Overall super seedling density per species present per 1 ha for zone 9 *(buckthorn shaded yellow, ash shaded green).*



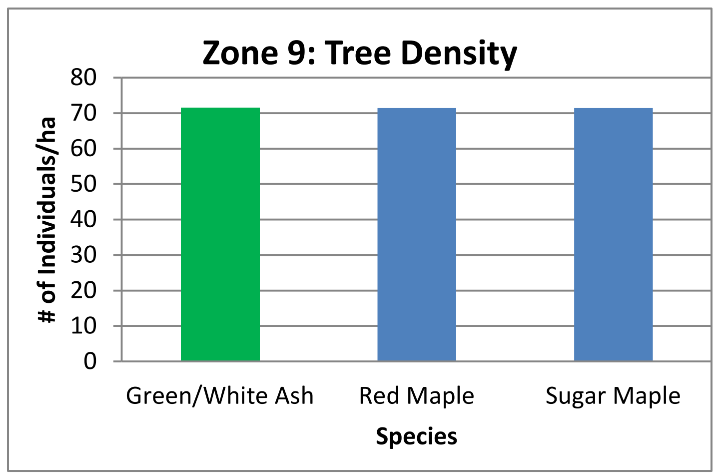


Figure.53. Overall sapling density per species present per 1 ha for zone 9 *(buckthorn shaded yellow, ash shaded green).* **Figure.54.** Overall tree density per species present per 1 ha for zone 9 *(ash shaded green).*

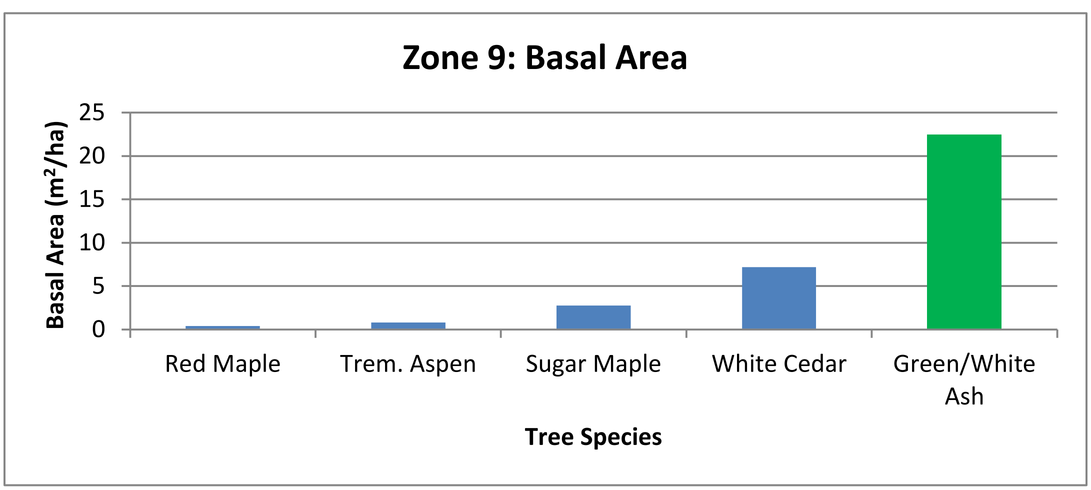
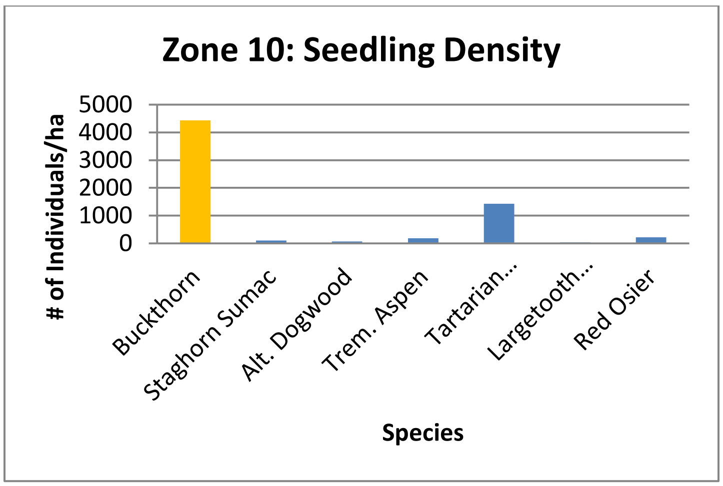


Figure.55. The basal area in square metres per ha for zone 9.

This area shows a dominance in mature ash trees, with >20 square metres of basal area, while the other species are less established when looking at the level of mature growth.

Zone 10 (Core campus):

Buckthorn formed the overall highest density of seedlings and saplings in zone 10. Tartarian honeysuckle formed the highest density of super seedlings. Tartarian honeysuckle appeared most commonly in tight groups of roughly 15 super seedlings. Overall mature tree density was low. Specimens that were observed were of poor health, bordering the label of standing deadwood.



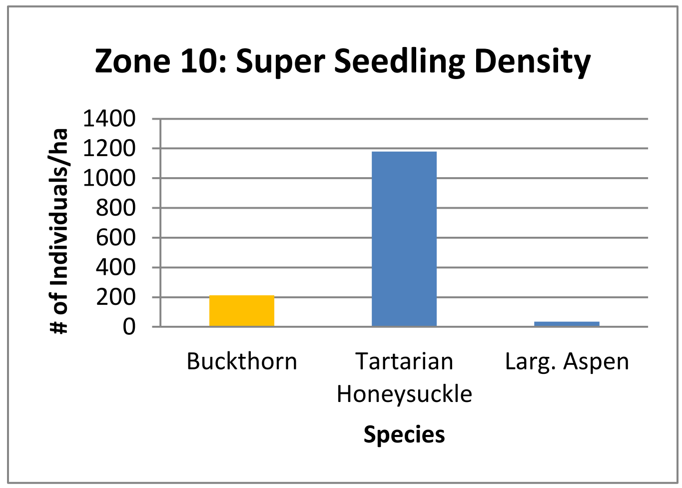
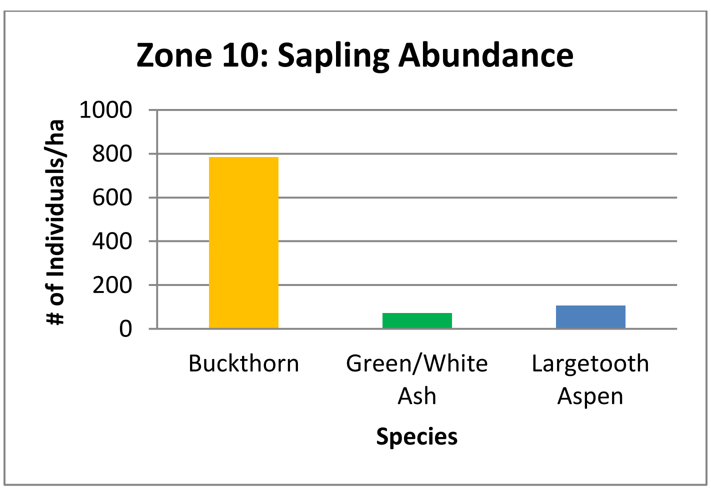


Figure.56. Overall seedling density per species present per 1 ha for zone 10 *(buckthorn shaded yellow).* **Figure.57.** Overall super seedling density per species present per 1 ha for zone 10 *(buckthorn shaded yellow).*



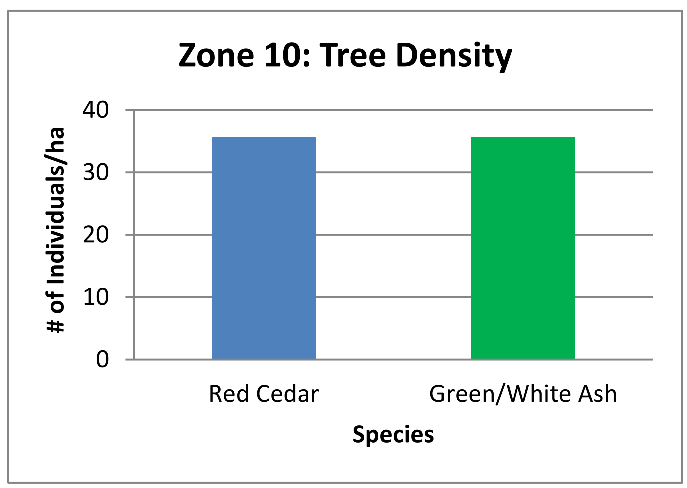
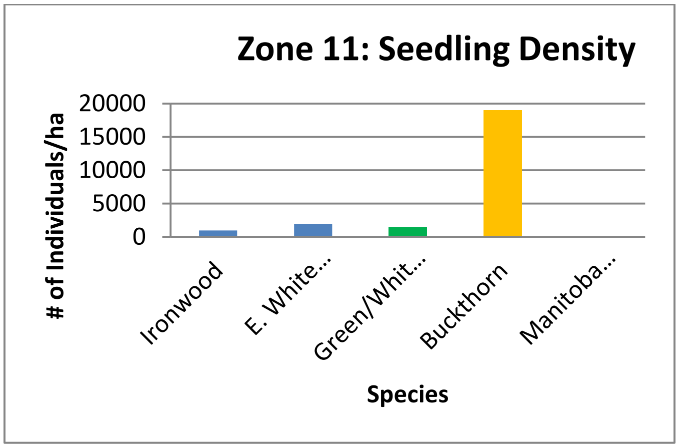


Figure.58. Overall sapling density per species present per 1 ha for zone 10 *(buckthorn shaded yellow, ash shaded green).* **Figure.59.** Overall tree density per species present per 1 ha for zone 10 *(ash shaded green).*

Zone 11 (Central Wildlife Sanctuary Nature Area):

Buckthorn formed the highest density of seedlings and super seedlings in zone 11. Ash formed the highest density of saplings. There was no mature ash found in the zone, with a dominant density of balsam polar.



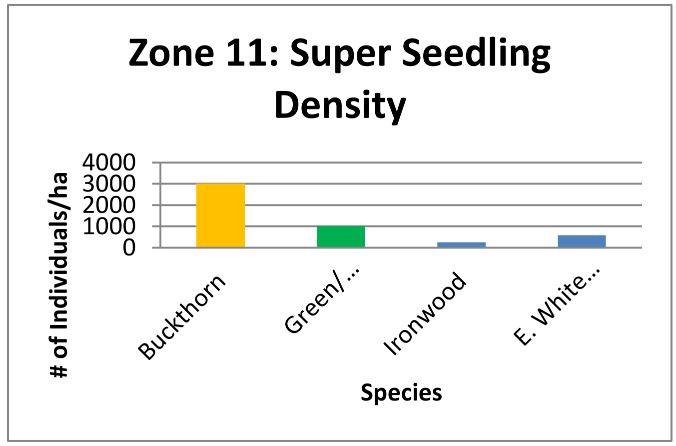
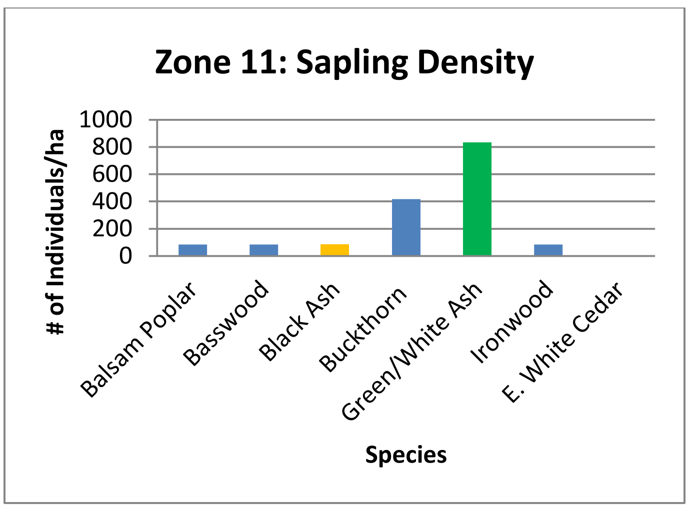


Figure.60. Overall seedling density per species present per 1 ha for zone 11 *(buckthorn shaded yellow, ash shaded green)*. **Figure.61.** Overall super seedling density per species present per 1 ha for zone 11 *(buckthorn shaded yellow, ash shaded green).*



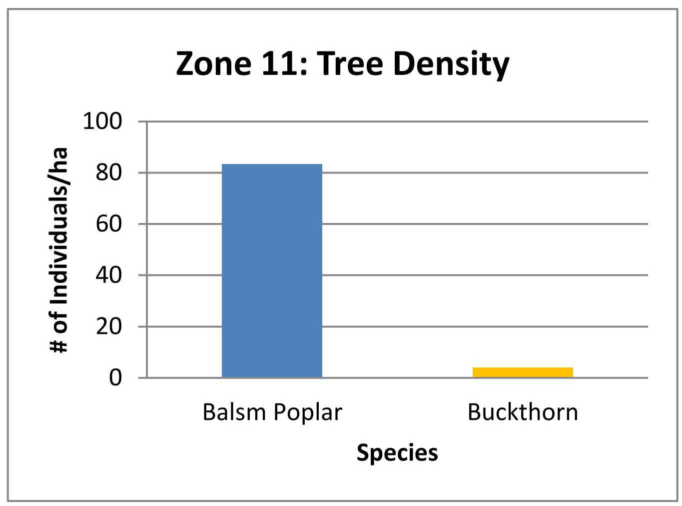


Figure.62. Overall sapling density per species present per 1 ha for zone 11 *(buckthorn shaded yellow, ash shaded green)*. **Figure.63.** Overall tree density per species present per 1 ha for zone 11 *(buckthorn shaded yellow, ash shaded green).*

Again in zone 11 there is a greater basal area comprised of ash, followed by the occasional elm tree. Cedars, poplars, and the invasive buckthorn exist as minimal mature establishment.

