MANAGING FOR EMERALD ASH BORER IN THE URBAN FOREST

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ABSTRACT

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Urban forestry is a concept applied to many cities, municipalities, and communities around the world. It is the practice of managing the interface between urban infrastructure and environmental green spaces. An invasive insect known as the emerald ash borer (*Agrilus planipennis* Fairmaire) has been devastating urban forests in southern Ontario since 2002. Larval feeding on ash (*Fraxinus spp)* can kill a tree in 3-5 years. Emerald ash borer (EAB) has been moving northward eliminating trees by the thousands, and was discovered in the City of Barrie in 2014. In order to manage for EAB, it is crucial to know where the ash trees are located. The City of Barrie has an inventory of publicly owned trees, but not of those on private property. In addition, the public may not be fully aware of the devastating effects of EAB on the urban forest and the associated management strategies. Obtaining the private ash tree inventory depends on residents to self-report on signs of EAB. Current aerial imagery for the City of Barrie was converted into a format suitable for common smart devices. It can be used as a visual aid in communicating the threat of EAB, and to highlight high risk areas. A pilot project of an urban forest health volunteer network was conducted successfully in the Town of Oakville in 2014. The same process of community engagement and urban forest management was demonstrated through a sample inventory in the City of Barrie. The data combined with the imagery is a crucial aid in developing an early detection rapid response management plan for the City. Future possibilities resulting from this thesis project could be the creation of an online database where members of the public can access the digital imagery, self-report on private trees, and remain informed on urban forest management strategies.

INTRODUCTION

BACKGROUND

The practice of sustainable urban forest management is becoming increasingly important with population growth, urban expansion, and stress placed on delicate ecosystems. Urban forestry is a practice taking place in cities all over the world. The notion of urban forestry is one which ties an urban area back to its natural roots. It is a concept of allowing residents of a city to still feel connected to the natural environment (Jorgensen 1986). Research has shown that trees actually strengthen communities and increase the friendliness of neighbourhoods (Sullivan and Kuo 1996). Houses, stores, and buildings with natural accents around them such as trees and grass are said to have an increased number of visitors; the presence of trees is also theorized to create a safer society, reducing crime rates (Sullivan and Kuo 1996). From an environmental perspective, trees provide a series of ecosystem services mitigating the sometimes harmful effects of urbanization (Manes 2012).

It is clear that urban forests are an invaluable aspect of a community; unfortunately they are also extremely vulnerable. Urban environments are not the ideal place for a tree to grow, and can be a very stressful environment. Adding to these pressures are the planting of non-native tree species which can have a negative impact on the natural flora and fauna of the area. There are also alien pests being transported through various vectors such a trade which are invading foreign urban forests around the globe. In North America, the beetle known as the emerald ash borer (*Agrilus* *planipennis* Fairmaire) is devastating urban and natural ash (*Fraxinus spp.)* forests (Sydnor 2011). The emerald ash borer (EAB) is native to China but has arrived in North America through shipping crates. It is now a problem that many urban foresters are working diligently to plan for. Since the arrival of EAB in 2002 constant research and planning has taken place to better management strategies for EAB (Canadian Forest Service 2012). Despite all of the research and planning, there is one major element leading to success or failure in management for EAB; cohesiveness of all members of a community and between communities.

EAB is spreading from city to city in the United States and in Canada. These cities and municipalities must work together and share management strategies in order to have a chance at slowing the spread and mitigating the devastating effects of the beetle. Within each municipality there is also the issue of land ownership; public and private. Public land is managed by the municipality, and private land is up to the individual land owner. In an urban center this can mean thousands of tiny parcels of land all owned by individual homeowners, and in some cases can also be combined with larger woodlots. Herein lies one of the major roots of the problem, not only does the municipality have to create a management plan to deal with EAB but they must also engage private land owners on the management strategies as well. If some cities do nothing their ash population will be decimated and the beetle will advance to the next place.

Within a community there are groups such as home owners, children, teachers, stakeholders and members of the government who must all work together in support of urban forest management to protect their urban forest. This notion of unity leads to the general purpose of this research; to bridge the gap between urban forestry and the associated community. Urban forest management is only effective when everyone is working together to support a common interest.

STUDY OBJECTIVES

The research of this thesis is focused on developing a framework for community engagement enabling self reporting and management of trees on private property. Research was conducted in two parts. The first explored how to engage and educate members of the community in forest health in the Town of Oakville. An urban forest health volunteer program (FHVP) was created with the four objectives; community awareness and education of invasive insects, early detection, updating municipal street tree inventory, tracking forest health trends over time (BioForest 2014). This program was focused on municipal trees on roadways. The second case study located in the City of Barrie in Ontario, Canada, focused on utilizing the concept of the successful FHVP in Oakville and building a framework to enable self reporting and management of ash trees on private property. EAB was discovered and confirmed in Barrie in August of 2014 (Rankin 2014). The urban forester for the city has created a two part "Emerald Ash Borer Program". The first phase is proactive and geared toward management prior to the arrival of the pest, and the second phase is post discovery (Rankin 2014). The program is geared to municipal trees, which leaves the challenge of ash trees on private property. The goal of this research is to aid the City of Barrie in their management plan for EAB through community engagement to facilitate self reporting on private ash trees.

There are five specific objectives to this research project. The first is to compile management strategies that have been used across Ontario and North America for EAB.

Examples of community engagement in urban forest management will also be researched. This research will support the third objective of creating a framework of how community engagement can be used to aid in supporting urban forest management planning in the City of Barrie. An engaged and informed community is incredibly important, but the question is how to keep people involved. Using aerial imagery for the City of Barrie, the concept of an online digital database where residents can self report on private trees and remain informed on urban forest management plans will be explored. This database fits the long term vision of keeping the City of Barrie green and providing a sound GIS online database so that they can adapt to any changes in the future with a proactive rapid response management plan supported by the public. The final objective is to apply of the information collected to develop a framework for early detection, rapid response for communities awaiting arrival of EAB.

LITERATURE REVIEW

Chapter 1: Urban Forestry

The term forestry is a complex concept to define as it is "commonly based on either land use, land cover, or administrative function" (Randrup et al. 2005:10). When the term forestry is connected to an urban area, the urban location and urban function become the defining factors (Randrup et al. 2005:10). The practice of urban forestry dates back to as early as 1864 (Konijendijk 2006). Over time it has changed and adapted to the growth and development of communities, people, and location. Today it can be defined as, "the art, science and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide society" (Konijendijk 2006:2). The concept can also be viewed as an urbanization of the forest, as city centers expand due to factors such as increasing population and subsequent pressure of societal values (Konijnendijk 2003). Urbanization is the process of altering nature to meet the needs of humans. Within this altered landscape many different habitat types unique to urban environments can be found, for example; residential yards, cemeteries, golf courses (Adams and Lindsey 2010:11). The rapid increase in population in the last one hundred years has shown a dramatic shift from predominantly rural living to urban dwelling. It is predicted by the United Nations that by 2050 the shift will continue towards urban living with two thirds of the world's population living in cities (Carreiro 2008:3).

The three pillars of sustainability (social, economic, environmental) must be kept in mind when considering urban forestry. The process of urbanization has many social advantages for humans, which can both boom and bust the economic world, and can also have very negative effects on the environment (Song 2006:v). Expansion of urban centers combined with habitat fragmentation creates a unique urban scenario with trees existing on an individual, stand, and forest level. These levels can be continuous, but often times are discontinuous between other urban infrastructures. According to Konijnendijk (2003) the urban forester is subsequently responsible for managing "in the entire area influenced by and utilized by the urban population".

The urban setting can be an extremely stressful environment for trees to grow and thrive in. Although the vast majority of people live in city centers, they are largely unaware of what an urban forest is and the subsequent pressures they create on it (Adams and Lindsey 2010:53). As population increases, so does the associated pressure on urban city centers and their environment. Urban expansion and denser populations usually means an alteration in things like; natural landscapes (aquatic and terrestrial), plant and animal relationships, amount and type of pollution released (Adams and Lindsey 2010:53). Urban trees provide many ecosystem services that mitigate many harmful effects of urbanization. Costanza et al (1997) define ecosystem services as, “the benefits human populations derive, directly or indirectly, from ecosystem function”. Chen and Jim (2008:54-63) categorize urban ecosystem services into the following categories; biomass functions, environmental benefits, recreation and aesthetic services, health and physiological services, wildlife habitat, biodiversity conservation, education, and sites for scientific research. A few examples of the ecosystem services of a tree include; carbon sequestration, flood prevention, air purification, shade, and wildlife habitat (Manes 2012). Trees also play a role in mitigating the energy cost associated with heating and cooling for buildings and homes. In the winter time coniferous trees can assist in reducing heating costs by creating wind breaks, while deciduous trees planted on the southern side of a building can allow the sun’s rays to warm up the interior space when the leaves are not present. In summer time when the leaves are on the tree, they can provide shade and therefore reduce the cooling cost (Miller 1988: 53).

On a global level the transformation of natural landscapes to city centers has reduced ecosystem services on a large scale. Looking at the city center itself, green infrastructure can reintroduce ecosystem services. Although, urbanization itself can alter, change, and/or decrease the services themselves (Adams and Lindsey 2010:67). According to Wu (2008:10) urbanization has led to a decrease in biodiversity and depletion of ecosystem services on a global scale.

An urban setting can be an incredibly hostile setting for trees to grow, resulting in trees that are often stressed. This stress can be due to a variety of factors including; drought, poor soil conditions, pollution, wounds, and salt management (roads). Trees themselves can be extremely efficient in mitigating these potentially stressful urban effects, there are alien insects and pathogens that threaten to devastate urban forests around the globe. Recently in Eastern North America the alien insect known as the emerald ash borer (*Agrilus planipennis* Fairmaire*)* has destroyed tens of thousands of ash (*Fraxinus* spp.) trees both in urban and natural settings (Sydnor 2011).

Taking these ecosystem services into consideration, there is the question of the value of an urban tree and collectively the urban forest. In general the value of an urban tree can be classified into three categories; social, economic, environmental. It is difficult to quantify many of these values into a monetary number, but quantification is necessary for the general public to see, understand, and make sound decisions when it comes to the urban forest (Chen and Jim 2008:63). There is no set calculator for the value of a tree, as a result various models have been generated based on different ecosystem services to calculate value (Chen and Jim 2008:64). One example of calculating the value of urban trees can be seen through a study conducted by Toronto Dominion (TD) Bank on the value of trees in Toronto's urban forest in 2014 (Alexander and McDonald 2014). In this study the city of Toronto is said to have ten million trees, consisting of 116 different species. Of these trees 6% are city owned street trees, 34% city park and natural areas, and the majority at 60% are privately owned (Alexander and McDonald 2014). The factors used to evaluate these trees included; wet weather flow reduction, air quality, energy savings, carbon sequestration, and energy emission abatement. The results of the study show that Toronto's urban forest is worth an estimated $7 billion, equating to $700/tree. The forest directly provides over $80 million ($8/tree) of environmental benefits to residents, working out to a savings of $125 per year for each individual home (Alexander and McDonald 2014). Urban trees are often seen as a deficit when looking at a municipal budget, but the TD Economic study suggests otherwise. The findings of Alexander and McDonald (2014) show that benefits out weight the cost with every dollar spent on maintaining the urban forest, as trees return between $1.35 to $3.20 of benefits and cost saving per year.

The United States Department of Agriculture (USDA) Forest Service, Northern Research Station (NRS), developed another method to quantify urban forest structure and function called the Urban Forest Effects Model (UFORE) (NRS 2009). The UFORE is computer generated using standardized field data from randomly located plots to generate attributes and forest functions such as species composition and subsequent effects on air pollution (NRS 2009). The UFORE model has been updated and expanded upon and is now called i-Tree. There are a wide range of i-Tree applications designed for all users of the urban forest from managers to residents to better understand and subsequently manage the landscape (NRS 2015). Specific to valuation of ecosystem services there is i-Tree Streets. This software allows urban forest inventories to be utilized to assign a monetary value to the following ecosystem services; energy conservation, air quality improvement, CO_2 reduction, stormwater control, and property value increase. The major benefit of i-Tree is that it is peer-reviewed and freely accessible (NRS 2015).

A simple calculator that any resident can use to measure the worth of their tree can be found through the organization called of Local Enhancement and Appreciation of Forests (LEAF). This calculator functions on the same premise of using ecosystem services trees provide to assign a monetary value to a tree (LEAF 2014). What is unique about this calculator is that it can be used to evaluate future benefits as well as estimated current or annual benefits of trees. It can be used on existing trees or if a homeowner is considering planting a tree, the estimator will generate a value to that tree being planted (LEAF 2014).

As discussed there are many tools that can be used to estimate the value of a single tree or an entire urban forest as a whole based on the ecosystem services trees provide. In a global attempt to raise awareness of the benefits of trees, and green infrastructure, these tools can be invaluable for managers and residents alike.

The practice of urban forestry exists all over the world; there is a global effort to keep cities green. In Asia, China is a great example of extensive research and planning efforts. Since 1990 there has been a great emphasis on ecosystem services and ensuring these systems are an active part of city centers (Jim 2009). In Europe the city of Freiburg, Germany is an excellent example of urban forest management as well as other green initiatives. It is considered the "Green City" due to its unmatched sustainable urban development and environmental protection (Guduric 2011). In North America, urban forestry was first recognized in the 1960s (Randrup et al. 2005: 12). In Canada it is estimated that 80% of the Canadian population lives in an urban center (Kenney 2003). Although historically urban forestry may not have been viewed as being important in Canada, some communities and organizations in Canada now consider urban forestry to be the ninth forest region of Canada (Rosen 2006). Kenney (2003) states that people residing in cities not only consider their urban forest to be important, but are conscientious and concerned that green spaces are being properly managed and concerned. As a result many Canadian cities are focusing heavily on protecting and enhancing their urban forest. As a nation, Canada has adapted an urban forest strategy which is a collaborative effort of communities to advance urban forestry in the country. Such a broad and large scale initiative relies on a number of things including but not limited to community action, policy, research, urban forest planning, and professional development (Kenney 2003).