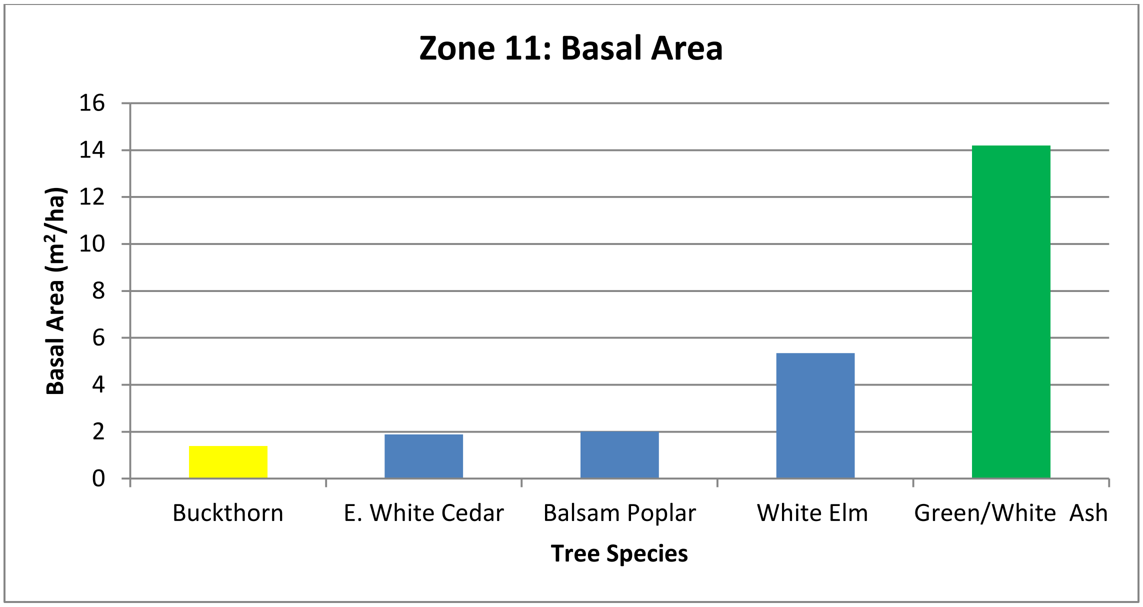


Figure.64. The basal area in square metres per ha for zone 11.

Summary of Results

In the broad scope of the data that was collected through forest characterization, it is clear that there is a more complicated issue than simply areas with dense ash populations being susceptible to invasion and mortality. The intensity of buckthorn community establishments at all levels of succession are alarming, especially when coupled with ash populations that may leave an empty path for this species to further invade the campus forests. When just focusing on the ash species, it is evident that a substantial portion of the nature areas within the Peterborough campus are host to vast establishments of ash trees, many of these existing at the size and maturity that will be favoured by the exotic borer. In many of the zones, including 2, 3, 4, 5, 6, 7, 8, and 9, ash species are some of the most established at mature stages amongst all other species, making up much of the healthy habitat and shade tree community within these forested areas. The magnitude of ash establishment on campus presents an obvious future challenge, simply put that if one species is responsible for close to a quarter of the entire mature tree community within a forest and such species is facing likely decimation, the forest ecosystem and species composition will drastically change in the future. Furthermore, the level of dominance that immature buckthorn communities are showing (seedling and saplings) in a time where significant gaps may be created within these ecosystems presents a greater issue that requires more attention than just focusing on the loss of ash alone. Early management/preparation and ecological intervention may be required to maintain stable conditions and foster important species interactions and functions that already exist. Finally, what species are excelling in the different zones is also made apparent, and considering the levels of establishment by these species at the varying stages of growth will contribute to more sound undertakings in the response to the need for forest management.

4.6 Field/Research Errors

Within the field results there are missing components of data that could have contributed to forest characterization in further detail. Due to seasonal limits, data collection was affected by the autumn sampling period with respect to observable/documentable biota. In this case, much of the shrub layer and forest-floor biota was beyond its seasonal threshold, and thus observations/characterization of potentially significant species were left out of this report. Although the forest floor characterization may have contributed to more detailed assumptions about the implications of ash harvesting or buckthorn invasion, it may be argued that such data was not crucial for the completion of this report, as the research concerns primarily tree species in the levels of succession beyond the first years of growth.

Furthermore, inconsistencies in field data may have occurred due to human error. The transect method may have been biased in some locations due to terrain and weather conditions; resulting in an imperfect transect placement. Additionally, it is assumed that all species data was collected accurately, although genuinely flawless tree identification cannot be guaranteed. With these challenges in mind, characterization was divided into zones in an attempt to represent the general forest ecosystem dynamics of each nature area, focusing on the locations that show the greatest densities of ash.

5. MANAGEMENT TOOLS AND STRATEGIES

The management tools and strategies can be broken down into 6 categories of focus:

- Inventory, Monitoring and Assessment;
- Treatments;
- Tree Removals;
- Tree Planting;

- Wood Waste Disposal; and
- Public Education and Communication.

5.1. Inventory, Monitoring and Assessment

The municipality of York Region outlines the various detection surveys utilized to gather qualitative data specifically revealing the presence of EAB, as well as delimitation surveys which indicate quantitative data related to the density and distribution of the pest around what is perceived to be the point of introduction to the area or the forefront of infestation. These type of surveys are optimal for identifying the age and severity of infestation, but are often labour-intensive and associated with a high cost value though very valuable in terms of monitoring efforts. Both detection and delimitation surveys can be statistically inaccurate at certain population thresholds due to incorrect recordings of EAB individuals that may occur in an area due to unforeseen circumstances such as transportation into the area by wind or other means, resulting in false positive results. The four survey methodologies currently in use throughout Canada for EAB are prism traps, visual examinations, branch sampling techniques, biological survey tools (i.e. sticky traps) and aerial and hyperspectral imagery. Prism traps are baited with plant volatile that emits pheromones throughout a short range which attract and ultimately capture EAB. Visual examinations for signs of entry and occupation are generally successful only after ash trees have been heavily infested. Branch sampling techniques are employed to detect signs of EAB activity prior to heavy infestation, where samples of the ash tree in question are brought back to a laboratory for further analysis. Biological Survey Tools such as sticky traps and native wasp species (*Cerceris fumipennis*), have indicated good usage in detecting low-level infestations (York Region, 2011). Aerial and hyperspectral imagery is acquired usually from satellite imagery or aircraft, and reveals ash trees that are showing signs of deterioration, indicating the presence of EAB. Further information on these varying survey techniques will be provided in the final report.

Inventory of ash trees of both public and private lands is crucial in determining their density, location, distribution, size, and condition. This is accomplished by sampling a select few ash trees throughout different zones to achieve an understanding of potential risk factors, as well as a direction for strategically managing the EAB invasion within areas of establishment. The "Suitability Criteria for Treatment of Ash Trees" model (see Appendix) will be utilized by the City to identify high value ash trees subject to pesticide treatments. Regular assessments and monitoring approaches will be carried out that include branch sampling, trapping and tree inventory in order to validate and provide the means to alter further management actions to the best suitability. The City of Guelph suggests in terms of future assessments that it is beneficial to remove larger ash trees as there will be more sunlight exposure to seedlings and younger non-ash tree species which will offer better efficiency in regards to succession. This factor may elude to a reassessment and alteration of original management plans and therefore should be monitored. Another factor that may elude to management plan alterations is the branch sampling and trapping methods that were originally included in the management plan by the City of Peterborough as a means of detecting the presence of EAB, but can also be employed to reveal indications towards the progress of EAB infestations. City maps developed by the City of Kitchener, the City of Guelph, the City of Cambridge and the City of Peterborough have been constructed to divide wards in order to determine level of risk based on predominance and health of ash trees and past EAB findings (See Appendix 1, Figure 1.1).

5.2. Treatment

Pesticides have been proven to be successful in prolonging the life expectancy of ash trees given that the product is applied during the initial stages of infestation or preemptively in non-infested trees facing potential invasion in high risk areas. Pesticide products generally must be administered with a pressurized system with the effectiveness depending on the intactness of the vascular system of the tree as this is a detrimental factor in the success of product translocation throughout the specimen. Traditional pesticide administering methods included topical treatments to the tree species by means of spray applications, generally applied to the exterior of the tree, though issues have arisen in the past in regards to biota other than EAB being affected. Injections of pesticides reduce risks of causing implications among non-target species. There are five pesticide products currently registered for EAB mitigation in Canada; ACECAP® 97, Confidor 200SL, Azadirachtin (TreeAzinTM), and IMA-JET and IMA-JET 10 as listed on February 21, 2016 by Health Canada. The most highly sought after pesticide among various municipalities appears to be TreeAzin™ which features less ecological damage than the other injectable pest control options.

The City of Peterborough is utilizing TreeAzin™ to treat high value ash trees for protection against EAB. This product is a bio-pesticide which is derived from plant extracts and has been proven to have a 95-97% success rate (City of Peterborough, 2013). The area of focus for this pesticide application will surround ash trees in locations with greatest economic, social or environmental concerns. This includes high profile specimens in parks or other areas of interest, and areas where a rather significant ash tree population exists which will be subject to major impacts with their decline. The treatments will need to be carried forward every two years until the threat of EAB has dissipated.

5.3. Tree Removal

While lacking efficiency on lessening the overall EAB populations in a broadly infested area, preemptive and active tree removal strategies will serve to reduce risks and mitigate long-term costs associated with potential hazards and liabilities. To limit hazardous conditions and minimize risks associated with dead and health deteriorated ash trees, specimens facing variable degrees of infestation may be subject to removal entirely. According to the City of Peterborough (2013), recent research suggests that ash trees become very dry and brittle upon annihilation brought upon by EAB infestations within 12-18 months. There are a variety of methods associated with the removal of ash trees such as felling the tree in situ without removal from the area, removal tree parts so only a stump remains, removing all parts of the tree including the stump, salvage logging operations to provide a means of cost recovery, and chipping, slabbing and/or burning the tree to destroy all EAB life stages. Tree removal will require the development of site-specific policies and protocols with an examination of zone usage such as site (i.e. trails, woodlands, roads, etc.) and size classes (i.e. small trees can be cut and left on site, while larger trees will most likely require removal from site). Careful consideration should be applied to the dynamics of costs (i.e. replacement species, time period of removal efforts, appropriate eradication method for site, etc.) and site specific conditions upon removal that will determine the degree of ecological integrity in a high volume ash tree area (i.e. successional stage, tree species composition, etc.).

Removal within the City of Peterborough area will follow shortly after a minimum property standards by-law is put into place. Focus will be applied to ash trees in high volume areas such as parks and open spaces within core public usage and exposure zones throughout Peterborough (City of Peterborough, 2013). Ash trees evading high usage and activity from the general public will be left to deteriorate on their own. Ash trees located on private properties are generally removed or treated at the expense of the landowner, but exceptions by certain municipalities may be made where trees pose a hazard towards the wellbeing of the public or property damage if the tree were to collapse. With officials requiring access to private properties to inspect, treat or remove trees infested with EAB, municipalities may want to consider enacting new laws or potentially strengthening existing by-laws to provide employees/inspectors rights to do so (York Region, 2011). However, the dynamics of public and private landowner responsibilities mostly lacks any type of application for Trent University, as the institution is largely governed by the ownership of one entity.

5.4. Tree Replacement and Planting

In high human activity areas where ash tree removal will take place, a replacement species will need to be selected for each individual extracted. Locations where ash species are dominant species and play a vital role in the ecology of the site and surrounding ecosystems (i.e. providing a means to prevent erosion, habitat for various biota, microclimate temperature regulations, and increase water quality), a plan to mitigate damage will need to be established. Tree replacement will be dependant upon inventory and site analysis of current and future ecological conditions in parks and open spaces to determine the placement and species composition of selection. Native tree species are optimal for selection in comparison to non-native tree species, and will be considered as replacement individual first and foremost prior to a hybrid or introduced tree species compatibility analysis’. Each tree species considered vary based on spatial and temporal conditions. Both hybrid and introduced tree species present the potential to become invasive given lack of competitors and predators in Canada adapted to combat overgrowth of such vegetation. Trees that are listed as invasive will be avoided altogether in order to protect the biodiversity of native forest communities. Though, it may take up to 30 years for a newly planted tree to offer the maximum benefits to urban forests being affected by EAB invasions (City of Peterborough, 2013). In addition, the identification and promotion of the growth of existing non-ash species through strategic forestry management practices will be employed to foster a naturally occurring seed bank and tree establishment. Upon successful establishment, maintenance and monitoring is expected to ensure removal and control of invasive plants or other competitors. It should be noted that areas withstanding the loss of ash trees are increasingly vulnerable to invasive plant species such as European buckthorn.