Urban forestry exists in Ontario in a variety of municipalities and cities with varying population sizes. Some larger cities have very successful urban forestry programs, while others recognize the importance of urban forestry but lack the funds to organize a planning team. As a result, urban forest management is sporadic and inconsistent in Ontario (Barker et al 2012). Northern Ontario has many forestry professionals and forestry based communities. It is suggested by Miller 2003 that professionals from the north can aid in successful urban forestry planning in southern Ontario with their expertise. Miller (2003) claims that southern Ontario communities are becoming environmentally unsustainable due to failures in the land use planning departments. Van Wassenaer et al (2000) agree with the notion that there are very few communities in Canada which have well managed urban forests. They suggest that an ecosystem approach to urban forest planning is required to increase the successful application or a management plan.

Chapter 2: Ash in the urban forest

The urban environment is a unique forest setting which can be incredibly stressful for trees to grow and thrive in. In addition to the challenges discussed in chapter 1, issues such as limited species diversity and distribution within a city center makes the urban forest susceptible to insect and disease infestations (Lacan and McBride 2008). Urban forests often include a variety of non-native trees as a component of species composition, which reduces the native biodiversity and subsequent resilience of that forest (Alvey 2006). The introduction of exotic species through city managers and private property owners is a challenge to biodiversity (Alvey 2006). The process of urbanization often results in the destruction of natural landscapes as cities grow and is replaced by a combination of non-native flora and grey infrastructure (McKinney 2006).

In addition to the problem of species diversity is the one of uniformity. McKinney (2006) explains that urban centers play a critical role in the homogenization of biodiversity as they tend to be uniform in nature both within the city and between cities. This uniformity can often be attributed to the fact that urban centers are habitats created for humans. It is a growing concern that humans have become disconnected with the natural world, and the vision for urban forests reflects that (McKinney 2006). Aside from the human factor, urban forests face other challenges such as; economics (cheapest nursery stock and availability), poor soil conditions, size of planting space (Lacan and McBride 2008). All of these factors contribute to the limited selection of trees that are suitable to survive in the urban forest. When a tree species is found that is socially acceptable and can withstand all of the stressful conditions of an urban forest it is often planted almost exclusively (Lacan and McBride 2008). There are hundreds of native tree species in North America, but according to Dreistadt et al (1990) approximately 75% of urban trees are from nine genera; maples (*Acer*), oak (*Quercu)s*, pine(*Pinus*), sycamore (*Platanus*), sweetgum (*Liquidambar*), elm (*Ulmus*), honey locust (*Gleditsia*), linden (*Tilia*), and ash (*Fraxinus*). This problem of monoculture in the urban forest enables susceptibility to outbreaks of insects and disease (Lacan and McBride 2008). Facilitating the movement of exotic species comes with the ever increasing scale of global trade and human international travel (Brockerhoff et al 2006).

Historically there have been three major outbreaks of insects and disease in the urban forests of North America; Gypsy moth (*Lymantria dispar* L.), Chestnut blight (*Cryphonectria parasitica* (Murrill) Barr.), Dutch Elm Disease (*Ophiostoma ulmi* (Buisman) Nannf.) (USDA 2015). Native to Europe, gypsy moth is a defoliating insect pest that was accidentally introduced to North America in the late 1800's (Brockerhoff et al 2006). Gypsy moth has a wide range of hosts with over 300 tree species, but prefers those of the oak genera (Humble and Stewart 1994). Since its arrival to North America in 1868, gypsy moth has caused major defoliation and in many cases tree mortality on a national scale. It spread from its original entry point in Massachusetts throughout eastern United States and into Canada (Humble and Stewart 1994). The gypsy moth population has not always been at outbreak levels. The population can exist in low densities, grow to outbreak levels, and repeat over time (Elkinton and Liebhold 1990). Several major attempts for eradication of the pest have been tried, but none have resulted in success. As of 2013 Jankovic and Petrovskii (2013) state that at that time gypsy moth occupied only a third of its potential habitat. With a wide ranging host species, the gypsy moth continues to defoliate trees in both the urban and natural forest settings in North America.

Chestnut blight is a lethal fungus which attacks American chestnut (*Castanea dentata* (Marsh.) Borkh.) (Rellou 2002). The blight is native to Asia and became established in North America through infested nursery stock. The first record of dead and dying chestnut trees was in New York City in 1904 (Rellou 2002). The fungus spread very rapidly, with a rate of expansion of 24 miles per year (Schlarbaum et al. 1998). By 1920 the spread reached southern Ontario, and by 1930 it was estimated that the majority of American chestnuts were infected. The death toll by 1940 was three and a half billion trees (Rellou 2002). In five decades the once dominant, prevalent, and beautiful American chestnut was almost virtually wiped out and became a threatened species (Schlarbaum et al 1998). Part of the reason why the fungus was able to spread so quickly was that American chestnuts have no natural defense to the chestnut blight. In addition, the fungus is transported by a variety of animals and insects which transport and subsequently disperse spores from infected trees to non infected trees (Rellou 2002). Management efforts for chestnut blight are focused on the restoration of American chestnut trees through the use of hypovirulent strains and hybridization. The hypovirulent strains of the fungus are a weaker strain of the normally ferocious fungus causing the rate of infection to slow allowing trees to respond and develop resistance (Rellou 2002). Hybridization of resistant Japanese and Chinese chestnut with the highly susceptible American chestnut, has resulted in partially resistant hybrids of chestnut. These hybrids can be used to help reintroduce chestnut to the landscape (Rellou 2002). Although these management efforts have been successful, chestnut blight was incredibly devastating to all chestnuts both in an urban and forested setting. The results of the blight can still be seen today, and work is still being done to reintroduce the species.

The American elm (*Ulmus Americana* L.) or white elm is native to eastern North America and has a very large range from Nova Scotia to Saskatchewan in Canada and south to Texas and Florida in the United States (Seiler et al 2015). Historically, the American elm was the favoured tree to plant in urban forests due to its rapid growth, longevity, tolerance to poor soil conditions and air pollution, and its beautiful vase like shape (USDA Forest Service 1999). When planted on streets, the canopies of mature American elms often intertwine creating a tunnel like overarching canopy on urban roads. As a result, it was widely planted in many cities. Decline of this beautiful shade tolerant tree was first observed in the 1930's in Ohio (Schlarbaum et al 1998). Like many other introduced species, the fungus Dutch elm disease (DED) arrived to North America through international trade. According to Schlarbaum et al (1998), the fungus was transported from Europe to North America on lumber which had not yet been debarked. There are two strains of the fungus, *Ophiostoma ulmi* which is non-aggressive and the more aggressive strain *Ophiostoma nova-ulmi* (Schlarbaum et al 1998). There are two bark beetles which enable the spread of the DED; the native elm bark beetle (*Hylurgopinus rufipes*) and the European elm bark beetle (*Scolytus multistriatus*). Both strains of the fungus rely on the elm bark beetle to transport the spores and gain entry to the tree (D'Arcy 2000). Once inside the tree, the fungus has the ability to move from tree to tree through root grafts. In the case of the urban forest where monocultures of elm on streets were very common, the fungus often had the ability to spread very rapidly via root grafts and the elm bark beetle (USDA Forest Service 1999). By 1977 nearly the entire range of American elm was infected by the rapid spread of this fungus (Schlarbaum et al 1998). There are a number of management strategies for DED including pruning of infested limbs, sanitation of entire trees, severing root grafts, spray of insecticide, injection of fungicides, and reducing monoculture plantations. In the long term, researching and creating genetically resistant cultivars of elm could be the answer to DED. Despite these practices the mortality rate of American elms due to DED is forty million and growing (D'Arcy 2000).

These major forest disturbances have left urban forests restricted to which species of trees they can plant which are hearty enough to withstand the stress of the urban forest. It created a conundrum of wanting to increase species diversity while ensuring that the species planted could survive the harsh urban forest (Raupp et al 2006). A study conducted by Raupp et al (2006) analyzed urban forest inventories to discover the species diversity. The results showed that trees in the *Acer* (maple) family were the most commonly planted, followed close by *Fraxinus* (ash). Many species in the ash family are native to North America. They are also very hardy trees being resistant to heat, tolerant to drought, flooding, and various soil types. The cold hardiness of ash enables it to be planted in more northern cities (Discovery trees 2015).

The component of ash in the urban forest is unique to each city. According to an urban forestry report by the City of Toronto in 2013, there are approximately 10.2 million trees in the Toronto urban forest representing 28% forest cover. Of those 10.2 million trees, approximately 860 000 (8.4%) are ash on both private and public land. Using the value of trees in an urban forest by TD (highlighted in Chapter 1), estimates of the value of ash, and cost of EAB can be made. Toronto's forest canopy of 10.2

million trees is estimated at a value of 7 billion dollars, resulting in the ash component at 8.4% being worth 857 million dollars. These ash are either at risk or have already been removed by the City. The report also estimates the cost of removing a tree to be $700 per tree. If we multiply this value by the 860 000 ash trees, it will cost the City of Toronto 602 million dollars for removals only. Once the trees are removed there is also the cost to replace.

Looking to the United States, the City of Chicago Illinois has approximately 3.6 million trees, creating 17.2% canopy cover in the City. The urban forest as a whole is valued at 14.8 million dollars (USDA 2010). According to the study of urban forest inventories by Raupp et al (2006), ash comprises 12% of Chicago's urban forest (432 000 trees). This is yet another example of a major North American city facing the same threat of decline and mortality in the urban forest due to EAB.

Examining the two locations for this thesis, the Town of Oakville, Ontario has approximately 1.9 million trees in its urban forest. Ash comprises 9.6% of that total with an estimated 177 300 ash trees (Town of Oakville 2011). The City of Barrie has an estimated 34 000 municipal street trees, 10% of which are ash for a total of 3 400 trees (Rankin 2013). It is clear that ash is a significant component of many urban forests in various cities, large or small, across North America.

Chapter 3: Emerald Ash Borer

As cities grow, urban forestry is becoming increasing important to maintain green infrastructure and peoples connection to nature. Urban forestry is ever evolving over time as new management strategies are constantly being established, foreign alien insects are also on the move threatening the ecological balance of many urban forests. As discussed in Chapter 2, there have been major historical outbreaks of invasive alien insects and disease, some of which we are still managing for today. Currently, urban forests in Eastern Canada and United States are facing great risk and mortality from the emerald ash borer.

The beetle is native to Asia but has been confirmed present in North American since 2002 (Canadian Forest Service 2012). The European and Mediterranean plant protection organization (EPPO 2005) outlines the taxonomic classification of emerald ash borer as follows; kingdom: animalia, phylum: anthropoda, class: insecta, order: coleoptra, family: buprestidae, genus: agrilus, species: *Agrilus planipennis* Fairmaire. The order coleoptra describes the largest order of the class insecta. The defining feature of this order is a hard, dense exoskeleton which covers most of the body, along with front wings which are just as hard (Meyer 2009). The family buprestidae is commonly known as metallic wood borers or jewel beetles. They are herbivores and the larvae are distinct flat headed wood borers (Meyers 2009). The genus agrilus describes flat headed woodboring beetles commonly found in Asia, Australia, Europe and North America. The larvae of this genus usually bore and feed on the cambial tissue of trees (EPPO 2005). The body of the adult emerald ash borer is bronze or golden green, with metallic shiny emerald green wing covers (Figure 1). The shape of the body is slender and elongate, with males smaller than females, ranging from 7.5-13.5 millimeters long and 3.1-3.4 millimeters wide (McCullough and Katovich 2004).

Figure 1. Adult emerald ash borer (NRCan 2015a)

Typically EAB has a one year life cycle, but in some cases (primarily when attacking healthy trees) it may take 2 years to complete (Herms and McCullough 2014). Adult emergence typically occurs in May and June. The duration of the emergence period can vary in length due to the geographical range and climate where the insect is (Herms and McCullough 2014). A unique identifier to emerald ash borer is the “D” shaped exit hole it creates when the adult emerges from the tree (

Figure 2). The exit hole is approximately 2-3mm in diameter and can be seen on the stem and branches of the tree (Herms and McCullough 2014). Upon emergence the adults walk to the canopy where they feed on leaf margins. After approximately 3-4 hours of feeding they can then fly (EPPO 2005). Adults can survive for 3-6 weeks. During this time frame they must feed for one week before mating can occur (Herms and McCullough 2014). Adult activity is greatest on warm sunny days, and virtually non active on cooler rainy days (EPPO 2005). Females can produce 40-70 eggs during her life time, and she lays each one individually on the bark usually in cracks/crevices or

beneath bark flakes (Herms and McCullough 2014). Eggs are oval in shape measuring 1 millimeter by 0.6 millimeters. They are light yellow initially, turning brown before hatching (EPPO 2005).