5.5. Wood Waste Disposal

It is indicated that Peterborough will most likely fall into a designated EAB regulated area, similar to other municipalities throughout Ontario. Upon ash tree removal (both preemptively and following EAB onslaught), it has been determined that the City of Peterborough staff will work with stakeholders in researching and identifying the most appropriate method to dispose of ash wood waste. Brush and small branches of wood waste are recommended to be incinerated as conducted in the Tri-Cities, London, and Guelph. These same cities and others have decided upon mulching wood waste for recreational infrastructure, and sale towards projects predetermined to be within city limits.

Based on methods of EAB management from the Glen Major Forest near Uxbridge ON; there is potential to use removed uninfected ash trees for forest rehabilitation purposes. Interpreters from Glen Major have outlined that piles of timber laid in non-congruent mounds with hollow gaps can enhance biodiversity and the ecological succession of a natural area. Mounds act both as shelter habitat for fauna, while also working as a catchment net for migrating seed. After a period of accumulated growth, mounds would take the role of contributors towards soil organic material accumulation. Habitat mounds such as those observed at the Glen Major Forest may be functional in forest communities of the Trent Nature Area which will have declined from strategic ash tree removal.

5.6. Public Education and Communication

A significant and crucial factor of consideration in the overall EAB management plan are programs designed specifically for public education and outreach initiatives. Various forms of media and strategies will be employed (i.e. social media updates, posters, informational brochures, etc.) to keep the public informed and assist property owners, with emphasis on those in high risk areas. Efforts towards public education and outreach initiatives are expected to be associated with higher expenses initially, but becoming a less expensive element over time. It is also imperative that municipalities and stakeholders local to the area are well informed and regular meetings are conducted with both involved in the decision process towards strategies and management options for EAB. York Region suggests that parks, forestry and additional staff personnel should be trained to identify signs and symptoms of EAB infestations to provide another means of monitoring EAB impacts within the area, and training should be provided by the municipalities to ensure qualification. Programs that offer incentives to landowners to encourage protection and remediation of forest cover dynamics and promoting land stewardship have been considered among various municipalities (i.e. the York Natural Planting Partnership (YNPP) program and the Backyard Tree Planting Program facilitated by York Region).

6. ASSESSING BUCKTHORN

6.1 Growth Patterns and Risks

Results have determined that European buckthorn is the most abundant invasive species in the Trent Nature Areas, and poses the greatest threat towards the inhibition of native vegetation regrowth. European Buckthorn alters the conditions of the landscape both above and below ground through physical and chemical manipulation of the landscape (Klionsky et al 2010). The species grows and reproduces at a rate quicker than almost any other species of shrub/tree in the Trent Nature Areas, except perhaps the likewise invasive Amur honeysuckle *(Lonicera mackii)* (Michigan Gov 2014). The characteristics responsible for the European buckthorn's rapid spread are the rhizomatous growth pattern, and the abundant yearly production of seed (Heidorn 2007). A Wisconsin study observed buckthorn seeds residing in the seed bank of an arid area being able to germinate after thirty years of dormancy (Klinsky et al 2010). As there are many mature buckthorn patches found throughout the TNAs, it can be assumed that a large fraction of the seeds in the seed bank are buckthorn. The spread of buckthorn seeds are difficult to maintain as they are a common food for songbirds which spread the seeds over vast areas (Michigan Gov 2014). Mature berries eventually dehydrate; becoming lite and are able to be blown by the wind outside the growth area of the tree which spawned them (Michigan Gov 2014).

Rhizomatous growth patterns permit the subterranean spread of European buckthorn through a vast root network that spawns shoots (Klionsky et al 2010). The shoots eventually develop into mature trees which mirror the original tree that spawned it (Klionsky et al 2010). Klionsky states that rhizomatous structures permit one successful strain of buckthorn to grow continuously for generations (Klionsky et al 2010). Potentially the most valuable function of rhizomatous structures to the spread of buckthorn is the suppression of other vegetative competition (Michigan Gov 2014). Aggressive buckthorn root networks overcrowd the roots of other trees/shrubs, inhibiting or debilitating competitive growth. Evidence from Klionsky's study determines that the rhizomes of the buckthorn plant have the ability diffuse allelochemicals into the surrounding soil strata that inhibit the roots of other plants from up-taking essential nutrients (Klionsky et al 2010). Although the specific allelochemical compound produced by buckthorn has yet to be identified, it is thought to work much the same way as the chemical thujone deposited by eastern white cedar *(Thuja occidentalis)* (Klionsky et al 2010). Klionsky shows that plant diversity has been identified as being significantly less in areas inhabited by high densities of buckthorn (Klionsky et al 2010). From the results found on the TNAs this has also been determined to be true; particularly in areas such as zone 6, section 2 and zone 10. These areas presented evidence that coexisting species of ash at all stages of growth appeared to be in declining state health; demonstrating signs of peeling bark, excessive lichen grown, brittle branches and debilitated bud regeneration. With ash trees being already placed under a condition of stress by competition with buckthorn; it can be argued that buckthorn will assist in the spread of emerald ash borer throughout the Trent Nature Areas. The removal of ash trees within the Trent Nature Areas should take into consideration the proximity of trees to patches of buckthorn and debilitated health as a consequence of buckthorn competition.

6.2 Introduction to Control Methods

Based on a stringent and in-depth study conducted by the City of Winnipeg for their Natural Areas Stewardship Commission, there are different types of control methods for European buckthorn that can target different results for various circumstances of buckthorn infestation. A commonality of all methods, is minimizing soil disturbance (Nature Manitoba 2014). Soil disturbance activates areas of the seed bank that can lead to the germination of previously dormant seed layers (Heidorn 2007). It must be stated that European buckthorn is one of the most persistent invasive species currently growing in Ontario. There is no method which is 100% successful. Multiple control techniques will be required to reduce the effects of buckthorn on the TNAs.

6.3 Hand Pulling

Optimal only for small scale buckthorn removal projects; pulling buckthorn by hand removes the entire plant structure both above and below the ground (Nature Manitoba 2014). Due to the laborious nature of this method, it is best conducted in small patches during period of the spring when soil is softest and there are no seeds on the plant that could be tossed and accidentally transported . It is important that the entire rhizome network is removed, as any severed roots could potentially spawn a new shoot. When removed; plants should be immediately placed into a thick garbage or canvas bag that can be sealed to prevent any material from falling out during transport (Nature Manitoba 2014). It is important that all broken sticks and twigs from the removed plant are collected; as there is potential for berries from the previous season to have remained on parts of the plant (Nature Manitoba 2014). Using a shovel or thorough stomping; soil disturbed from the removal of the plant should be compacted to the best of one's ability (Nature Manitoba 2014). Hand pulling is the control method which poses the greatest risk towards activating the seed bank (Nature Manitoba 2014). Of the assessed zones on the TNAs, hand pulling would be most effective in areas where buckthorn was found on the fringes of riparian zones. This includes areas of zone 2,3,5 and 11.

6.4 Chemical Herbicide Application

One potential mechanism of ash tree removal is the application of glyphosate on sawed off stumps (Au et al 2014). The glyphosate is typically applied in a paste that goes directly on the stump, directly underneath the cut (Au et al 2014). The glyphosate is best applied during fall immediately after the plant enters winter dormancy (Au et al 2014). The reasoning for this time period is that most the plants nutrients are stored at this time, and the maximum amount of stored tissue can be intoxicated by the glyphosate (Au et al 2014). It is crucial that the glyphosate be applied immediately to green tissue within five minute of cutting down the tree (Au et al 2014). Otherwise the stump will develop a resin that will insulate the tissue from the glyphosate (Au et al 2014). As with the hand pulling, it is important that the cut down material is properly disposed of, and that there is no risk of contamination from residual plant matter (Nature Manitoba 2014). Studies have determined that glyphosate is effective on average 88% of the time, killing the root base of the main plant as well as most connected rhizomatous structures (Au et al 2014). Larger trees may often take successive years of application to completely kill one plant (Au et al 2014). A major disadvantage to glyphosate application is the cost of large scale use (Au et al 2014). To make glyphosate a cost efficient method in the TNAs, glyphosate would likely only be able to be applied to the largest and most prominent of buckthorn trees (Au et al 2014). Another concern may be that certain student groups may express objection to herbicide application in the TNAs. It should be noted that the riparian glyphosate restrictions that are observed when glyphosate is sprayed, do not typically apply when applied as a paste (Au et al 2014). Likewise, precautions should be observed so as not to risk environmental contamination through herbicide leaching.

6.5 Biological Herbicide Application

Chontrol Peat Paste (CPP) is a developing method of biological remediation for trees across North America (Au et al 2014). It is typically used for Manitoba maples, scots pine, poplars and other aggressive or invasive tree species (Au et al 2014). The paste is filled with spores from the *Chondrostereum purpureum* fungus which infiltrates healthy cambium tissue, and consumes it over time (Au et al 2014). A tree is typically girdled, and like the glyphosate is immediately applied before the formation of a resin (Au et al 2014). Over the successive 2-3 years, the fungus weakens the tree inhibiting aggressive tendencies (Au et al 2014). In the case of buckthorn, a weakened plant may allow other species to overpower and eventually outcompete the plant (Au et al 2014). There has been not observed risk of widespread being initiated in forest communities from paste application (Au et al 2014). The fungus will travel through rhizomatous root systems, but will not spread between the roots of different plants (Au et al 2014). Although CPP is not officially designated for buckthorn control, there have been many successful cases across North America where it has been successful (Au et al 2014). Although CPP has been approved for use by nearly all provincial governments (including Ontario); many municipalities have reserved approval and are still in the waiting process (Nature Manitoba 2014). The City of Peterborough has currently not passed legislation either in support for or against CPP. Although there are great benefits to be had from CPP application, it is a costly to apply and would be best on small scale application (Au et al 2014). There have been no statements as to whether there is a difference in effectiveness between riparian and upland environments (Au et al 2014).

6.6 Cover Suppression

The principal controllable limiting factor for European buckthorn is light exposure. Buckthorn requires high levels of light exposure to adequately grow, and will become outcompeted in areas where plants are covered by forest canopy or tall grass cover (Michigan Gov 2014). Throughout the zones in the TNAs, it was observed that the areas with the most mature trees (and consequently the largest canopies) maintained the lowest densities of buckthorn. Upon reviewing buckthorn remediation strategies of other local authorities, it appears that inhibiting light penetration is the most common method of buckthorn suppression. The point of cover suppression is not to kill buckthorn communities, but rather to weaken them (Nature Manitoba 2014). The process of cover suppression entails the temporary suppression of buckthorn while systematically creating plant communities which will be able to establish and outcompete the dormant buckthorn community (Nature Manitoba 2014). When the cover is removed there will almost always be an instant resurgence of shoots (Nature Manitoba 2014). A study in Manitoba covered up a large patch of buckthorn for three years to study whether the subterranean rhizomes would deteriorate (Nature Manitoba 2014). Findings discovered that a resurgence of shoots from dormant rhizomes within a month of removing the cover (Nature Manitoba 2014).

Typically the project is conducted by cutting down a dense patch of buckthorn in mid spring, when most of the plant's nutrients are in the above ground tissue; but seeds have not grown mature enough to be at the stage germination (Nature Manitoba 2014). The above ground matter is harvested and safely contained (Nature Manitoba 2014). A ground cover is laid across the entire patch, ensuring there aren't shoots penetrating through the barrier (Nature Manitoba 2014). The barrier is constructed through either laying a nylon landscaping barrier, or laying a dense layer of mulch high in lignin material (Nature Manitoba 2014). Desirable plants are planted in holes constructed through the weed barrier or mulch (Nature Manitoba 2014). Monitoring of plants should be conducted on a regular basis so as to ensure that buckthorn sprouts aren't intruding through holes made for desirable species. Mulch is beneficial as a sustainable weed barrier which contributes organic material to the soil layer in the long term (Nature Manitoba 2014). A source of mulch on the TNAs could be either from the systematically removed ash or from the mature buckthorn trees. Mulch is considered a less secure barrier than nylon as there is an ability for penetration by persistent buckthorn shoots, and may require more regular maintenance of shoot removal by hand (Nature Manitoba 2014). Nylon weed barrier is an unsustainable resource that offers not addition to the soil it covers (Nature Manitoba 2014). Nylon barriers however offer a nearly impenetrable barrier that requires very little follow up maintenance after application (Nature Manitoba 2014). It is important to identify that both barriers limit all understory growth, and the entire plant community growing amongst buckthorn will also be suppressed (Nature Manitoba 2014). This could include native rhizomatous grass communities which are incapable of the same longevity of dormancy as buckthorn (Nature Manitoba 2014). It could also lead to the decline of a seed bank from excessive predation from detritivores preferring the covered habitat (Nature Manitoba 2014). In acknowledging the entire present biota, it should be stated that cover suppression should only be conducted in areas where the benefit of removing buckthorn outweighs the cost of potentially causing long-term damage to the pre-existing biota.