Figure 2. D-shaped exit hole of emerald ash borer (Winmill 2014)

Eggs hatch within 7-10 days, at which point the first instar larva tunnels through the bark into the cambium where it begins to feed. The characteristic feeding pattern of EAB larva is in serpentine or "S" shaped galleries in the phloem and outer sapwood. Typically these galleries begin very small and tight, over time as the larva grows become wider and larger as seen in Figure 4 (McCullough and Katovich 2004). The galleries are filled with sawdust and frass from feeding and are typically 20 to 30 centimeters long for any individual larva. The larvae tunnel and feed from mid June to mid October (EPPO 2005). Fully grown, the larvae range in size from 26-32 millimeters long. They are typically white or cream coloured with a brown head (Figure 3). The abdomen consists of ten segments ending with pincer appendages (McCullough and Katovich 2004).

Figure 3. Emerald ash borer larva (CFIA 2015)

The larvae complete four instars during their feeding cycle, and cease to feed as mature fourth instars in October. Mature prepupal fourth instar larva overwinter in pupal cases in the outer bark or within outer edge of sapwood (1-2 centimeters) (Herms and McCullough 2014). Overwintering this way helps to protect the larva from predators and harsh climatic conditions. Surviving the winter, successful larva will pupate in April and May. The new adults remain under the bark for 1-2 weeks and then emerge through the bark through D-shaped exit holes where the process begins again (EPPO 2005).

It is the larval feeding stage of the EAB life cycle which causes the most damage to trees. Vascular tissue in a tree runs vertically between roots and canopy. The feeding of the larva occurs horizontally in the serpentine pattern, repeatedly severing vascular tissue. This feeding pattern escalated by high larval density in one tree causes the tree to become girdled. The tree can no longer perform the vital function of transporting water and nutrients throughout its system and will begin to shut down and in the case of trees native to North America, die (Anulewicz et al 2008).

Signs and symptoms of EAB infestation normally take a few years to show, and when they do the tree is normally already under severe infestation. The Ontario Ministry of Natural Resources (OMNR) defines signs and symptoms in their guide to detecting emerald ash borer damage as, “a sign is physical damage to a tree” and “a symptom is a tree’s response to insect attack” (2006). Signs of attack include; S-shaped larval galleries, adult D-shaped exit holes, and leaf notch of adult feeding (OMNR 2006). A tree may show signs of damage from animals and birds feeding on the emerald ash borer larvae. Woodpecker damage is a common sign, as well as peeled or stripped bark from squirrels searching for the larva (Figure 4) (OMNR 2006).

a)  b) 

Figure 4.Signs of emerald ash borer attack: a) woodpecker damage b) serpentine larval feeding galleries (Winmill 2014)

Symptoms the tree exhibits when under attack include; epicormic shoots, bark cracks, premature yellowing of foliage, dead branches, crown thinning, and heavy seed production (OMNR 2006). These symptoms are a result of restricted flow of water and nutrients throughout the tree. Epicormic shoots are also known as “water sprouts” and they are a trees lifeline in trying to put out new shoots to photosynthesize and allow the tree to survive (OMNR 2006). Producing lots of seed is also a trees last attempt to reproduce and pass on its gene pool. Figure 5 shows a tree infested with emerald ash borer, exhibiting symptoms of epicormic shoots, crown thinning, yellowing foliage, and dead branches.

Figure 5. A tree exhibiting symptoms of emerald ash borer: epicormics shoots, crown thinning, dead branches (Winmill 2014)

Signs and symptoms of EAB can take several years to show. There are a couple reasons for this, the first being that often the upper portion of the canopy is infested first making signs and symptoms within eyesight limited. The trunk is usually infested later in the attack (Herms and McCullough 2014). Another reason for delayed presence is that it takes a year or two for the feeding to cause enough damage in the tree to show symptoms. In addition, the insect is very small, making the signs hard to see no matter where they are in the tree. When decline is obvious the tree is in very severe decline, with a mortality rate of 1-3 years once infested (EPPO 2005).

In its native range of northeastern China, Korea, and eastern Russia, EAB plays the role of a secondary colonizer of ash trees. Typically they are only able to attack trees that are already stressed, in decline, or dying (Herms and McCullough 2014). As a prelude to the devastation to come in North America, there were reports of extensive mortality in horticultural ash in China, which is the white ash (*Fraxinus americana* L.) native to North America (Herms and McCullough 2014). These reports were proven true as EAB is lethal to trees of the ash family in North America. Herms and McCullough describe emerald ash borer as an "occasional pest" in China (2014).

There are 27 species of ash native to China with a history of coexisting with emerald ash borer. Of these 27, there are 3 which are the most commonly attacked by EAB; *F. mandshurica* Rupr., *F. rhynchophylla* (Hance) A.E. Murray, and *F. chinesis* Roxb. (Wang et al 2009). Ash species native to North America but introduced in China which are very susceptible to attack include; *F. pennslyvanica* (Vahl) Fern. , *F. americana* L., and *F. velutina* Torr. (Wang et al 2009). Wang et al (2009) states in a paper on EAB in China, that because emerald ash borer is not a serious forest pest in China, there was limited resources available to learn from in order to manage for it in North America. Herms and McCullough (2014) raised the same problem, "two pages that described some life-history traits were translated from a Chinese textbook and a few taxonomic reports had been published in scientific journals" when EAB was first discovered in North America. As a result of limited knowledge and highly susceptible native ash trees, the invasion in North America began one of the deadliest threats to urban and natural forests in Eastern North America.

Chapter 4: EAB in North America

The first signs of mass decline and mortality in ash trees were observed in the summer of 2001 in greater Detroit, Michigan, United States of America (Herms and McCullough 2014). On July 9 2002, beetles reared from the ash logs were positively identified as emerald ash borer. Shortly after on August 7, 2002, the beetles were also positively identified as EAB in Windsor Ontario, Canada (Herms and McCullough 2014). Although it was confirmed as EAB in 2002, it is estimated from tree ring analysis that the insect was present in the area for close to ten years prior to being identified (NRCan 2015a). The method of arrival of the emerald ash borer is not known for certain, but it is thought to have been accidentally imported through infested wood packaging materials (CFIA 2015).

Since its discovery in Detroit and Windsor in 2002, the spread has been rapid through the United States and Canada. In 2003, just one year after positive identification, it was estimated that between five and seven million ash trees were dead or dying in southeast Michigan (Herms and McCullough 2014). Management efforts at this time were erratic and, as discussed in Chapter 3, had little guidance as there was limited information to learn from of emerald ash borer life history and management in its native range. Early EAB management efforts in Canada and the United States focused on finding the edges of the infestation, prevention of movement, sanitation, and eradication (Youso 2004). In the spring of 2004, Ontario removed a total of 85, 000 ash trees between Lake St.Clair and Lake Erie in an attempt to prevent the movement of the insect (Youso 2004). The swath which was removed was called a “fire break”, was ten kilometers wide. Unfortunately, the fire break did not prevent the spread and by 2006 populations were identified in London, Ontario. Westward in Minnesota, alarms were raised as the U.S Forest service noted that northern Minnesota had the highest concentration of ash trees in the county. The amount of ash planted in urban cities, notably the Twin Cities in Minnesota, was high due to the devastation caused by DED (Youso 2004). An article written by Poland and McCullough in 2006 states that according to surveys conducted in 2004, approximately 15 million ash trees both in the forest and urban forest were dead or dying due to EAB. At this time it was estimated by the USDA forest service that approximately 850 million ash trees were threatened by EAB in Michigan alone (Poland and McCullough 2006).

In Canada, the population had spread to reach Toronto in 2007. In 2013 the population expanded as far as Simcoe County, Peterborough County, District of Algoma, and Manitoulin Island (NRCan 2015a). In Quebec, populations were confirmed in Gatineau and Montreal in 2011 (NRCan 2015a). The Canadian Food Inspection Agency (CFIA) is the federal agency responsible for controlling and restricting entry of invasive plant pests in Canada (CFIA 2014). They have developed numerous compliance mandates and border controls to reduce the spread and restrict entry of further infested material. With the current state of the infestation, the primary mandate of the CFIA is to slow the artificial spread of EAB through surveillance, regulation and enforcement, investment in research, and communications and outreach activities (CFIA 2014). Through the progression of the infestation, the CFIA delineated quarantine zones surrounding known populations in an attempt to reduce the human assisted migration of the beetle. Figure 6 depicts the regulated areas delineated by the CFIA in 2013 along with the red dots indicating new finds in that year.

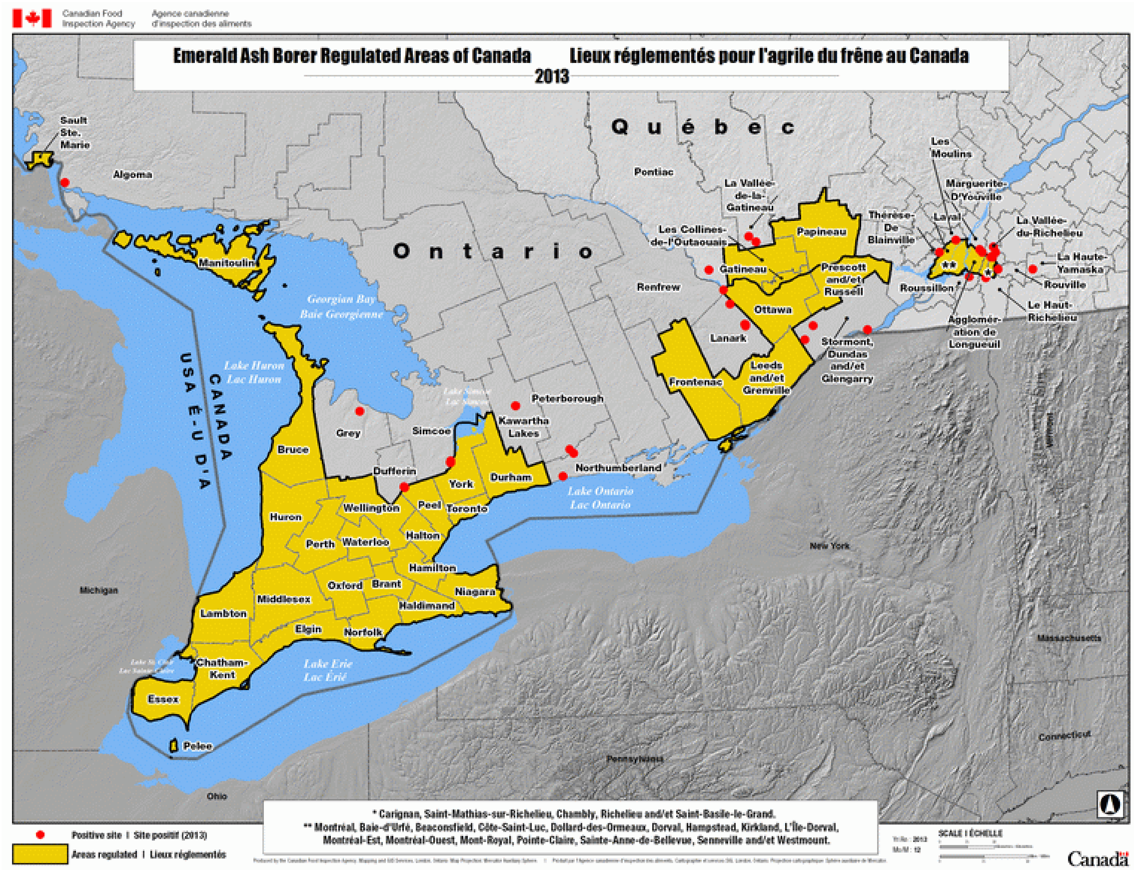


Figure 6. CFIA Emerald ash borer regulated areas of Canada 2013. (CFIA 2014)

By 2014 the spread was so vast that they merged the quarantine zones together, linking Ontario and Quebec infestations (Figure 7). In these regulated areas, movement of commercial ash wood commodities and firewood is restricted as a management effort to slow the spread (CFIA 2014).