7. MANAGEMENT PLAN OPTIONS

There are four different options for managing the Emerald Ash Borer (EAB) invasion:

1. Do Nothing/Minimal Management
2. Active Management
3. Pre-Emptive Management
4. Aggressive Management

7.1. Option 1: Do Nothing/Minimal Management

Elements:

- There would be zero action taken towards the management of ash trees in response to potential or already occurring EAB infestations outside of regular maintenance of trees.
- Allow nature to take its course with very minimal intervention from the municipalities
- Regular maintenance would be unrestricted by species, and carried out when a safety risk or obstruction poses a problem.
- There would be no special surveys or control actions taken to mitigate EAB associated problems.
- The replacement of trees would be non-existent or essentially devoid of any urgent action and there would not be any incentives for private landowners specific to ash mortality/replacement.
- Communication and public outreach initiatives would be very minimal or essentially non-existent

Pros:

- There would be very minimal preliminary or acute expenses on EAB
- The variability on expected outcome would be reduced significantly, especially considering a no action plan would result in a near 100% ash mortality rate over the next 10 years
- Public acceptance can potentially be manipulated

Cons:

- Risks would increase by a substantial amount with mass devastation of ash trees creating hazardous conditions posing liability and public safety implications
- Removing trees reactively and proactively has been determined as being more cost extensive
- Considering the large and widespread decimation tendencies of EAB, forestry workers may have a difficult time keeping up with the removal of dangerous trees
- Lack of survey data places restrictions on the ability to efficiently determine and react to hazardous trees or to provide advice to property owners
- Severe and unforeseen environmental impacts and alterations as a result of the loss of ash species is expected
- The loss of biodiversity is also expected as a result of habitat alterations and deterioration due to ash tree devastation
- Permanent loss of genetic diversity for genus *Fraxinus*
- Aesthetic and recreational complications and value depletions along roadways and other areas of significance
- Loss of trees would result in extensive erosion in riparian and inclined landscapes

• Open canopy without a plan would subject exposed areas to invasive plant species (ex. European Buckthorn)
Discussion: • York Region reviewed some of the potential pros and cons associated with the do nothing/minimal management approach and determined that irrespective of the option selected, most urban, roadside and woodland ash trees are expected to die over the next 10 years. Thus, they have decided that it would be best to salvage high value urban trees and preserve urban canopy, in addition to replacing roadside trees to preserve aesthetic and environmental values. • The City of Peterborough acknowledges that a do nothing/minimal management approach provides zero control over the rate of infestation and the death of ash trees, conserving none of the present benefits provided by the trees. This zero response approach is not favorable for the reason that it would jeopardize public safety and ignore present reactive and safety-driven forestry workloads (The City of Peterborough, 2013). There is no reversing the decision and selecting a different approach later in outbreak as all other options are lost when infestation becomes severely predominant.

7.2. Option 2: Active Management

Elements: • Action towards tree removal and inoculation is done purely on the basis of the rate of EAB invasion • There would be no foresight and preemptive action for areas which were in areas of potential future invasion • Tree assessment would be conducted only for areas where EAB has already been documented • Public outreach would be available only in areas where EAB has been documented • Trees of cultural or visual significance would be inoculated • Private landowners within areas known to be inhabited by EAB would be able purchase inoculation through the administrative body • Weak and withering trees within EAB affected areas would be subject to removal in high human activity areas where risk is largest. • Replacement trees would be planted in areas of significance (i.e. along municipally owned roads in urban areas) • Enticing consideration, the treatment of some high value and heritage trees may be completed. However this factor is not a major component of focus.
Pros: • Trees of cultural or scenic significance could be preserved through inoculation • Landowners would have the ability to preserve desired trees at a personal cost • Much more proactive and responsible approach to managing costs in comparison to option 1 • Erosion control could be maintained in riparian and inclined areas • Reforestation of depleted areas would occur; contributing to function and aesthetics

- Through systematic tree removal, EAB habitat would be limited in areas already invaded

Cons:
- EAB is at risk of spreading unimpeded into new areas
- Ash removal is more costly in trees already infested by EAB (quarantine cost)
- Less of a focus on private landowner ability to pay for inoculation
- Losses to biodiversity and genetic diversity of genus *Fraxinus* would still be very viable with this option.
- Greater risk of property/infrastructure damage from dead and dying EAB infested ash

Discussion:
- Financial analysis from the City of Guelph estimated that cost efficiency of the active plan versus proactive plan was basically the same overall sum; costing more money in the later years of the management plan.
- City of London planners voiced that although the active management plan was an option in their project proposal, it was believed to be ineffective in the overall suppression of EAB spread.

7.3. Option 3: Pre-Emptive Management/Aggressive

Elements
- Areas of potential future EAB invasion are researched, and plans are created to conduct tree removal and inoculation pre-emptively before EAB invasion
- Action towards tree removal and inoculation is done both in areas of existing and projected EAB invasion
- Greater focus on populations growing on privately owned/managed properties
- Tree assessment would be conducted for areas both where EAB has already invaded as well as areas of potential EAB invasion
- Public outreach would be targeted towards areas where EAB is both projected to disperse and is already inhabiting
- Trees of cultural or visual significance would be inoculated in areas both affected by EAB and forecast for future invasive
- Private landowners within areas known to be inhabited by EAB would be able purchase inoculation through the administrative body
- Weak and withering trees within EAB affected areas would be subject to removal in high human activity areas where risk is largest.
- Replacement trees would be planted wherever trees are removed
- Enticing consideration, the treatment of some high value and heritage trees may be completed.

Pros
- Trees of cultural or scenic significance could be preserved through greater rates of inoculation
- Landowners would have the ability to preserve higher rates of desired trees at a personal cost

• Much more proactive and responsible approach to managing costs in planning for the long term • Erosion control could be maintained in riparian and inclined areas • Reforestation of depleted areas would occur; contributing to function and aesthetics • Through systematic tree removal, EAB habitat would be limited in areas already invaded • Less risk of property/infrastructure damage from dead and dying EAB infested ash • Cost effective in the long term as EAB management is required less in management plan • Permits the mitigation of invasive plant species in forest ecosystems prior to the invasion of EAB
Cons • Greater funds/resources required during the large scale removal process in pre-empted sites • Potential waste of funds/resources managing areas that would not have been invaded • Removal of healthy ash trees and disregarding natural adaptation
Discussion • It can be noted that all forestry serves in cities/regions which propose a pre-emptive/aggressive plan, place it as their official recommendation • The city of Barrie cites the benefits of using the time span between inoculation/removal and the EAB invasion to create pre-emptive plan to suppress potential invasive plant species (ex. European buckthorn, dog strangling vine) • The tri-city's plans all stressed the importance of using the pre-emptive measure as a method of public safety in preventing destruction caused by fallen trees on private and public property

8. REMOVAL/ REPLACEMENT METHODS

Specific to the campus forest community and composition, a removal plan and various techniques as well as replacement species are discussed in this section.

8.1 Removal Methods

Most of the assessed remediation plans outlined by municipal EAB strategies either result in the removal of all ash, or a combination of both large scale removal and the strategic inoculation of specific trees. Through addressing the sheer number of ash trees currently growing within the TNAs, it must be identified that the removal of all trees would be costly in both resources and time. There would also be a significant risk of debilitation of pre-existing habitat which could result from the intrusion of logging operations and the removal of lumber. Hereby our recommendation is that only trees in areas of exposure be subject to removal. As recommended by the City of London and York Region; all trees within 50m of roads or trails should be removed. This prevents the risk of dead trees blocking roads and trails, while also creating a buffer area without ash between areas of exposure and areas within the forest. Reducing numbers of potentially weakened ash trees will also remove stock which could act as incubators in an EAB onslaught. Although many individual ash trees may be able to survive an EAB invasion, it is best to lean on the side of security and remove all potential elements of risk involved with the potential spread of EAB. The TNAs have an elaborate trail network of both officially constructed and unregulated trails (goat paths). Based on frequency of use and area of fragmentation caused by trails, it is recommended that 50m buffers only be created around trails which receive intensive use.

In the removal of ash trees, it is recommended that trees be cut as low to the ground as possible so as to provide little exposure of the residual cambium layer that could be accessed by EAB. Root networks of the trees should be left in the soil as they will continue to play an important role in erosion control; while also contributing organic material to the soil. Measures should be taken ensure there as little soil disturbance as possible so as not to provoke invasive species which may be residing in the seed bank. Soil disruption also risks disturbing perennial forb underbrush root structures. This alteration could compromise the ease of restructuring the biota in the absence of ash trees. Such species may include: sharp-lobed hepatica *(Hepatica nobilus acuta)*, wild sarsaparilla *(Aralia nudicaulus)*, false solomon's seal *(Maianthemum racemosum)* and Canada mayflower *(Maianthemum canadensis)*. Such species were observed in areas of the Lady Eaton Drumlin; and based on local distribution could be assumed that such species would be found in zones of assessment.

8.2 Suggested Species for Replacement

The challenge of re-vegetating the forest gaps created by the loss or removal of ash species will require consideration of a variety of replacement options. The species in consideration will vary depending on site specific characteristics that determine the success of planting a species. These include: soil pH, depth, moisture content, colloid content, canopy cover, slope/aspect, land use, and interactions between local biota. In the situation of the TNAs, one must consider the invasive buckthorn and how the canopy gap will fill in the process of succession after removal or mortality. The following is a short list of some possible species to adopt into the management plan based on the variability of site specifications amongst the nature areas, and the more common species that have been established in the areas that are capable of succeeding beyond buckthorn and adopting the habitat the ash has used.

8.2.1 Trees

Basswood *(Tilia americana)*
Height:35-50ft, Spread:25-30ft
Site Preferences: Will tolerate drought once established, requires moist-well drained soils, pH 6.5-8.2

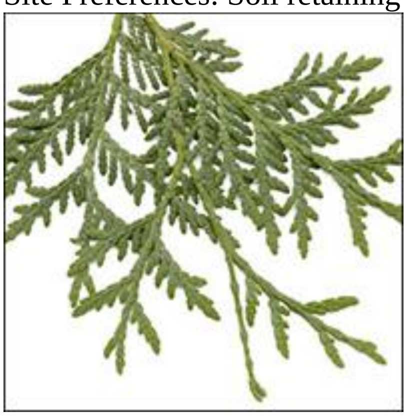
Bur Oak *(Quercus macrocarpa)*
Height: 55ft, Spread: 45ft
Site Preferences: Drought and intermittent flooding tolerant, pH 5-8.2

Common Chokecherry *(Prunus virginiana)*

Height: 20-30ft, Spread: 18-25ft
Site Preferences: Tolerant of moist and dry sites, pH adaptable

Eastern Hemlock *(Tsuga canadensis)*
Height: >30m
Site Preferences: Moist soil conditions, sun or shade

Eastern White Cedar *(Thuja occidentalis)*
Height: 15m
Site Preferences: Soil retaining water, moist soil



Elms (*Ulmus spp.)*
Height: 40-50ft, Spread: 30-50ft
Site Preferences: preferences vary, pH 5-8.2

Hackberry *(Celtis occidentalis)*
Height: 20m, Spread: 15m
Site Preferences: Drought tolerant, salt sensitive, pH 5-8.2, tolerates light shade, wind, and heat

Trembling Aspen, Largetooth Aspen, Balsam Poplar *(Populus spp)*
Height: 30m
Site Preferences: Moist soils, seasonal flooding, light shade- full sunlight

Sugar Maple *(Acer saccharum)*
Height: 60 - 80 ft, Spread: 40-50 ft
Site Preferences: Moist, well drained soil , neutral to slightly acidic soil pH

Red Maple *(Acer rubrum)*
Height: 40-60 ft, Spread: 25-40 ft
Site Preferences: Moist soils necessary, flood tolerance, salt sensitive, pH 5-7

Red Oak *(Quercus Rubra)*
Height: 35m
Site Preferences: Well- moderately drained soil, moderately shade tolerant

8.2.2 Shrubs

American Elderberry *(Sambucus canadensis)*
Height: <3m
Site Preferences: Damp and dry soil, full sunlight

Buttonbush *(Cephalanthus occidentalis)*
Height: <3m
Site Preferences: Constantly moist soil, swamps, riparian zones

Highbush Cranberry *(Viburnum trilobum)*
Height: 2m
Site Preferences: all soil conditions, full sun or light shade

Nannyberry *(Viburnum lentango)*
Height: <3m
Site Preferences: Moist yet drained soils, full sun or light shade

Red Osier Dogwood *(Cornus stolonifera)*
Height: <2.5m
Site Preferences: Moist soils, high organic content, suited to riparian zones

Serviceberry *(Amelanchier spp.)*
Height: 1-5m
Site Preferences: Wide range of soil conditions, partial shade to full sun

8.2.3 Recommended Plants for Zones

The ideal filler species which would be best suited to replace ash in each zone has been classified based on the topography, biota and rate of soil saturation. It has been determined that ash trees may not always be best replaced by trees. Varieties of shrubs may be best suited to spawn successional growth, and compete with communities of European buckthorn. The proportion of each species being planted in each zone should be at the discretion of those conducting field plantings. Balance should be created between planning for future forest canopy cover and creating a path of succession that includes biodiversity. It is recommended that each zone include as many species as is practical for the area.