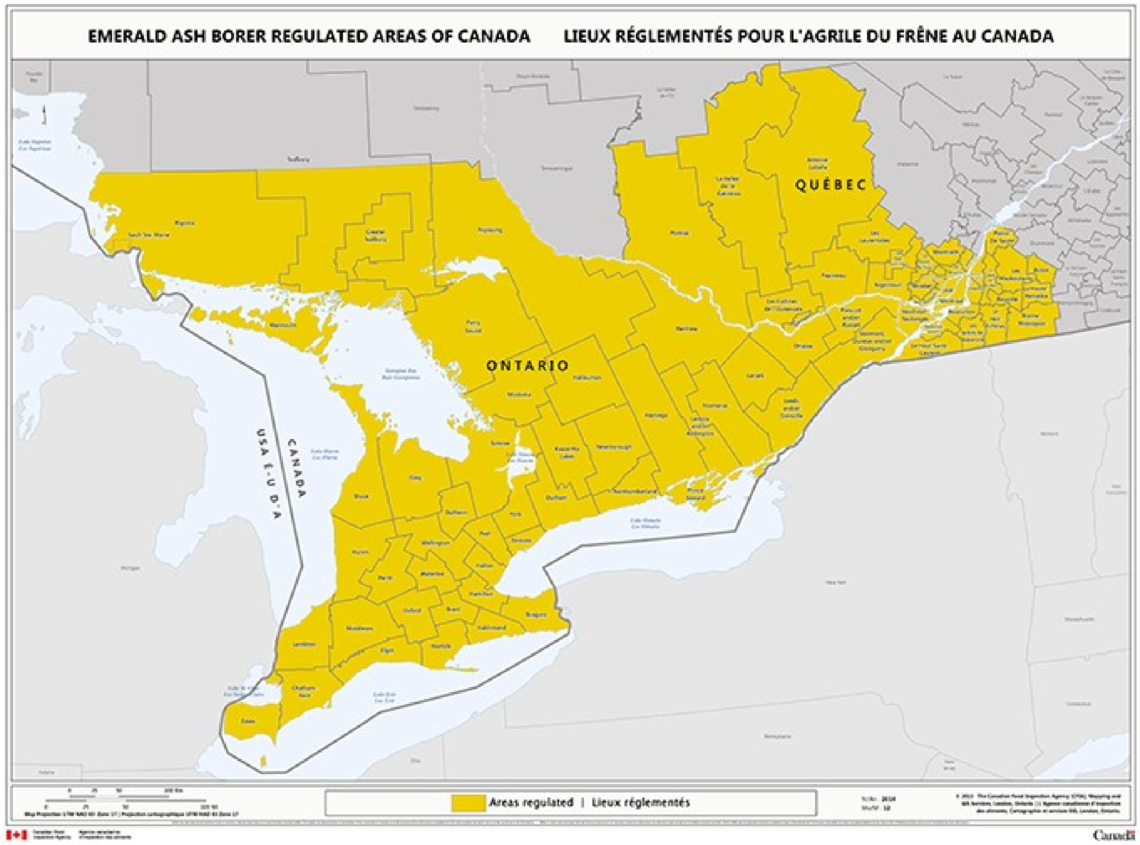


Figure 7. CFIA emerald ash borer regulated areas of Canada as of April 1, 2014. (CFIA 2014)

The emerald ash borer has killed millions of trees and has caused an estimated cost of twelve billion dollars to urban communities in North America (Canadian Forest Service (CFS) 2012). Currently in Ontario the beetle has spread as far north as Sault Ste. Marie. Although the spread of emerald ash borer is still sporadic it is feared that it will become continuous, devastating urban communities and ash dominated forests along the way (CFS 2012). The combined spread of the insect in North America can be seen in Figure 8, and reaches as far north in Canada as Sault Ste Marie, south in the United States to Georgia and Louisiana, and west to an isolated pocket in Colarado. In total, populations of emerald ash borer are present in 2 provinces in Canada and 25 states in the United States (USDA and APHIS 2015).

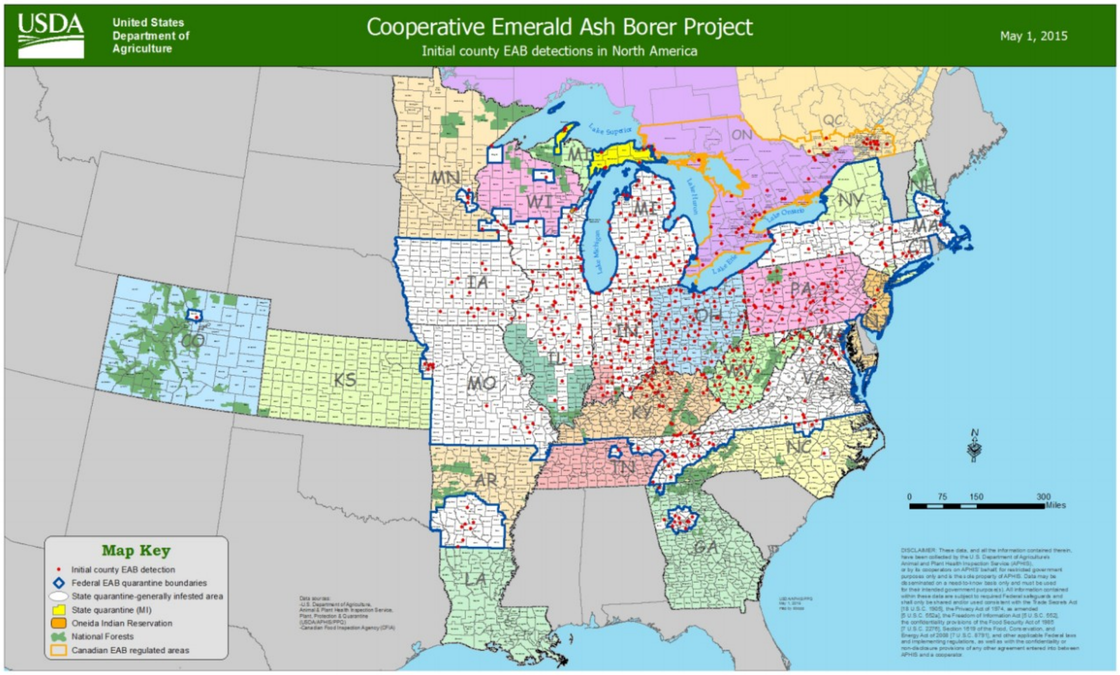


Figure 8. USDA initial county EAB detections in North America as of May 1 2015. (USDA and APHIS 2015)

There are two main vectors facilitating such rapid spread of EAB; biology of the beetle, and human assisted migration. The biology of the beetle indicates that they are very good fliers. In a study conducted by Taylor et al (2010) on flight simulation of emerald ash borer, it was found that on average beetles flew greater than 750 meters in 24 hours. There were outlier beetles in the data set which were found to fly much farther (Taylor et al 2010). Studies conducted on dispersal found that most eggs are laid within 100 m of the adult emergence point, but there were some found greater than 700 meters away (McCullough and Mercader 2011). It was also found that unmated females could fly twice as far as male beetles, and mated females could in turn fly twice as far as unmated females (USDA-APHIS 2015).

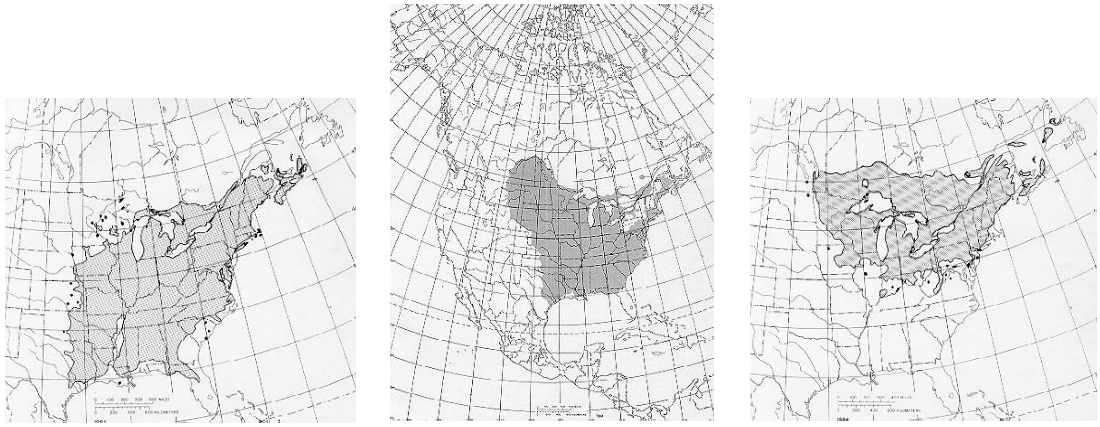
In addition to natural spread, human assisted migration is a significant contributor to migration of EAB. Human assisted migration can happen in many forms, but the two main vectors of concern are the transportation of wood products, primarily firewood, and movement of infested nursery stock (McCullough and Mercader 2011). Transportation of firewood is one of the major gateways for distribution of the emerald ash borer (Jacobi et al 2011). Due to the biology of EAB, we know that it spends the majority of its lifecycle under the bark of the tree either overwintering or feeding. Studies have concluded that adults can emerge from ash logs or firewood for up to a year or longer after the tree has been cut (McCullough and Mercader 2011). With many of the signs of infestation also being hidden from sight, the emerald ash borer is often not considered by unsuspecting people transporting wood. A study conducted by Jacobi et al (2011) on the transportation of firewood in fifteen Colorado State Parks, and thirty campgrounds in thirteen National parks in Arizona, Colorado, Nevada, Utah, and Wyoming found a concerning amount of movement of firewood. The study resulted in discovering that in state parks, 66% of campers brought their own wood, but only 4% was from outside the state. In national parks however 60% of campers brought their own wood and 39% was from outside the state. This means that 329 919 campers could be bringing out of state fire wood to the national parks surveyed annually (Jacobi et al 2011).

In the early years of the infestation, transportation of infested nursery stock was a major contributor to the facilitation of spread for emerald ash borer. Soon after EAB was positively identified, the Michigan Department of Agriculture put in place a quarantine to regulate movement of ash products (nursery trees, logs) from infested counties (Herms and McCullough 2014). Unfortunately some nursery stock was still transported. An example of this is noted by Muirhead et al (2005) where in April of 2003 a nursery in Maryland received a shipment of 121 infested saplings from a quarantine zone in Michigan. These trees were then planted at one site in Virginia and four more in Maryland (Muirhead et al 2005).

Human assisted transportation of the beetle allows for pocket populations to develop. Muirhead et al (2005) makes note of many examples of these in the early years of the confirmed infestation. In 2003 the quarantine zone in Michigan included 13 counties. Within that year six new populations were reported outside the quarantine zone, one of those being 200 kilometers away from the nearest population. Similar pocket populations were discovered in the same time frame in Ohio, with a report from a location 250km from the nearest population. In 2004 the distance and number of new finds outside the quarantine zones increased, including the spread into Indiana with four new populations each 100 kilometers from the nearest confirmed population.

By September of 2003, the infestation had spread in the United States to 21 states and in Canada, two provinces (Herms and McCullough 2014). In 2004, there were 23 new populations discovered in Canada, confirming the insect had breached the fire wall (Muirhead et al 2005). Efforts to eradicate began in 2003 but were terminated shortly after (Herms and McCullough 2014).The rapid spread of the insect and subsequent discoveries of so many pocket populations along with extreme economic cost made the concept of eradication short lived. Consequently, efforts were and still are focused on limiting the transportation of the beetle. It is absolutely essential to regulate the assisted migration of the beetle in order to slow the spread and conserve urban and ash dominated forests. Pocket populations are still happening despite quarantine zones. An example of this is those discovered in Colorado, Arkansas, and Georgia as seen in Figure 8 (USDA and APHIS 2015). Eventually with the combination of natural spread and human assisted migration, the pocket populations and natural epicenter of the infestation will both grow and have the potential to coalesce in the future (Herms and McCollough 2014).

The spread of EAB depends heavily on host availability. In North America, ash trees are one of the most commonly distributed hardwood species found in the forest, as well as being one of the most popular trees to plant in urban settings (Poland and McCullough 2006). In its native range in Asia, the EAB typically attacks stressed trees. Trees in urban centers are often stressed due to poor planting conditions, and as a result, not only are the ash trees themselves susceptible, they are stressed, making them an easy target. These types of conditions can play a major role in enabling the establishment of invasive insects such as the EAB (Poland and McCullough 2006). When considering the management of EAB, it is imperative to know the susceptibility of host tree species. It has been discovered that all ash species native to North America are susceptible to EAB to some degree (Herms and McCullough 2014). In total there are 16 species of ash Native to North America, and 4 to Canada (Farrar 1995).The three most commonly and widely distributed species of ash native to North America can be seen in Figure 9 and include; white ash (*Fraxinus Americana* L.), green ash (*Fraxinus pennsylvanica* Marsh.), black ash (*Fraxinus nigra* Marsh.) (Herms and McCullough 2014).



(a) *F. Americana* (b) *F. pennsylvanica* (c) *F. nigra*

Figure 9. Distribution of most common *Fraxinus* spp. in North America (USDA Forest Service 2015)

An important contrast of ash in the native range of EAB compared to that of North America, is that the range in North America is fairly contiguous (Figure 9) whereas in Asia it is made up of many isolated pockets (MacFarlane and Meyer 2004). Other species of ash are still significant but have a much smaller range. Examples of these include pumpkin ash (*Fraxinus profunda* (Bush) Bush), blue ash (*Fraxinus quadrangulata* Michx.), and Oregon ash (*Fraxinus latifolia* Benth.) (MacFarlane and Meyer 2004). A study done by Tanis and McCullough 2012 in Michigan United States determined that there is a difference in susceptibility between blue ash and white ash. The results of the study determined that although both species are indeed susceptible, white ash is preferred over blue ash. In forest stands where EAB was present, white ash was more heavily affected than blue ash (Tanis and McCullough 2012).Of all these species, the three most susceptible species are green, black, and white ash, with white being slightly less vulnerable than the other two. The most resistant North American species is blue ash, which is consistent with the Tanis and McCullough study (Herms and McCullough 2014). Knowing and understanding the susceptibility of ash species is important to consider when outlining and zoning areas of high risk.

In addition to the susceptibility of the ash species, the potential for EAB to establish in non ash host trees is a threat that must also be considered. In its native range, EAB mostly attacks ash trees, but there have been cases documented where it has been found on Asian species of elm (*Ulmaceae*), walnut (*Juglandaceae*), and wingnut (*Pterocarya*) (McCullough et al 2003). To address this concern, McCullough et al (2003) ran two research trials. The first was to assess the success of ovipositioning females and larval development on a variety of hosts. The second was on host preference. The results showed that alternate hosts were in fact suitable for ovipostioning, but the larvae were malformed and small. When given a choice, ash was the preferred host (McCullough et al 2003).