Trees	**Zones**
Basswood	1,2,3,4,6,7,8,9,10,11
Bur Oak	1,2,4,6,8,9,10
Common Chokecherry	1,2,3,4,5,6,7,8,9,10,11
Eastern Hemlock	3,5,7,11
Eastern White Cedar	1,2,3,4,5,6,7,8,9,10,11
Elms	1,2,3,4,6,7,8,9,10
Hackberry	1,2,4,6,7,8,9,10
Poplars	1,2,3,4,5,6,7,8,9,10,11
Sugar Maple	1,2,4,6,8,9,10
Red Maple	3,5,7,11
Red Oak	1,2,4,6,8,9,10
Shrubs	
American Elderberry	1,2,3,4,5,6,7,8,9,10,11
Buttonbush	3,5,7,11
Highbush Cranberry	1,2,3,4,5,6,7,8,9,10,11
Nannyberry	1,2,3,4,5,6,7,8,9,10,11
Red Osier Dogwood	1,2,3,4,5,6,7,8,9,10,11
Serviceberry	1,2,3,4,5,6,7,8,9,10,11

8.3 Local Options

Kawartha Conservation - Seedling Distribution Program 2016

- Available to landowners in the Kawartha Watershed who are undertaking stewardship planting project to aid in the promotion of watershed ecology. For large scale tree planting (greater than a few acres), staff should be contacted to inquire about further contacts http://kawarthaconservation.com/seedling-distribution

ArborCare -The Tree Pros

- With 15 years in the tree care industry, this company specializes in dangerous tree removals and have a staff of certified arborists. From planting to insect and disease control, some of their commercial clients include Kawartha Credit Union, Remax, and the Kawartha Participation Project. http://www.thetreepros.com/

Richardson's Pine needle Farms

- Providing evergreens and deciduous species, this operation is a second-generation tree seedling provider specializing in native species. Most of their plants are field grown and are available bare-root in the spring and fall. Their 2016 catalogue is available online: http://pineneedlefarms.ca/2016-pineneedle-farms-catalogue.pdf

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10. APPENDIX

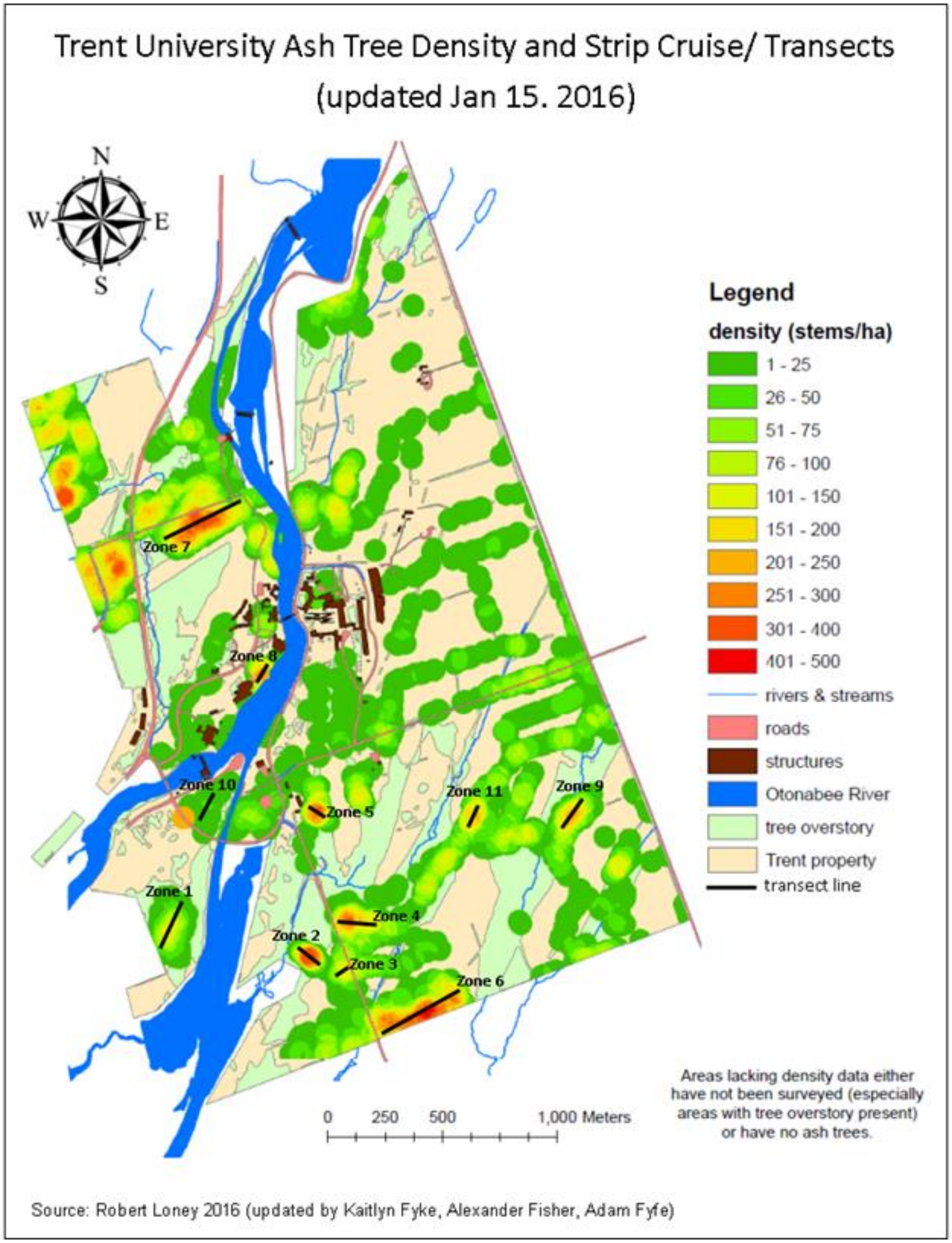

Figure.1. Map of the Trent nature area depicting ash tree density per ha, lines depict location of sample transects.

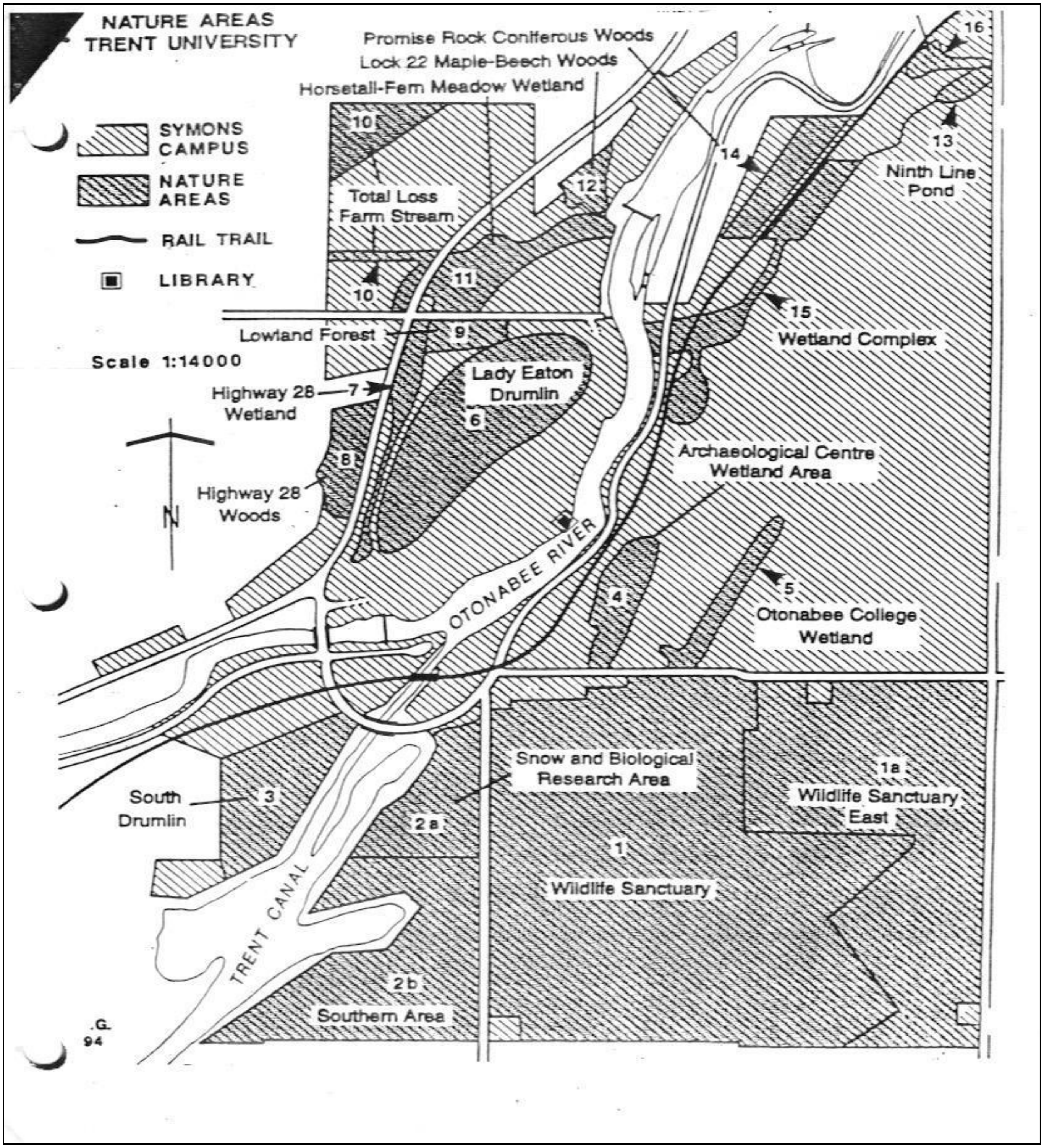

Figure.2. Division of Trent Nature Areas.

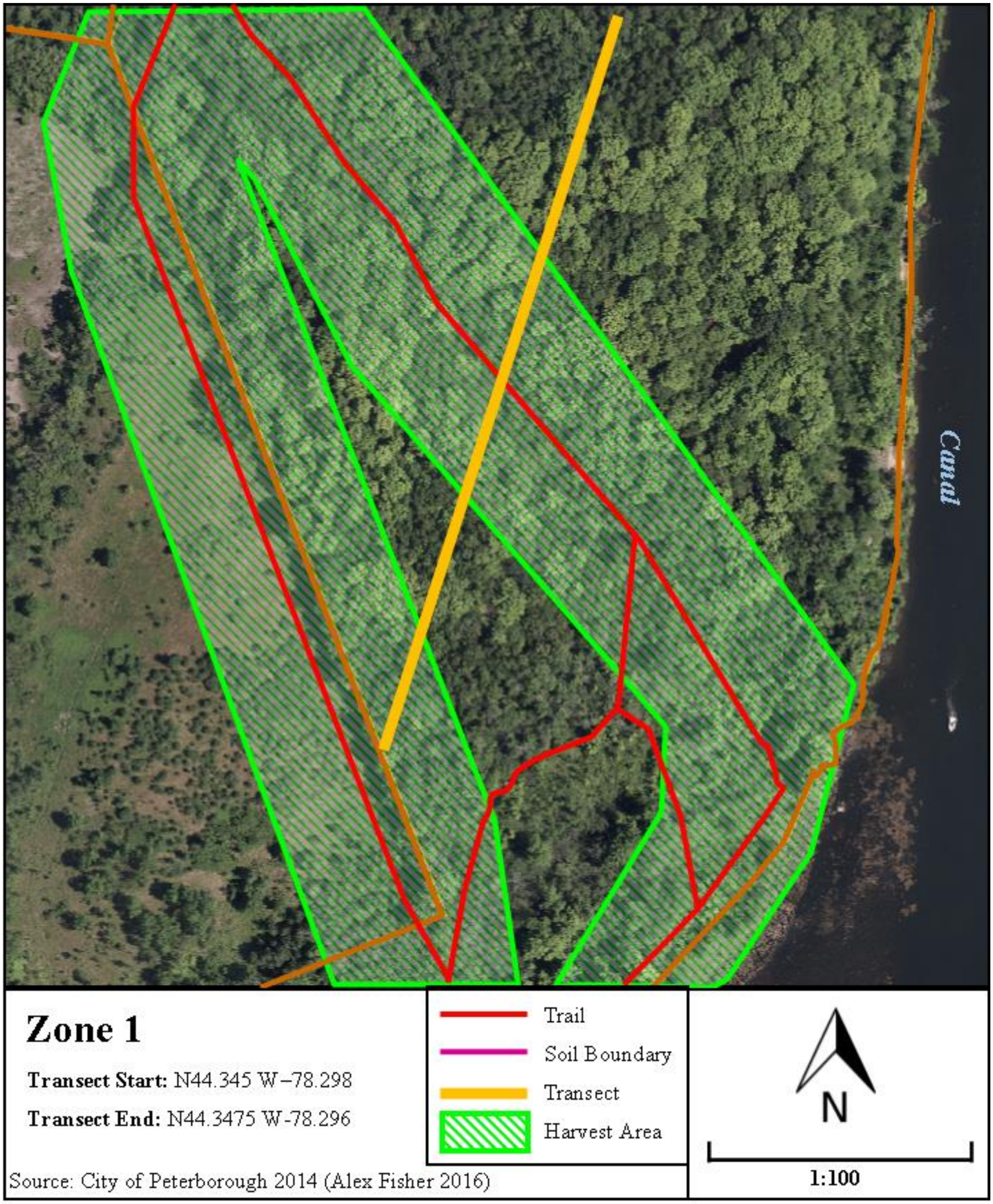

Figure.3. The area of harvest for zone 1 is 50m on either side of major trails and roads.