In 2014 the idea of EAB attacking another tree species became real when evidence of infestation was confirmed in the white fringe tree (*Chionathus virginicus* L.) in Ohio (Cipollini 2015). The emerald ash borer was confirmed to have completed its lifecycle in the white fringe tree, and chosen it as a host when ash was still available and in proximity (Cipollini 2015). White fringe tree is in the same family as ash (*Oleaceae*), and it is the most closely related to the *Fraxinus* genus (Scarr 2015). The Ontario Ministry of Natural Resources and Forestry (OMNRF) provincial entomologist Taylor Scarr addressed this new discovery by commenting on the similarity of ash and fringetree as they are in the same family so they are, “likely to have some chemistry and physiology in common with Asian ash” (2015). Although white fringe tree is planted mostly as a horticultural tree and has a smaller range, it should still be considered when making management decisions (Cipollini 2015). In addition, monitoring of other species in the olive family should be on going.

The emerald ash borer infestation in North America is now considered the most destructive invasive pest that North American forests have ever seen (Hamilton 2011). In 2011in the United States, the death toll from EAB was approximately 60 million ash trees in 15 states (Hamilton 2011). The infestation is now in 25 States plus two Canadian provinces and the mortality rate is ever increasing (USDA – APHIS 2015). In the United States there are an estimated 8 billion ash trees at risk from EAB (Hamilton 2011).

Chapter 5: Management for EAB

Management for emerald ash borer generally follows an integrated pest management (IPM) approach. IPM is usually case specific to individual pests, but the foundation of the program is the same. The United States Environmental Protection Agency (EPA) defines the goal of an IPM is to, “manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment” (2014). A combination of existing knowledge about the life cycle of the pest, associated environmental impact, and available pest control methods are all used to create the IPM. The approach is a series of management techniques as opposed to one single plan. It is usually set up following a four tiered system; set action thresholds, monitor and identify pests, prevention, and control (EPA 2014). Communities with established EAB populations would focus on the control aspect of the IPM approach. Areas which are not yet infested but are at risk should focus heavily on the prevention aspect of the IPM strategy with control methods in place if the prevention fails (EPA 2014).

There are a number of management strategies in place which are used to manage for EAB. Many of these strategies are most effective when used together. The fundamental step to management for EAB is acquiring an inventory; knowing where the ash trees are, and how many there are (Ryan 2013). An accurate up-to-date inventory allows for managers to delineate the risk EAB may pose to the land they are managing. Depending on the amount and location of the ash, the landscape can undergo a risk assessment and management strategies can be devised to manage for the insect (Ryan 2013). Ash has been a very popular tree species to plant in the urban forest, making it essential to map and monitor. Tree inventories also allow managers to assess biodiversity in the forest. By understanding the species composition, managers can plan to increase biodiversity through planting (Alvey, 2006). This is incredibly useful especially when managers plan for removal of ash and need to plan what to replace it with. Street tree inventories in the urban forest are often done by individual tree assessment. Various inventory methods on the landscape level in natural forest settings can be applied (aerial image interpretation, sample plots).

Management of the emerald ash borer has been an evolving process since it was first discovered in 2002. Early management strategies were focused on finding the infestations, delineating the population, regulating the affected areas and eradicating the insect (Herms and McCullough 2014). These strategies are still applied today, with the exception of eradication because it is not economically or technically feasible (Herms and McCullough 2014). With such an aggressive insect, management strategies are focused on managing for the insect not managing the insect itself. Detection and monitoring using visual surveys, pheromone traps, trap trees, and sticky bands were the initial modes of population tracking (Poland and McCullough 2006). EAB is a very difficult insect to manage due to its biology. Typically EAB colonize the upper canopy of a tree first, making visual surveys incredibly difficult at times. The surveyor often relies on the symptoms exhibited by a tree which normally indicates the infestation is at least one year old. In addition, the majority of the life cycle is spent in the bark hidden from site (Poland and McCullough 2006).

Management for EAB depends on a variety of factors including location, type of forest under threat, budget, and resources (Ryan 2013). Options for management range from doing nothing to very aggressive management (Persad and Tobin 2015). Success of any management strategy relies heavily on early detection of the infestation. In areas of new infestation, populations are usually low, meaning that it will take a few years for the population to establish and increase, reaching destructive infestation levels (Persad and Tobin 2015). Low population numbers means the tree will take longer to exhibit signs and symptoms, delaying the detection of the beetle (McCullough and Mercader 2011). This may result in multiple generations completing their lifecycle before being detected (Kovacs et al 2009).

Early detection of emerald ash borer is done typically by three methods; visual surveys, trap trees, and artificial traps (McCullough and Mercader 2011). A preliminary step to establishing this plan is to know the current inventory of private and public ash trees. High resolution imagery can be used to determine and identify urban vegetation (Iovan et al 2008). Visual surveys include people physically looking at the trees and assessing for signs and symptoms of EAB. This can be a lengthy, expensive, and labour intensive initiative which may not even be that effective considering signs and symptoms are difficult to detect early (Herms and McCullough 2014).

Trap trees or "detection trees" are ash trees that are deliberately girdled to attract ovipositing females. These females are highly attracted to stressed ash trees, and so this process is used for early detection. Detection trees are felled in the fall and debarked to locate larval activity and determine population density (Herms and McCullough 2014). These trees were used in the early years of the infestation in the effort made by the Michigan Department of Agriculture (MDA) to delimit the extent of the infestation. A statewide grid was established with one tree per thirty six square miles (Poland and McCullough 2006). The trees were checked visually in the summer (assessments and sticky band checks) and then felled in the winter and debarked. This effort was effective and showed that the infestation was much larger than originally thought with many outlier populations on trees exhibiting little to no outward signs of infestation (Poland and McCullough 2006). Despite detection trees being the most successful tool for early detection, it is a very expensive and labour intensive process which cannot always be applied (Herms and McCullough 2014).

The use of artificial traps to detect EAB is complicated because the adult beetles, "do not produce long distance sex or attraction pheromones" (McCullough and Mercader 2011). Instead, the beetles uses volatiles from host trees as well as visual cues to find the ash trees. As a result, pheromone traps cannot be used for this insect. Sticky prism traps with artificial volatile lures are used instead. These traps are often purple or green and are hung from the canopy of ash trees (Herms and McCullough 2014). The problem with these traps is that the artificial volatile lure must compete with the volatile emitted from ash trees (McCullough and Mercader 2011). Therefore it must be just as, if not more, attractive than that emitted from the host tree in order to attract the beetle. Much research and development has gone into this effort to increase the effectiveness of the lures (McCullough and Mercador 2011). There is another kind of trap called a “double decker trap”. These traps are baited with the same lure as the prism traps, but instead of being hung in the canopy, two of them are attached to PVC piping. The pole is placed in full sunlight, close to the edge of wooded areas with a high component of ash. This trap design plays to the biology of the beetle, it prefers the sun, is a visual cue, and has the volatile lure (Herms and McCullough 2014). Research conducted on the efficacy of the double decker traps has been inconclusive, with only a generalization being made that they may be more efficient in low population densities and prism traps at high densities (Herms and McCullough 2014). It is important to note that the traps are effective for early detection, it is not for use in reducing the population.

The current management protocol in place by the USDA and APHIS includes, “thousands of artificial traps baited with host volatiles, visual surveys of ash trees in high-risk sites, and outreach activities to increase public awareness of *A.planipennis*” (McCullough and Mercader 2011). Upon confirmation of newly infested areas, quarantines are put in place to restrict and regulate transportation of ash trees, logs, firewood, and other related material. The specific management plan for private property and municipal properties are up to the forester or land owner (McCullough and Mercader 2011).

Treatment of ash trees is an option for managing for emerald ash borer. Options for chemical treatment are complicated by the biology of the insect, governmental regulation, and the geographical range of the insect. In addition, there is also the economic evaluation to consider of the value of the tree (dead versus alive) to cost of treatment (Herms et al 2014). Studies show that the benefits of trees increase with size. It can therefore be assumed that it makes economical sense to target large ash trees for treatment (Herms et al 2014). Treatment is applied on an individual tree basis, therefore the location of trees in question would have to be considered. Research has shown that treating landscape trees is more economically feasible than the cost of removing the same tree (Herms et al 2014).

There are several insecticide options for emerald ash borer, differing in both application method and chemical formulation. Herms et al (2014) classify application methods into three categories for systemic insecticides; soil injections or drenches, trunk injections, lower trunk sprays. Each of these methods has the same goal of translocation through the vascular tissue throughout the tree (Herms et al 2014). With soil injections the roots absorb the insecticide and subsequently transport it throughout the tree. The chemical can be applied by either injection at multiple locations around the tree, or drenching. Drenching is a process where the chemical is mixed with water and applied directly to the soil surrounding the base of the tree (Herms et al 2014). In trunk injections, often a small hole is drilled into the tree at multiple locations around the tree and the insecticide is applied directly into the vascular tissue (Herms et al 2014). In lower trunk sprays the insecticide is sprayed onto the lower portion of the main stem of a tree. The chemical has been found to penetrate the bark and then subsequently taken up through the vascular tissue and translocated throughout the tree (Herms et al 2014). The fourth option is a cover spray which can be applied to the trunk, main branches and sometimes foliage (Herms et al 2014). Both the systemic insecticides and canopy spray target adults feeding on foliage, but only the systemic insecticides target larvae feeding under the bark (Herms et al 2014).

The chemical formulation for these application methods vary by the active ingredient which makes them toxic to the insect itself (Herms et al 2014). There are four common active ingredients in the systemic insecticides; imidacloprid, dinotefuran, azadarachtin, and emamectin benzoate. From the active ingredients listed, all are lethal to the insect, with the exception of azadarachtin (Herms et al 2014). The impact on larvae and adult stages of the beetle are slightly different when azadarchtin is ingested. The foliage ingested by feeding adult beetles is not directly toxic to the beetle, rather it reduces female fertility and renders eggs unviable. When ingested by larvae, it limits growth and prevents molting into the next life stage (BioForest n.d).

Research from Michigan and Ohio State universities on the efficacy of these methods has been completed (Herms et al 2014). The soil application of insecticides had varying results from high to low efficacy from numerous field trials. The inconsistent results may be due to factors such as application placement, size of the tree, soil type, and soil moisture (Herms et al 2014). Trials for trunk injection showed efficacy of products with the active ingredient emamectin benzoate and azadarachtin. These chemicals combined with application method resulted in protection against emerald ash borer for up to two years (Herms et al 2014). Research was also done using formulations with imidacloprid as the active ingredient, but the results were more varied in terms of success (Herms et al 2014). Efficacy results for basal trunk sprays showed that they were effective but only for one year. Treatment in this form must be annual (Herms et al 2014).

The major active ingredients for systemic insecticides are all are registered in the United States under the Environmental Protection Agency (EPA) (Hahn et al 2011, BioForest n.d). In Canada, pesticides are regulated by Health Canada's Pest Management Regulatory Agency (PMRA). The PMRA has four insecticides registered for use against emerald ash borer. The active ingredients in these are imidacloprid, azadarachtin, and acephate (PMRA 2015). Research has been done on environmental hazards of these chemicals as well as toxicity to other life forms (Hahn et al 2011). Particular concern has been placed on pesticides which are considered neonicotinoids (David Suzuki Foundation 2014). The Ontario Ministry of the Environment and Climate Change (OMECC) defines neonicotinoids as, "a class of synthetic pesticides that are chemically similar to nicotine. They are neurotoxins that kill insects through attacking receptors in nerve synapses" (2015). Both imidacloprid and dinotefuran are classed as neonicotinoids (EPA 2004, OMECC 2015). There are three neonicotinoids which are considered highly toxic; imidacloprid, thiamethozam, and clothianidin (OMECC 2015). Imidacloprid is the most commonly used active ingredient worldwide to control pests in agriculture, turf, and landscape trees and plants (Hahn et al 2011).

Recently, there has been major public and environmental concern regarding the use of neonicotinoids and their effect on honey bees. The David Suzuki Foundation raises questions and concerns about the risk of neonicotinoid pesticides and their adverse affect on bees and other pollinators (David Suzuki Foundation, 2014). On their website is an application where members of the public can email ministers to add their support in banning neonicotinoid pesticides. A poll on the website indicates that 73 463 people have used the email service to ministers, and the Foundation has a goal of reaching 100 000 participants (David Suzuki Foundation 2014). Another example of public and environmental concern of neonicotinoids is documented by Mellino from EcoWatch on March 4 2015, when a rally of people gathered in front of the white house to deliver a petition with more than four million signatures to President Obama to protect bees and other pollinators.

The serious concern for pollinators was addressed through research on imidaclorprid use against emerald ash borer. Research by Hahn et al state that, “ash trees are wind pollinated and are not a nectar source for bees…it is highly unlikely that bees would be exposed to systemic insecticides applied to ash” (2011). Although trunk injections may be considered low risk, when applying insecticide through the soil, particular attention must be paid to what is planted around the tree. Flowering plants which are pollinated by bees and other insects could take up the chemical (Hahn et al 2011). It is advised to use the injection method when flowering plants are in close proximity to an ash tree that will be treated (Herms et al 2014). If soil drenching does occur close to flowing plants, the best management response is to destroy the plants (Herms et al 2014). To reduce non targeted exposure, the site of application should be cleared thoroughly as imidacloprid can also bind to organic matter (e.g leaf litter) (Herms et al 2014). There is also the concern of runoff when using the soil application method. Dinotefuran is more soluble in water than imidacloprid, but both break down slowly in water with the absence of light (Herms et al 2014). Surface water surveys in Canada and the United States have shown that imidaclorprid is not often detected in surface water in agricultural or urban areas (Herms et al 2014).