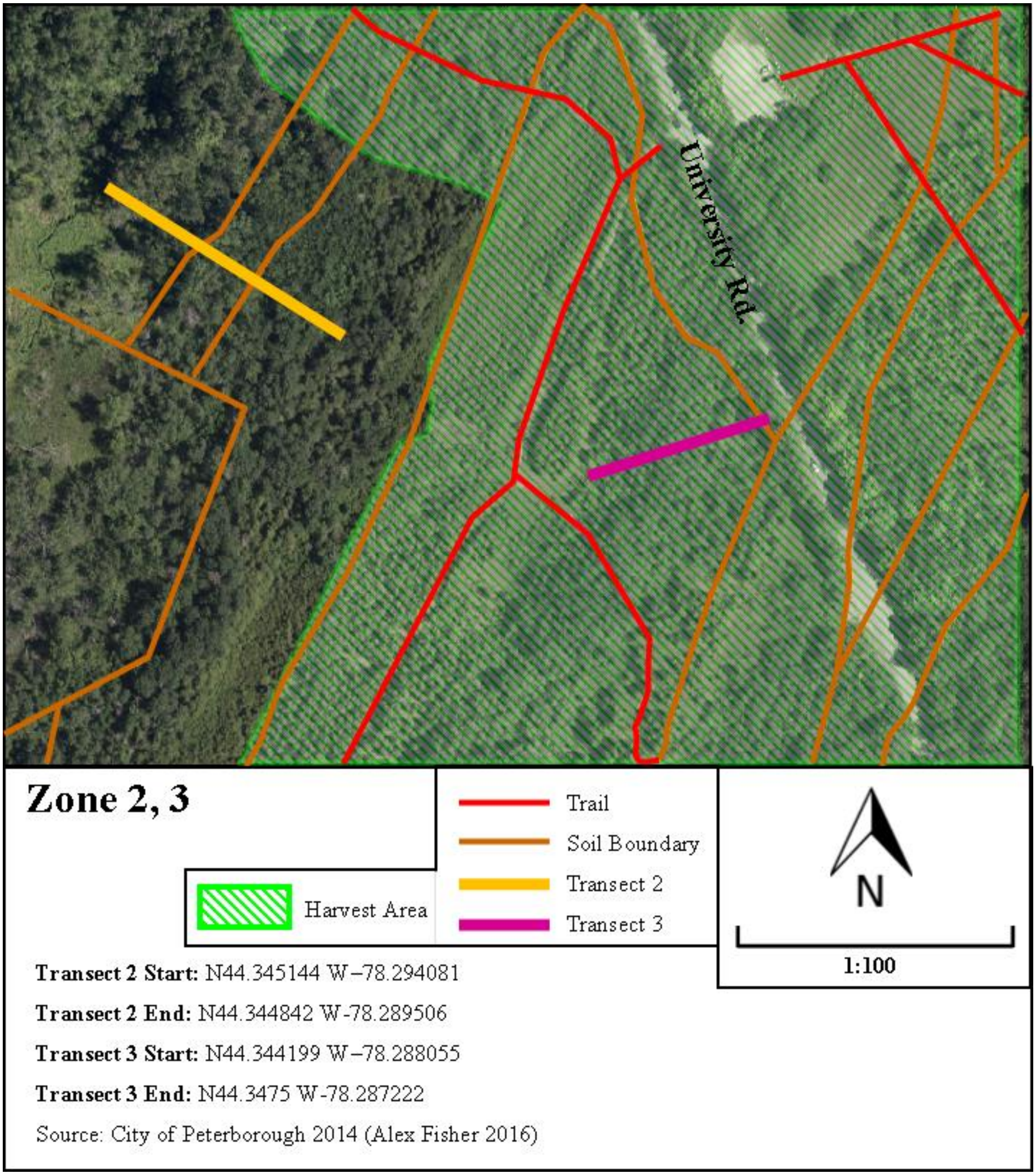

Figure.4. The area of harvest for zone 2 and 3 is 50m on either side of major trails and roads.

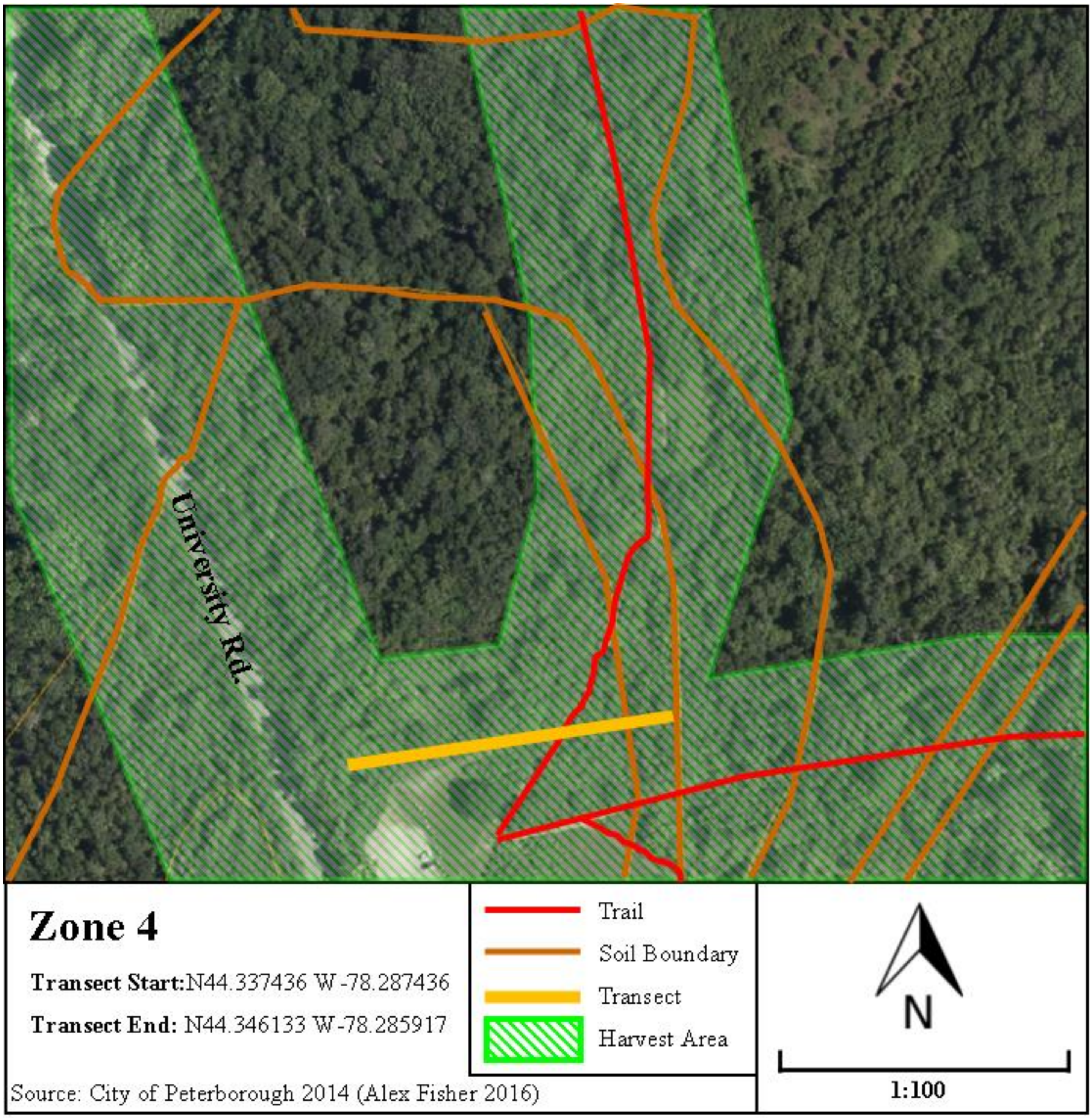

Figure.5. The area of harvest for zone 4 is 50m on either side of major trails and roads.

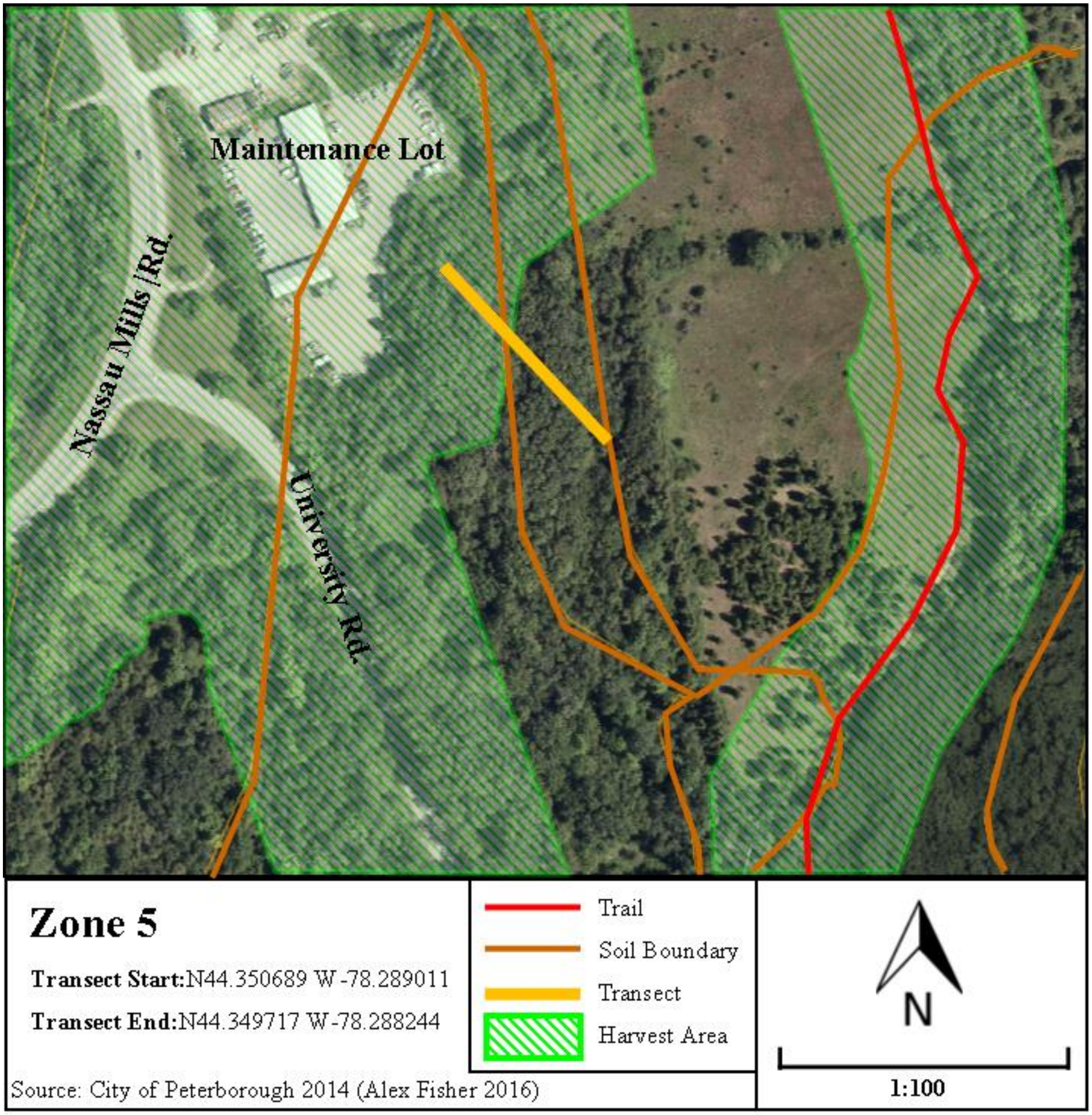

Figure.6. The area of harvest for zone 5 is 50m on either side of major trails and roads.

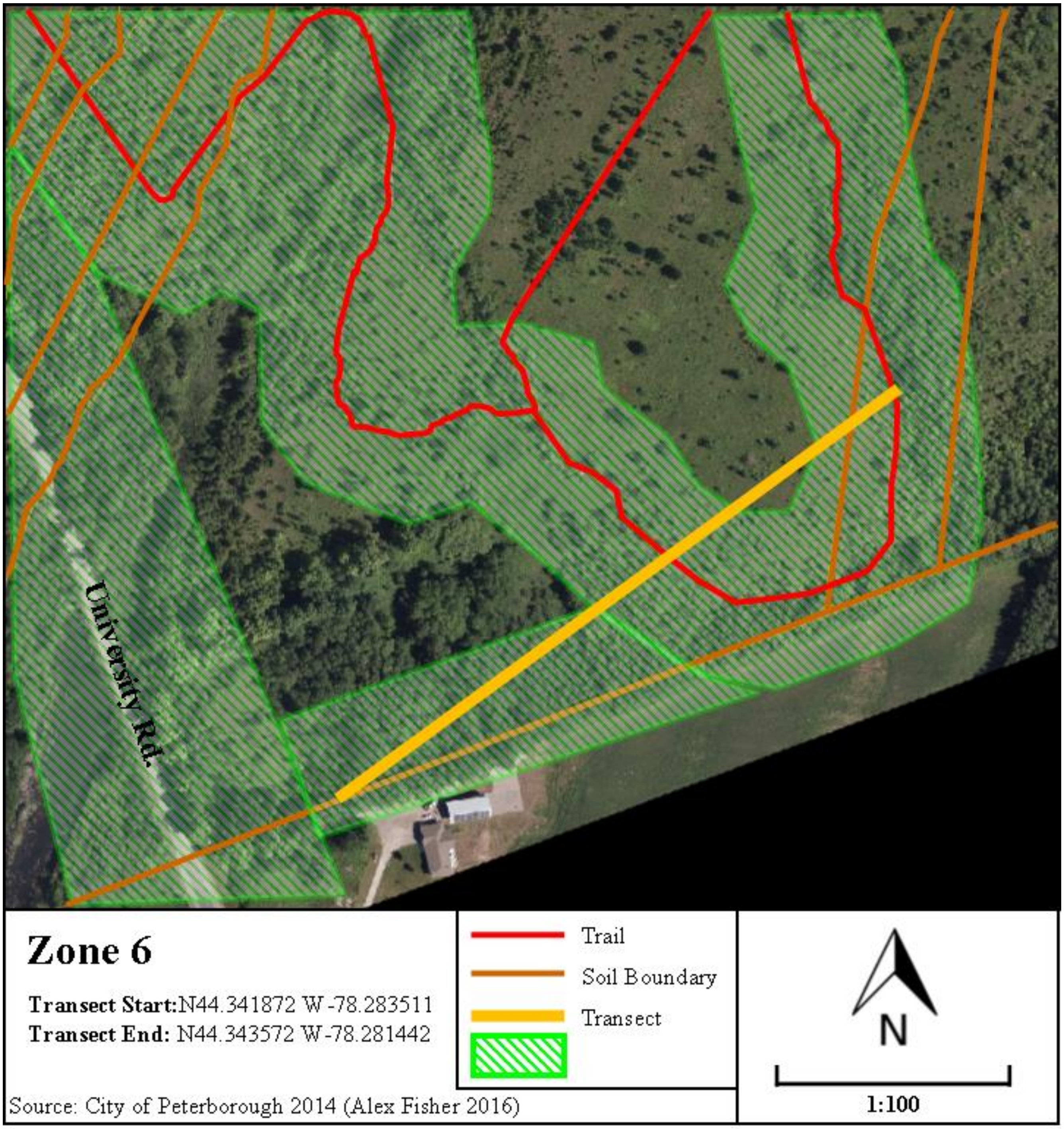

Figure.7. The area of harvest for zone 6 is 50m on either side of major trails and roads.

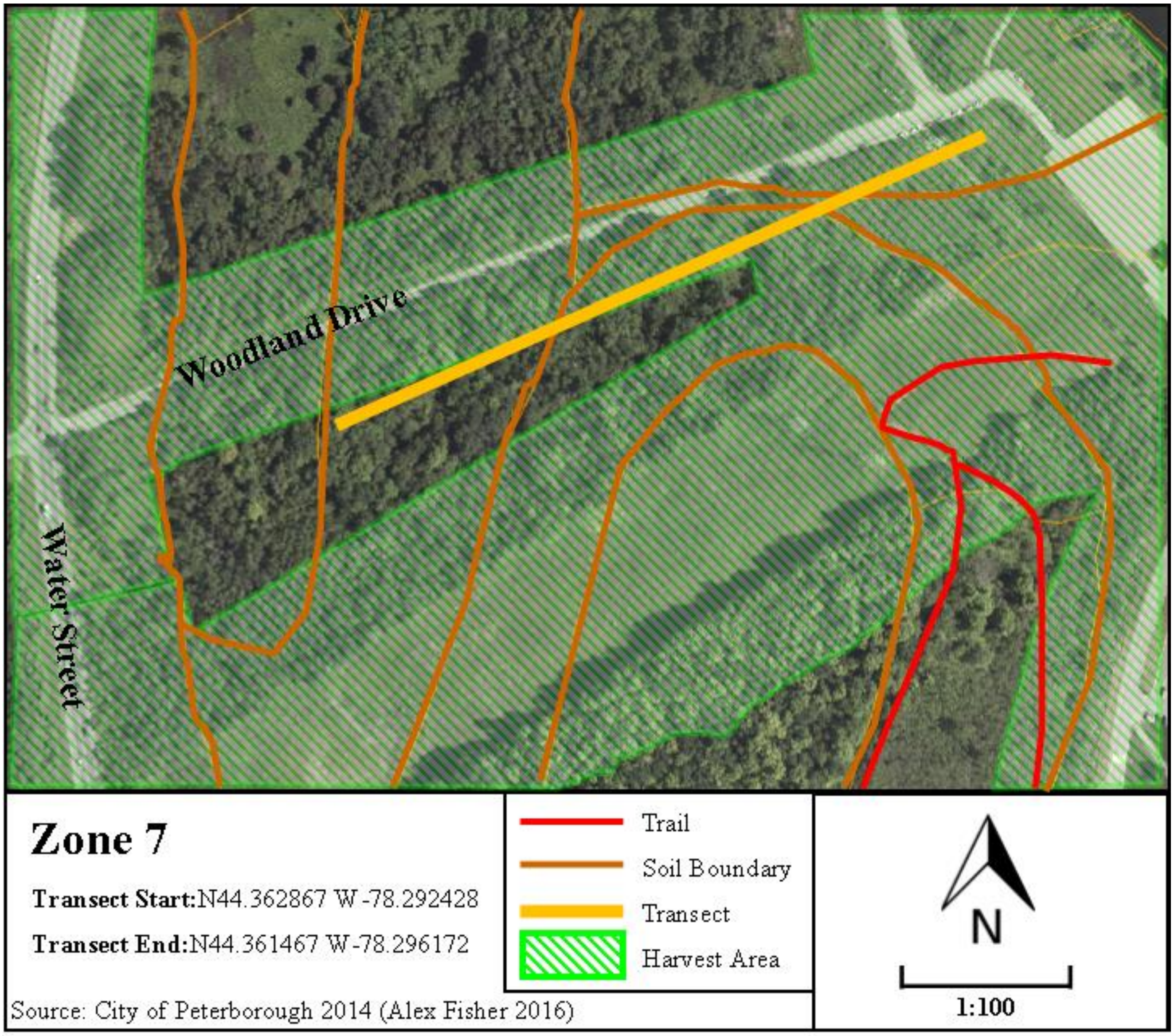

Figure.8. The area of harvest for zone 7 is 50m on either side of major trails and roads.

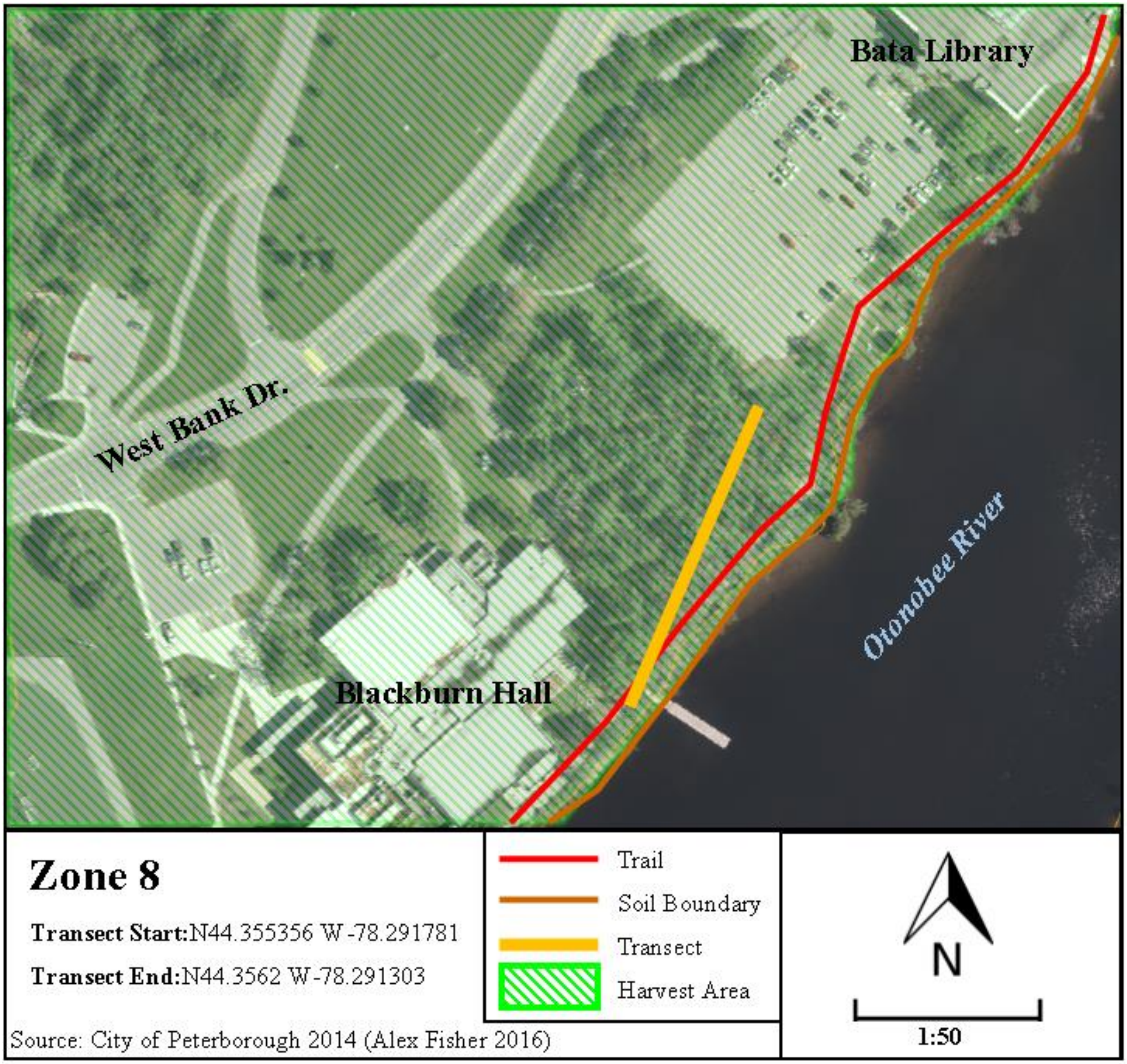

Figure.9. The area of harvest for zone 8 is 50m on either side of major trails and roads.

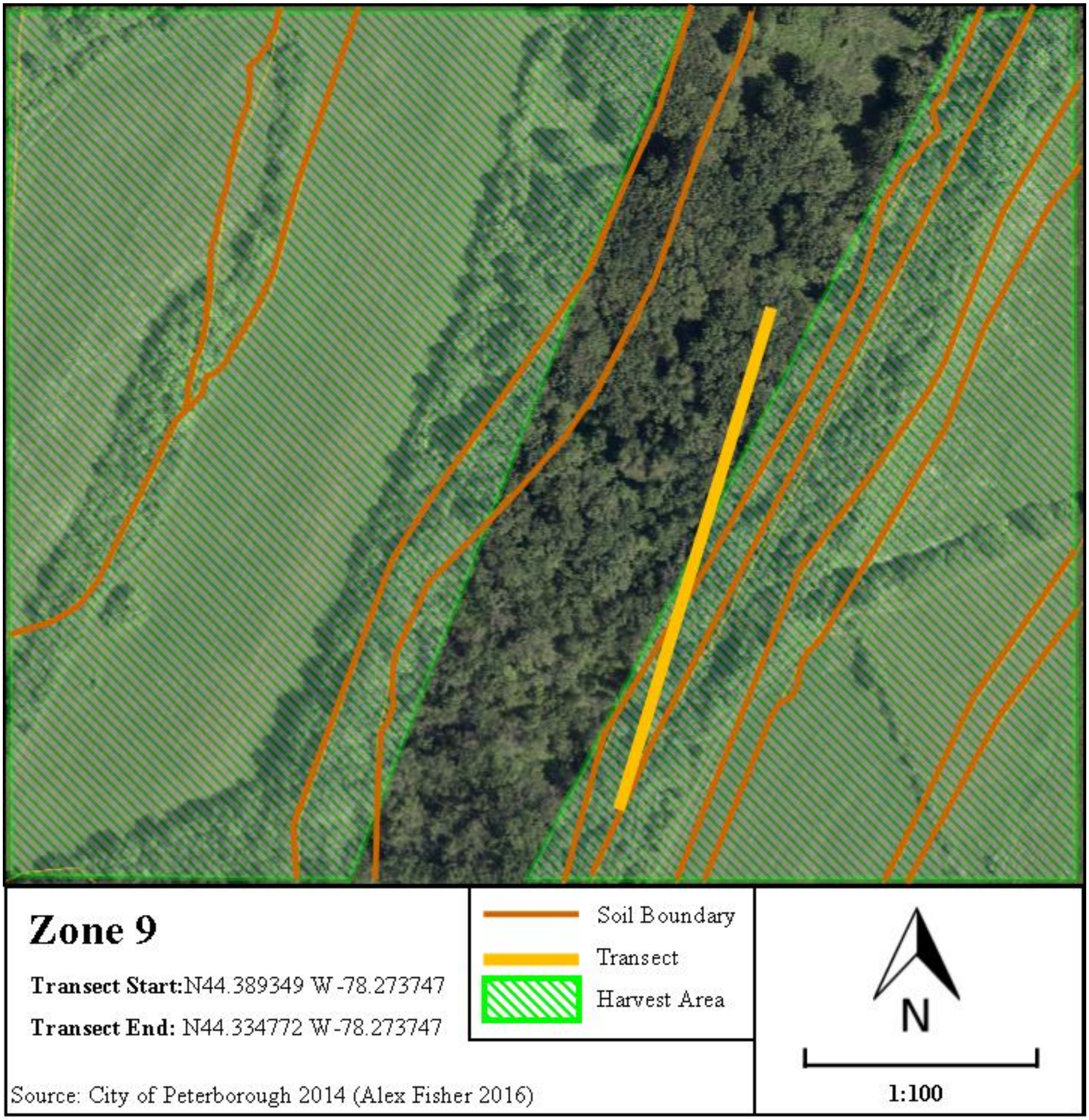

Figure.10. The area of harvest for zone 2 and 3 is 50m on either side of major trails and roads.