The active ingredient azadarachtin is an alternative to neonicotinoid chemicals. It is a bioinsecticide derived from the seeds of the neem tree (*Azadiracta indica*) (Thompson and Kreutzweiser 2007). A study conducted by Thompson and Kreutzweiser (2007) concluded that, “azadirachtin is relatively non-toxic to mammals, birds, and bees”. Research has also been conducted on the effects of azadirachtin as a systemic insecticide injected into the trunk of an ash tree and the resulting toxicity in senesced leaves of that tree. Results from the study confirm that there were no significant reductions in survival, consumption, and growth rates in earthworms, or aquatic insects. There was also no significant difference in both terrestrial and aquatic microbial decomposition of leaf material (Kreutzweiser et al 2011). Azadirachtin is the active ingredient in the commercial insecticide TreeAzin, which is registered for use in Canada against many insect pests including trunk injections for emerald ash borer. It is registered in Ontario as a class 4 pesticide, meaning it is the least hazardous product available on a commercial scale (BioForest n.d).

In addition to pesticides, research is also being done on the use of biological control (biocontrol) for emerald ash borer in North America. APHIS defines a biological control as, “the reduction of pest populations through the use of natural enemies such as parasitoids (stingless wasps), predators, pathogens, antagonists (to control plant disease), or competitors” (2014). Three stingless wasp species native to China were under consideration for introduction to North America in an effort to control outbreak populations of emerald ash borer; *Spathius agrili, Tetrastichus planipennisi, Ooblus* *agrili* (APHIS 2014). All three wasp species utilize emerald ash borer as the host where it lays its eggs. The *S. agrili* has a very long ovipositor which it uses to drill through the bark and lay its eggs on the host; EAB larva. Once hatched, the larva feed upon the EAB larva which kills it (APHIS 2014). *T. planipennisi* has a similar approach except its ovipositor is much shorter and is therefore limited to small diameter trees with thin bark. It also lays its eggs inside the EAB larva not on it, killing the host from the inside out (APHIS 2014). *O. agrili* differs from the other two wasps in that it targets the EAB eggs as hosts instead of the larva. The female deposits eggs using her oviposter inside the EAB eggs. When the eggs hatch they kill the EAB larva before it can emerge from the egg (APHIS 2014).

In the United States all three wasp species were released in 2007; *Spathius agrili, Tetrastichus planipennisi, Ooblus agrili* (APHIS 2014). In 2013, only one of these three wasps was released in Canada, *T. planipennisi* (CFIA 2013). It was originally planned for *S. agrili* to also be released in Canada, but it was discovered that it cannot survive north of 40 degrees of latitude (CFIA 2013). A risk benefit analysis was conducted for these wasps, with specific focus on host specificity. Research supported that the wasps targeted EAB specifically and risk of attacking other insects was low (AHPIS 2014). The stingless wasps are not expected to eradicate the insect, only to help reduce population to manageable levels (CFIA 2013). In Canada, *T.planipennisi* was released by Natural Resources Canada – Canadian Forest Service in southwestern Ontario and Huron County (CFIA 2013). In the United States the wasp species were first released in Michigan, followed by 19 other states (APHIS 2014). In order to monitor the populations and success of these stingless wasps, monitoring programs are in place which includes traps and tree felling and debarking programs (USDA-APHIS 2013). It is still early in the program and research is ongoing.

Another example of innovation in the fight against emerald ash borer, is the development of genetic hybrids of ash to breed resistance into North American ash trees. Ash trees in the native range of emerald ash borer have developed evolutionary resistance to attack by the beetle. Conversely, the ash trees native to North America do not have any natural defense (Koch et al 2008). Research on the cross breeding of Asian and North American ash species by Koch et al (2008) has been called the "development of novel ash hybrids". The goal of cross breeding of the two species is to determine the genetic markers of the genes responsible for resistance and subsequently create an ash breeding program. From an urban planning perspective, if this project is successful than it could be possible to market the hybrids for use to reintroduce ash to the urban forest (Koch et al 2008). There is also research being done on North American ash trees that seem to be "surviving" the outbreak (Kerr 2010). Research by Kathleen Knight at the USDA Northern Research Station in Delaware is focusing on these native trees, stressing the importance that the seed stock from these trees will allow preservation of North American ash, while research continues on emerald ash borer (Kerr 2010). The hope of successfully developing genetically modified ash species is strengthened by success in the past with other historical outbreaks including chestnut blight and dutch elm disease (Koch et al 2008, University of Minnesota 2014).

Taking all of these management options into consideration, communities awaiting the arrival of emerald ash borer or currently facing an infestation must develop an urban forest management plan to manage for the insect. There are a number of management tools that urban forests and planners are currently using to deal with the EAB. Sadof et al (2011) propose an online cost benefit calculator for making decisions on what should be done with EAB infested trees. Management practices depend on risk and level of infestation. There are generally three options when dealing with an infestation; do nothing, cut and replace infested trees, inject with systemic insecticide (Sadof et al 2011). Mercader et al presents three similar approaches in a study conducted in 2011 on EAB management, with the elimination of the "do nothing" option and replacing it with girdling ash trees within management area to attract ovipositing females, and subsequently destroying those trees in the fall.

These management methods are often employed in a combined approach. No matter the method chosen, everything has a price. When considering the option of "doing nothing" there can still be costs associated, as EAB is lethal to North American ash trees. It is projected that without the use of any pesticide, all ash trees in an infestation zone would be dead in ten years (Herms and McCullough 2014). In many cases, dead trees in an urban environment are considered hazards and must be taken down (Town of Oakville 2007). As a result, in this scenario of "doing nothing" there would still be the cost of labour, removing and disposing of the dead tree, stumping, and potentially replacing with new sapling. The doing nothing scenario in a woodlot or forested area is more realistic. In this setting forest managers may chose to just leave the dead tree and not do anything about it. If dead trees in a woodlot or forested area pose a risk to human safety, they must then be removed (McNeil 2013).

Management of emerald ash borer is focused on slowing the spread, reducing growth of the population, and subsequently minimizing the impact of the beetle

(McCullough and Mercader 2011). A management strategy called SLAM (SLow Ash Mortality) was created in 2008 in an attempt to provide guidance in slowing the onset and progression of EAB. Management strategies used in SLAM include use of trap trees, systemic insecticide, and harvest/removal of ash trees (McCullough and Mercader 2011). The SLAM approach can be modified to fit different landscape scenarios (e.g. urban vs forested). This is especially true when assessing the cost benefit of treating ash trees. Trees in an urban setting are more accessible to applicators, and application needs to be done on an individual tree basis. Urban centers may also have a street tree inventory which allows managers to know exactly where each ash tree is. As a result this may make more economic sense in an urban setting (McCullough and Mercader 2011). In theory harvesting ash trees to reduce host availability is an effective management strategy. However, it can have implications by increasing the amount of wood material being transported, and also force the beetle to fly further; increasing the spread of the population (McCullough and Mercader 2011). All management options have economic and environmental pros and cons. Using one method exclusively is often not the best management strategy, so the use of the SLAM framework tries to integrate these methods together to achieve optimum management success (McCullough and Mercader 2011).

Population dynamics are important to take into consideration when planning for emerald ash borer. The population size fluctuates over the course of an infestation (Herms et al 2014). It could seemingly appear small at the beginning while evidence of its presence is usually hidden and under the safety of the bark, the population is building. When the population reaches peak densities, the majority of untreated ash trees will die, usually between 3 and 5 years. When the host species dies and food becomes limited, the population will decrease (Hermes et al 2014).

Proactive management can be done using modeling efforts to estimate the spread of emerald ash borer into new areas. Ecological niche models can be used to project the potential distribution of EAB throughout Canada and the United States. Two models proposed by Sobek-Swant et al (2012) are run based on the distribution of EAB in its native range in China. Using the ecological factors controlling its survivability in China, a potential range map can be drawn up for North America. Cities in North America which fall into the projected range of distribution of the model could then decide to develop a management plan for EAB if it does in fact follow the model and land in those places.

Proactive management also allows for high value ash trees to be identified for treatment (McCullough 2015). In addition, when practicing proactive versus reactive management treatment can begin before or early into the infestation. When an infestation is within 10 to 15 miles of the tree in question for treatment, then treatment should begin (Hermes et al 2014). If treated too late efficacy of the insecticides is decreased. This is because the larvae of EAB damage the vascular tissue of the tree, which is what is required to translocate the insecticide (Herms et al 2014). A proactive approach also enables the chance to conduct early education of members of the public on the impending risk. Presumably, raising awareness of the threat of EAB would help build support for management efforts, as well as reduce the spread through human assisted migration (Poland and McCullough 2006).

Raising public awareness also helps in tackling the issue of ash trees on private property. In an urban center there is both public and private property, wherein both government and property owners have responsibility for trees on that land (City of Peterborough 2013). Depending on the population size there can be hundreds of thousands of individual property owners. This raises the issue of management of ash on private property. Many municipalities are encouraging homeowners to treat trees on private property through information bulletins on their website. The City of Peterborough is an example of a proactive community providing information and creating awareness of management options in the community through their Emerald Ash Borer Management Plan (2013). Increasing the complexity of this issue is the fact that signs and symptoms are often hidden and not obvious until it is too late, and the tree is past the threshold of decline to treat. To an unsuspecting homeowner the decline can happen very rapidly. Other municipalities such as Beaconsfield, QC have adopted a very aggressive proactive strategy of treatment and removals. Their message to homeowners is that everyone must take action, and there are only two options: treat or remove. In order to encourage treatment and preservation of the urban canopy, they have taken on the responsibility of private ash tree inspections (upon the request of the homeowner). In addition, they are providing at 10% discount on the cost of treatment if homeowners decide to go that route instead of removing their tree (City of Beaconsfield 2015).

No matter the management strategy chosen, the estimated economic impact of emerald ash borer is on an astronomical scale. A cost potential study conducted by Kovacs et al (2009) on the 25 infested states in the United States, implies a cost projection of treatment, removal, and replacement within communities between 2009-

2019 at an estimated $10.7 billion dollars. When expanding this projection to include land outside of the communities, that number is expected to double (Kovacs et al 2009).

When considering the economic impact of EAB, the damage goes beyond treatment, removal, and replacement. It also affects industries which rely on trees and plants (Herms and McCullough 2014). Both producers and end users are affected by this. For example, the regulations placed on transporting nursery stock affected 9 500 nurseries in southeast Michigan alone (Herms and McCullough 2014). The forestry industry is another example of a producer that will be affected. End users who rely on ash products will be severely affected (Herms and McCullough 2014). As the infestation grows, the quarantine and regulated areas also grow, increasing the economic impact of this invasive insect in North America (Herms and McCullough 2014).

Chapter 6: What does this mean for other places?

The future prospective of EAB is one of uncertainty. With extensive research, management through insecticide application seems to be an effective and cost efficient method for preserving landscape trees (Herms and McCullough 2014). As the population grows and spreads from the urban forest to larger forest settings, the management options become fewer. Treatment with insecticide on an individual tree basis becomes less economically feasible, leaving the management options of biological controls and harvesting (Herms and McCullough 2014).

Focusing on the Canadian perspective, the infestation to date is predominately in southern Ontario and Quebec. There are pocket populations in more northern Ontario in Manitoulin Island and Sault Ste. Marie (NRCan 2015a). The infestation is expected to grow and continue to spread in Canada as there is still a vast amount of ash in cities and on the landscape which have not yet been affected (NRCan 2015a). The Forest Resources of Ontario report in 2011, quantifies the results of the 2010 Forest Resource Inventory (FRI) (MNR 2011). The FRI in Ontario quantifies species composition and distribution across the province of Ontario in the area of the undertaking. The results of the 2010 FRI show that all species of ash account for a total volume of 20 781.6 cubic meters. The total area containing a portion of ash is 726 070 hectares (MNR 2011, pp111). The total amount of forest in the area of the undertaking is 36.5 million hectares (MNR 2011: 39). These values show that ash represents approximately 2% of the forest in the area of undertaking. As stated by Hermes and McCullough (2014) management in the natural forest is limited to harvesting and biological controls.

Although 2% may not represent a large portion of the forest composition, it may still be enough to enable natural spread through the forest throughout the province. In addition to this 2%, there is all of the ash planted in urban environments. In Canadian municipalities alone, the projected cost of management of ash on street and backyard (private) trees is estimated to cost $890 million over a 30 year period (McKenney et al 2012). In Ontario, the mortality rate is already estimated at 20 million trees and growing (City of Thunder Bay 2015).

Adding to the complexity and severity of the threat of EAB, only deciduous trees can be planted on boulevards in urban settings. Safety is the primary reason for this, coniferous trees do not allow for people to “see through” them for oncoming traffic and pedestrians. They also do not promote good grass growth which can be important to homeowners (City of Thunder Bay 2015). In order to promote biodiversity in the urban forest, many municipalities set a limit for the maximum percent species composition that can be planted.

In the City of Thunder Bay, Ontario, The City Parks Division Standards and Specifications states that, “no more than 20% of single genus is to be planted, and no more than 10% of a single species is to be planted within a subdivision development” (City of Thunder Bay 2015). Targets like this can be difficult for more northern cities to attain as a result of the climate. The selection of native deciduous tree species is slim. In the City of Thunder Bay, there are 21 tree species on the urban forest planting list, 14 large stature trees and 7 smaller (City of Thunder Bay 2015). This list no longer includes ash due to the imminent threat of EAB. Although the City of Thunder Bay is in Northwestern Ontario, and has not yet been attacked by EAB, the city is planning for its arrival. Populations are established and confirmed in both St. Paul Minnesota and Sault Ste. Marie (Figure 8). The species composition of Thunder Bay’s municipal urban forest is made up of over 25% (approximately 6400) ash species. The number of ash trees found on private property within the urban forest of Thunder Bay is unknown (City of Thunder Bay 2015). Since the urban forest is composed of both public and private land, the uncertainty of quantity and location of ash trees on the private portion is very concerning, if the beetle becomes present in the Thunder Bay area.

In an attempt to raise public awareness of the severity of the impact EAB would have on the urban canopy cover, the City of Thunder Bay launched an EAB ribbon campaign. The campaign is designed to draw attention to the sheer number of ash trees in the town by wrapping them with green ribbon. The ribbon has information on the hazard of moving firewood, references for further reading material, and management options (City of Thunder Bay 2014). Early management efforts are focused through an EAB task force comprised of representatives from the City of Thunder Bay, MNR, CFIA, private and non-profit agencies (City of Thunder Bay 2015). The task force is actively developing strategies for increasing community awareness, early detection, and partner development (City of Thunder Bay 2015). Thunder Bay is just one example of many municipalities awaiting the arrival of EAB.

Looking outside of North America, EAB has become an invasive pest to other urban forests. In 2007 EAB was positively identified in the urban forests of Moscow, Russia (Baranchikov et al 2008). Surveys upon discovery showed the beetle was fairly evenly distributed and established throughout the city. Baranchikov et al report that ash is the sixth most common genus found in the Moscow urban forest, with *F. pennsylvanica* being the most common. The abundance of *F. pennsylvanica* appears to be a common factor in many of the recorded outbreaks. Early management focused on removing hundreds of infested, dead and dying ash trees (Baranchikov et al 2008). Further studies in 2009 showed that the infestation had spread up to 100 kilometers west and south of Moscow (Straw et al 2013).

In addition to the devastation EAB is causing in Moscow and surrounding area, even more disturbing is the potential for spread. There is no geographical barrier from Russia to the rest of Europe. Moscow is very close to the fringe of the natural range of *F. excelsior* (European ash) which is the most commonly occurring species of ash in Europe (Straw et al 2013). Research conducted by Straw et al in 2013, suggests EAB is spreading at an approximate rate of 30 kilometers per year from Moscow. There is little information on European ash susceptibility, but if indeed it is susceptible and EAB spreads, the potential of major economic and environmental loss is very high (Straw et al 2013). European ash trees outside of Russia are already under attack by an invasive pathogen *Chalara fraxinea*. The combined threat of weakened ash trees from *C. fraxinea* and EAB leaves a bleak future outlook for ash in the European and Asian continents (Straw et al 2013).

Chapter 7: Community Engagement

The general public plays a large role in the management efforts for emerald ash borer. In an urban setting, trees on public property are the responsibility of the municipality, but all those on private property are the responsibility of the individual land owner. In any given town or city this could mean thousands of individual landowners within one municipality. It is imperative for all members of a community to work together to enhance the value of the urban forest and maximize its benefits (Escobedo et al 2007).

It is estimated that in southern Ontario, approximate 40-60% of urban trees are on private property (Ursic et al n.d). In addition, spread of EAB is facilitated through human assisted migration. Making people aware of this issue could reduce and slow the spread of EAB through human interaction (City of Thunder Bay 2015). Travel has never been easier for today’s human population, as a result people are moving around the globe at an unprecedented rate. Statistics Canada states that in 2012, approximately 22.7 million people visited the USA from Canada. This is just an example to show the flow of the human population across borders, and some of this travel could help transport unwanted pests and disease, like the emerald ash borer.

The question faced with dealing with community awareness and EAB management is one of what tools and methods are effective when communicating with and educating the public. Obtaining sufficient funding for community outreach programs as well as retaining interest from the community are two major hurdles when working with the public (Ursic et al n.d).

It is suggested by Krasny et al that a fundamental element of learning is through real world application (2009). It is supported and built upon by repetition between those learning and the environment they are learning about. Subsequently, public learning can lead to adaptive resource management as well as resilient social-ecological systems (Krasny et al 2009). In order to gain interest and support in community led projects, it is key to understand the psychological factors of what makes a person want to volunteer or become involved in a program (Moskell et al 2010). Urban forest managers can then build programs revolving around these motivations to create meaningful ways a person can volunteer (Moskell et al 2010). The International Association for Public Participation (IAP2) states that in addition to meaningful volunteering, it is also critical to convey how the input of those involved will affect decision making (2015). The IAP2 outlines five categories of engaging the public in their spectrum of public participation; inform, consult, involve, collaborate, empower (2015). It is important to note that the purpose of community engagement is educating and informing members of the public, not necessarily aiming to achieve 100% consensus, but to generate better understanding (Robertson and Lepik 2013).

From an urban forestry perspective it is first important to understand why an individual may want to become involved in something to do with the urban forest. The very foundation of this could simply be people's feelings towards trees. A study conducted by Zhang and Zheng in 2011 addressed this point specifically as they studied residents feelings towards urban trees as well as their willingness to support urban tree programs. It was determined that unanimously people preferred trees on their property and community. In terms of becoming involved in the urban forest, Zhang and Zheng (2011) identify tree planting, public awareness, and volunteer training as the most important activities.

When considering tools and programs for community engagement it is important to consider funding. Canada differs from the United States in that Canadian municipalities do not fall under federal or provincial jurisdiction (Ursic et al n.d). As a result, Canadian municipalities must rely on themselves to promote and fund activities. With each individual municipality on its own to manage the urban forest, partnerships and collaboration to achieve cohesive regional strategies can be difficult (Greene et al 2011). Success of community outreach may be limited to those places where the population values the urban forest. A generalization by Ursic et al (n.d) state that cities with a large population may have the most success in urban forestry initiatives as the population generally values the urban forest more. In order to garner interest in smaller communities, educational programs are suggested by Zhang and Zheng (2011). Urban planners and managers can ensure this happens through various outlets including tree agencies and the media (Zhang and Zheng 2011).

Community engagement strategies outlined by Moskell et al (2010) include education, long term communication, interagency collaboration, hands-on involvement, stewards sense of ownership, and opportunities for public input. Of these strategies, education specifically on urban forestry benefits was ranked the most successful by urban forestry practitioners. Participants of a study on engagement in urban forestry responded that the hands-on aspect of programs such as tree planting and street-tree inventories was a successful method of engagement (Moskell et al 2010). In the same study challenges were also discussed, with lack of knowledge of the general public being the primary challenge professionals faced when conducting engagement initiatives (Moskell et al 2010).

There are many examples of successful community engagement initiatives in urban forestry across North America. In Canada there are very large successful programs such as the community organization of Local Enhancement and Appreciation of Forests (LEAF) in Toronto, ON. This not for profit community organization does many things to aid and benefit the urban forest of Toronto including programs to plant trees, educate residents, and various ways to volunteer (LEAF 2014). LEAF has programs specific to EAB as well as increasing awareness of private property through their back yard tree planting program. Another example of a community outreach initiative is the citizen pruner programs. This style of program is in cities as large as New York City, NY, USA and as small as Thunder Bay, ON, CA. The goal of this program is twofold, first to engage residents in the urban forest and secondly to reduce tree maintenance cost for municipalities. In this program residents receive training courses on pruning trees, and then apply those skills on young trees in the urban forest (City of Thunder Bay 2015, and Trees New York 2015).

Community engagement with a focus on invasive species management is multifaceted. Not only is it important to have community members on board for understanding the threat of EAB and their role in the spread of the population through human assisted migration, it is also the responsibility of homeowners to do something with the ash trees on private property (Fechtelkotter et al 2010). Greene et al (2011) outline the challenge and importance of educating the public that the trees on private property are just as important as those on municipal property through a study on increasing canopy cover through back yard planting in Toronto Ontario, CA. City managers, foresters, and planners have no jurisdiction on this land and so they must educate the public to take action.

A tool that could be used to address private tree management is aerial photography. Aerial photography provides a unique "birds eye view" of the landscape, offering a different point of view and perspective for many features including the urban forest (NRCan 2015b). There are many different options to acquire aerial photography including both analog and digital technology. Some of these options include satellites, aircrafts, and ground-based methods (Li et al 2009). Until the advent of the digital era in the 1970's, aerial photography was film based and included black and white, colour, colour-infrared, and black and white infrared. While hot air balloons were used in the last century, the aerial photography concept took off with the introduction of aircraft. The application of aerial photography became a mainstream tool for natural resources inventory in the 1930's (Li et al 2009). Digital technology to replace film started in the 1960's, but it was not until the 1990's that digital photography became a mainstay tool in image capture (Franklin 2001). In addition to the ability to take a photo from an aerial perspective, there are also the sensors used to take the photo to consider. With technological advances there are a wide range of new applications which can capture aerial observations of the earth in various bands of the electromagnetic spectrum. This information can be recorded and saved as hard copy or softcopy imagery (Li et al 2009). Urban forestry applications require sub-meter spatial resolution photography (imagery), which can in theory be acquired from a space borne image sensor such as QuickBird or Pleiades (Satellite Imaging Corp 2014). However from an operation point of view in an urban forestry setting, air borne photography will be a mainstay tool for years to come.

If an individual has access to the internet then imagery can be viewed for free on programs such as Google Earth (Google 2015). Google Earth has a variety of applications which are readily available to users of all ranges of experience and needs. There are desktop, web, and mobile applications which support various imagery viewing options (Google 2015). If a resident would like to simply view their neighbourhood or city from a remote sensing perspective and not for a specific purpose then Google Earth may be a suitable tool. For the purpose of community engagement on current threats to the urban forest like EAB, the imagery needs to be fairly recent and be of a high resolution quality. However, Google imagery is generally space borne and the end user does not have control of image type, image corrections, cloud issues, dates, and time of year (Google 2015). These factors make Google unsuitable for an urban forestry program.

Since the advent of aerial photography for vegetation identification and health status, the use of stereoscopic viewing has been the main practice (Sayn-Wittgenstein 1978). Stereoscopic viewing is enabled when aerial photographs are acquired with at least 50% overlap (NRCan 2015b). Through the use of a stereoscope which optically allows the left eye to see the first photograph, and the right eye to see the subsequent overlapping photograph the viewer will see a three dimensional image (Wolf and Dewitt 2000). In recent years the optical viewing through a stereoscope has been adapted to use with computer displays. With computer displays, a number of techniques are employed with the common thread of having the left eye seeing the first image and the right eye seeing the second overlapping image. This can be achieved through active or passive stereo viewing. Active stereo viewing uses a combination of a screen and eye glasses, whereby the system is set up to allow the left image to briefly be seen by the left eye, typically for a fraction of a second ($1/30^{th}$ to $1/60^{th}$ of a second) with a right left "flipping" or shutter technology (Baker 2012). The main problem with this is strain on the analyst's eyes. An alternative technology is through passive stereo viewing where polarized glasses separate the image to the right and left eyes. This is the common technology used in movie theaters of polarized viewing (Baker 2012). A second advantage of the polarized approach is the cost of the glasses which are significantly lower than those required for electronic shutter glasses. Whether the system is using shutter or polarized glasses, a sophisticated image analysis system is required, making it somewhat prohibitive for public use.

Viewing photos in stereo is the preferred method for photo interpretation because a three dimensional view of an object, in this case trees, allows the depth to be seen. Depth into the features allows photo interpreters to be more precise when viewing characteristics about the features which help identify it. For a tree this can be crown shape, depth, and even topography of the landscape where the tree is found (Sayn-Wittgenstein 1978). The forest resource inventory for the province of Ontario uses this method as the imagery is flown during leaf on periods and includes stereo pairs for photo interpretation of Ontario's forests (MNR 2009).

Analyzing imagery for photo interpretation of the forest can be done in three general ways; using actual photographs with a stereoscope, digitally on a computer, or through an anaglyph. The tool being explored in this research is the use of the anaglyph for the three dimensional viewing. The premise of an anaglyph is, "using complimentary colours to separate the views from the left and the right" (Iizuka 2006). This technology was developed by the movie industry in the 1950's as a means to show the public three dimensional movies. The anaglyph process is based on representing the shift in features of the photograph (such as trees) caused by the fact that the same tree is photographed from two different vantage points (left photo, right photo). This shift is referred to as parallax (Wolf and Dewitt 2000). In the anaglyph process, parallax is added to a photo frame with red and blue colours, making the image look somewhat blurry without the use of proper glasses. These glasses have one red lens and the other blue. It is a way to generate an image in three dimensions by overlaying one stereo pair in red and the other image in cyan (Hopkins 2001). The image is then viewed while the user is wearing red/blue glasses.

For the purpose of this research, the use would be converting aerial imagery into a 3D format of anaglyphs which can be accessible to the general public. The reason for this is imagery converted into an anaglyph creates a file size which is manageable for the average person without access to high end technology. It can be stored as a single graphics file and is also easily convertible into accessible formats (e.g. TIFF) (Hopkins 2001). As a result these files can easily be transferred to members of the public or put online in a database format for public use in viewing the urban forest. Anaglyphs can be viewed on any computer, tablet, or smart device. They can also be printed on paper. They are a very versatile tool to distribute and teach members of the public to use for community engagement initiatives. The draw back with anaglyphs is that you cannot make precise measurements such as tree heights, but they do provide a three dimensional perspective and can be very useful in representing the landscape.