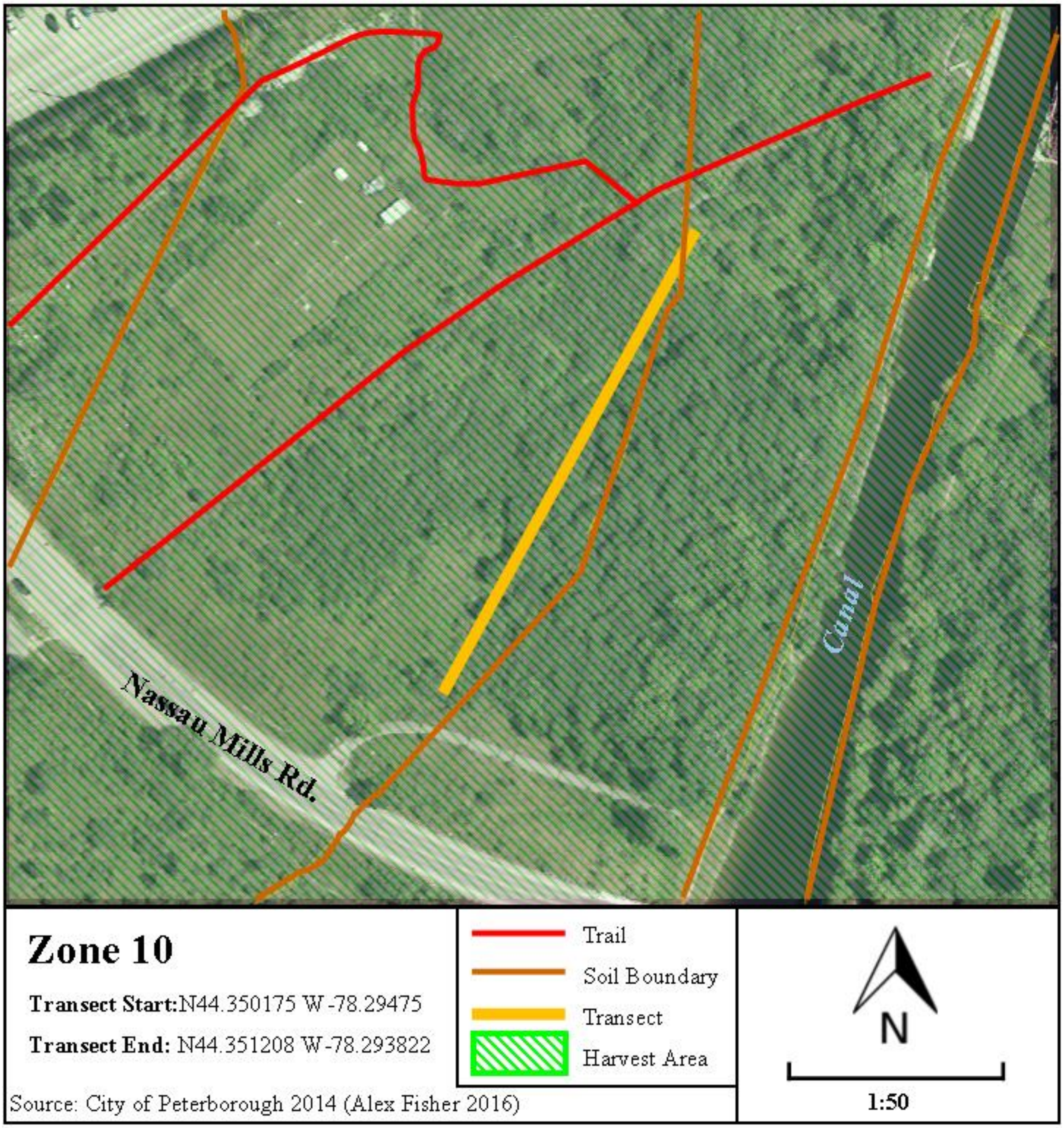

Figure.11. The area of harvest for zone 10 is 50m on either side of major trails and roads.

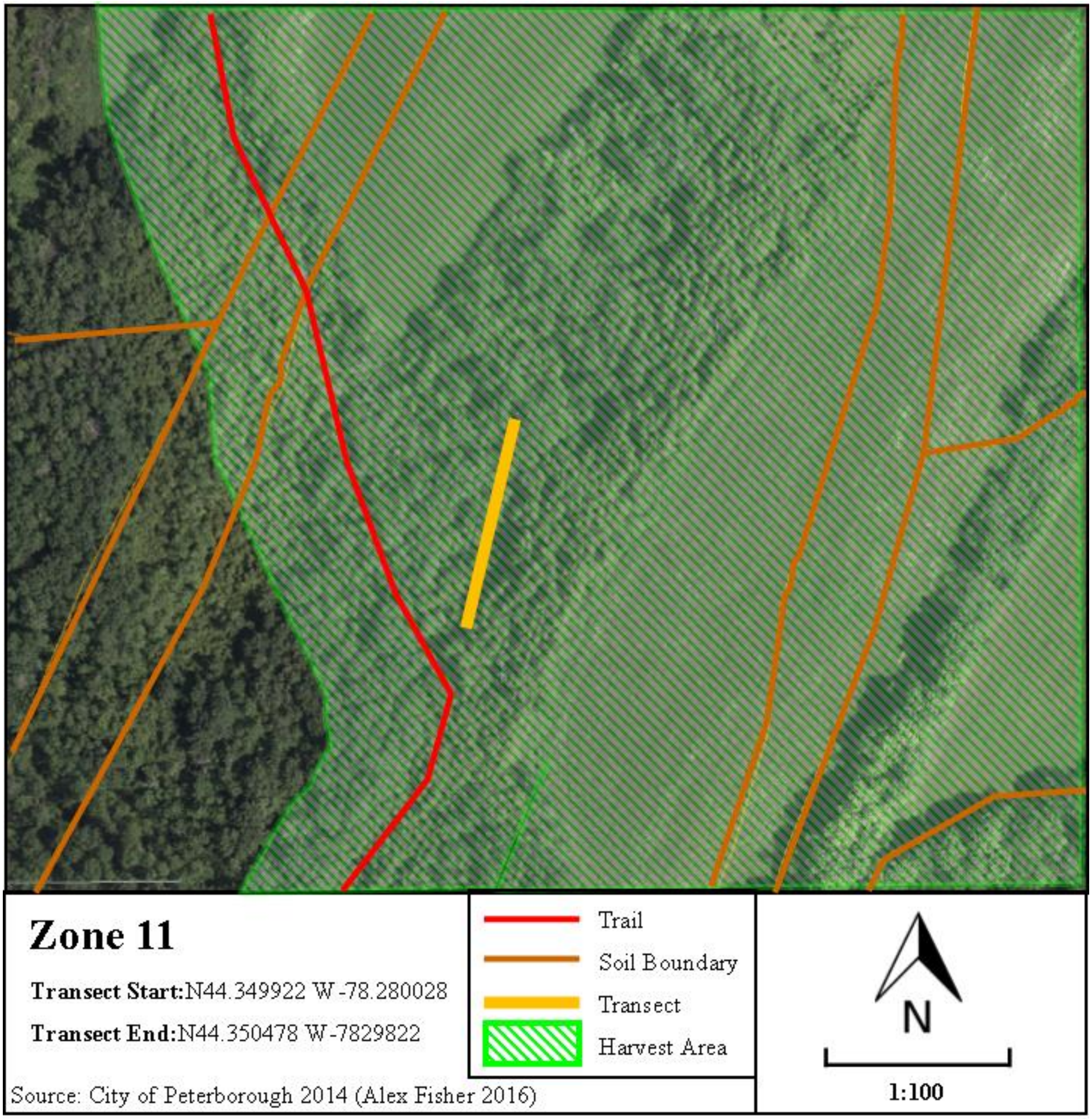

Figure.12. The area of harvest for zone 11 is 50m on either side of major trails and roads.

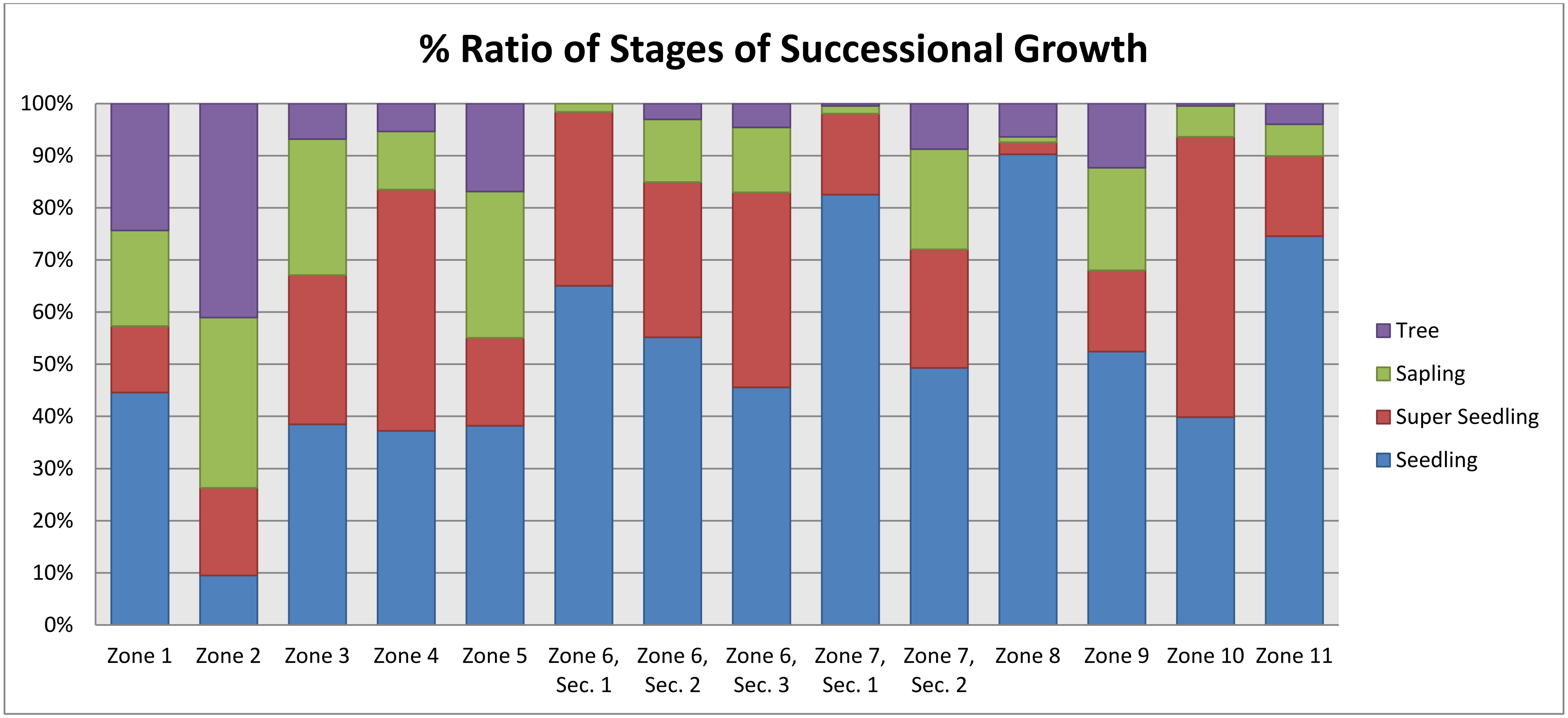

Figure.13. Composite bar graph depicting the percentage of tree, sapling, super sapling and seedling per zone/section. Higher percentages of younger stages of growth are indicative of lesser levels succession.