In addition to useful and effective tools, such as aerial photography, there is another challenge to consider, time. Often management practices for invasive insects revolve around rapid response. MacKenzie and Larson (2010) outline three issues associated with time when attempting to manage for invasive insects and engage the community together. The first is an inability to create a trustworthy relationship as response time is too quick. Secondly, early detection of invasives often comes with little scientific knowledge and associated protocol for engaging the public. Lastly, community and stakeholder engagement can be a lengthy process so government may not want to engage the community as they "rapid response" is the preferred plan of action (MacKenzie and Larson 2010).

From the perspective of communities awaiting the arrival of emerald ash borer, time can be utilized proactively to engage the public instead of reactively if the infestation was already under way. The City of Thunder Bay, ON is using this approach with the ribbon campaign and task force previously discussed in Chapter 6. An example of community response and action against invasive pests can be seen in Winnipeg, Manitoba, Canada. The Elm Guard Program is a collection of community groups taking action to educate, detect, monitor, and report dutch elm disease in Winnipeg (Trees

Winnipeg 2014). The issue of private property is again raised in the case of DED. According to Trees Winnipeg (2014) an estimated 80% of elms in the Winnipeg urban forest are located on private property. The elm guard program offers incentives like cheaper group rates for pruning , workshops, tree plants, and organized basal sprays for community members to encourage proactive management of DED on private property (Trees Winnipeg 2014).

A similar program is needed for response for private tree management for emerald ash borer. In Canada and the US, there has been a strong focus on developing websites and information packages for community education of EAB. A national EAB website was created between various states in the US and the provinces of Ontario and Quebec in Canada. The website is www.emeraldashboer.info and it provides information on all aspects of EAB from biology, insecticides, spread, delimitation maps, moving firewood, information for home owners, publications and resources, and much more (USDA and MSU 2015). There is also the initiative taken on by many municipalities, government organizations, and environmental groups in North America of an EAB awareness week. In 2015, the week was May 18-24th. Examples of participants included the Eastern Ontario Model Forest (EOMF), where the provincial entomologist, Taylor Scarr, provided a provincial update on EAB (EOMF 2015).

Raising awareness of EAB is only the first step in hopes of managing or slowing the spread of the insect. The second requirement is to develop a way to have individuals monitor and report findings on private property. Individual organizations and municipalities are running their own campaigns to raise awareness of the threat of EAB and call on residents to take action on private trees. The City of Guelph Ontario has highlighted that homeowners are responsible for trees on private property and the two management options available to them is treatment or removal (City of Guelph 2015). The City of Burlington, Ontario is calling for action on private trees as well in their Urban Forest Management Plan (2010). One of the main goals of the plan is to transition management from reactive to proactive. The plan highlights that the majority of urban trees within the city are on private land, and as a result these land owners have the greatest impact on urban forest health . It is also recognized that the city does not have an inspection request service, making emergency response to threats of the urban forest difficult (City of Burlington 2010). Just next door to the City of Burlington, is the Town of Oakville. The Town of Oakville is leading edge in EAB management. The Town has the most aggressive management plan in Canada, with a treatment rate of 75% of public ash trees (Town of Oakville 2015). In order to make the management efforts of the Town even more effective they are also calling on residents to either treat or remove ash trees on private property. Several resources are available on the Town website from identification of ash, to management options of ash on your property (Town of Oakville 2015).

From research it is clear that municipalities, government agencies and environmental organizations are making an effort to raise awareness and educate members of the public on EAB. It is also apparent that municipalities are trying to convey to the public that the only management options for private trees are treatment or removal. The following case studies in the Town of Oakville and City of Barrie will address a framework to take the next step in community engagement, from awareness to action. Outreach strategies to educate, train, and motivate the community to ultimately self report on private trees will be explored and discussed.

METHODS

The methodology for this thesis is divided into two parts. The first is an initial case study on the Town of Oakville in partnership with BioForest Technologies Inc. in the development and implementation of an urban forest health volunteer program (FHVP). The second is utilizing that protocol and building upon it to develop a framework for the City of Barrie to encourage management and self reporting on private trees.

The Town of Oakville - Urban Forest Health Volunteer Program

1.1 Acquiring volunteers

The process of initiating a volunteer network hinged on building a volunteer base. In order to establish a volunteer network, significant advertising was required to publicize the program and encourage participation within the community. The Town of Oakville has a facet of the urban forestry department which spearheads communication between the Town and residents with EAB; the Oakville Canopy Club. Getting the word out about the initiation of the FHVP was conducted primarily through the Oakville Canopy Club, and began in early June 2014. The Canopy Club has an existing group of followers from individual residents to community groups such as Oakville Green. Advertising through social media (Canopy Club Facebook and Twitter accounts) allowed word to spread to these people and subsequently passed on to others (BioForest 2014).

Community events were also attended by Town of Oakville and BioForest staff such as Arbor Day and the Oakville Conserves Energy Fair to promote the FHVP through the Canopy Club. Those expressing interest were asked to sign up with their email addresses to receive further information about the program. Lastly, independent of the FHVP, the Town of Oakville forestry and communications staff were in the process of conducting a phone survey to assess the feelings of residents towards urban forestry. A question regarding the FHVP was added to the survey and those interested were asked to give their email for more information. All of the names generated from these outreach efforts were used as the inaugural contact group for the FHVP (BioForest 2014).

1.2 Protocol for FHVP

The program was designed to have volunteers assess the health of municipal street trees. Attributes to be measured and assessed during the survey were; address, tree ID number, tree species, diameter at breast height (DBH), live/dead status, stem condition, crown condition, and presence of invasive insects (

APPENDIX I). Stem condition and crown condition were overarching categories which were further divided into subcategories. Stem condition was to be recorded as present or absent for the following categories; broken main stem, mechanical damage, woodpecker holes, cracks, cankers, and/or conks. If none of these were present then it was classified as normal (having no defects). Crown condition was composed of three subcategories: canopy health, dead top, and storm damage. Canopy health was assessed based on a ranked scale from 1to 5 where; 1 = 0 – 5%, 2 = 6 – 25%, 3 = 26 – 50%, 4 = 51 – 75%, 5 = > 75%. A score for overall canopy health, defoliation, and discolouration were assigned. On this scale a 1 would indicate a healthy tree showing zero to five percent symptoms of the category being assessed. A five would indicate a very unhealthy canopy with greater than 75 percent of the canopy exhibiting signs of the category being assessed. Dead top and storm damage were assessed as yes or no (BioForest 2014). A detailed protocol was given to all volunteers explaining the process of the survey, as well as all terms and categories to be assessed (

APPENDIX I).

In addition to basic tree health, volunteers were also on the lookout for presence of invasive insects. Volunteers were trained on the identification of the three major invasive insects threatening the Town of Oakville; EAB, gypsy moth, and Asian long-horned beetle. Invasive insects were recorded as a yes or no. In the case that signs and/or symptoms of any of these three were found, then it would be recorded as present on the Individual Tree Assessment data sheet and then the volunteer would proceed to fill out a secondary Invasive Insects data sheet which asks for presence of specific signs and symptoms (APPENDIX II) (BioForest 2014). An option on both data sheets was a request for inspection. In any case the volunteer is not sure of what they are looking at, the option to request an inspection can be selected. An inspection would alert BioForest staff to make a field visit to the site and inspect further (BioForest 2014).

To determine where the volunteers will survey, those who responded to attend the training night were asked to provide their postal code. The postal codes were used to generate an atlas for each volunteer to survey. The purpose of this was twofold, ease of the volunteers to survey in close proximity to their home and also to avoid overlap with another volunteer. The atlas was generated using aerial imagery and the street tree inventory for the Town of Oakville in ArcGIS. Each atlas consisted of an overview gird map composed of 25 cells, each 150m^2 for a total survey area of 3750m^2 (Figure 10). Each cell was assigned a label with a letter and number (ie. A1 to A5, B1 to B5 etc) to ensure volunteers were surveying the correct cell (Figure 11). Within these cells features such as roads, addresses, points for Town trees, and tree ID numbers were generated. The tree ID is a unique identifying number given by the Town of Oakville in the existing street tree inventory. This number tags each individual tree and all the associated attributes with it (BioForest 2014).

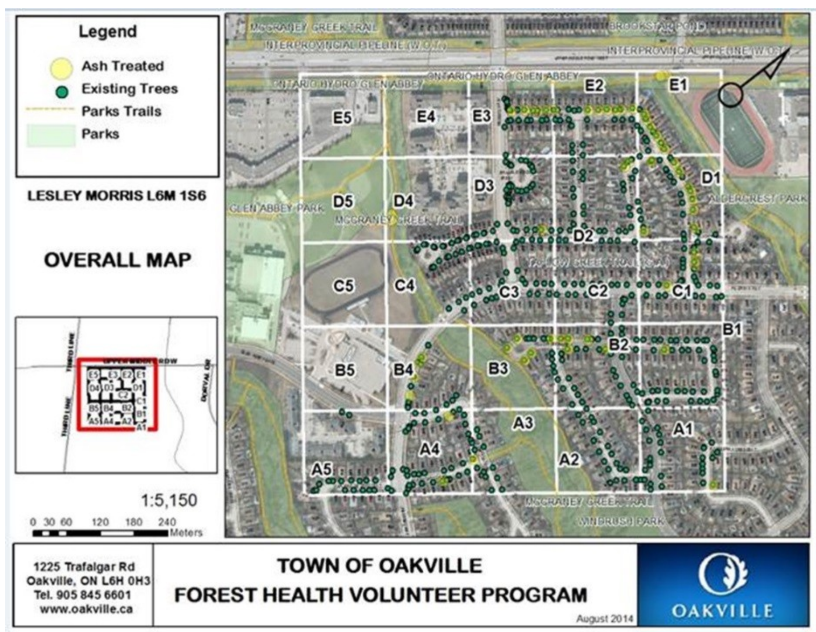


Figure 10. Example of survey atlas assigned to individual volunteers (Source: BioForest 2014)

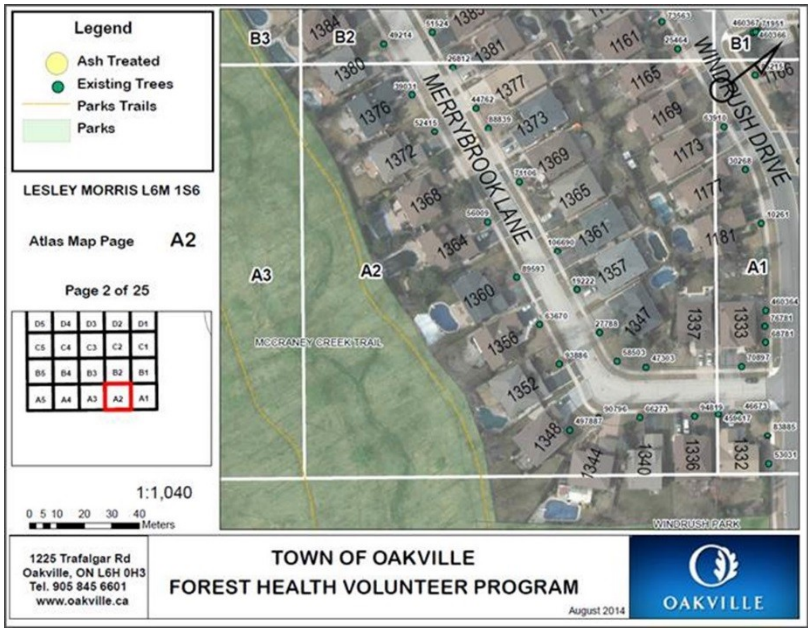


Figure 11. Example of an individual 150m2 cell to be surveyed
(Source: BioForest 2014)

Using the Town of Oakville's GIS urban forest inventory, attribute tables consisting of tree ID numbers, address, and tree species were generated and included in the atlas. The detailed survey and cell maps combined with the associated attribute tables allowed volunteers to cross reference location of the tree with house address and tree species. This effectively minimized error in the survey ensuring the right data was collected for the right tree (BioForest 2014).

Survey information (maps and attribute tables) were combined with survey protocol (APPENDIX I), blank data sheets (APPENDIX II), and field guides (APPENDIX III) into a volunteer package. The field guides were laminated visual guides to aid in identification and assessment of tree health and invasive insects. All of these items were placed into a binder supplied by the Town of Oakville for the volunteers to take into the field with them (BioForest 2014).

<u>1.3. FHVP Training Night</u>

A training night was held to meet the volunteers, introduce the program, and train participants on how to conduct their surveys. The session was held on August 11, 2014 at a community center in Oakville. The training night was two hours long and was split into a one hour lecture style in a classroom setting, and one hour outdoor training. Volunteers were welcomed by the Manager of Parks and Open Space for the Town of Oakville, John McNeil. BioForest staff then presented a PowerPoint^{TM} presentation to deliver the in class training on the program. Topics covered included; purpose of the program, data to be collected, how to collect the data, submission of data. Presentation was supplemented with visual aids to help teach various aspects of forest health, primarily identification of invasive insects.

Volunteers were asked to bring their binders outside for the outdoor portion of the training. BioForest staff led a field tour with sample maps for the training area to teach participants how to read a map, orient themselves, and follow survey protocol for each tree. Prior to the training day BioForest staff created a preset walking tour, identifying and flagging trees which exhibited the tree health conditions in the survey. These trees were assessed as a group with the volunteers to help teach how to assess the various aspects of the survey. Once stem and crown conditions were practiced, BioForest staff led the group through an example of assessing a tree following the protocol. The group was then divided in half each with a BioForest staff member to lead, and then were asked to collectively assess a tree on their own (BioForest 2014). The outdoor practice allowed volunteers to ask many questions to better understand the various aspects of tree health. The training night concluded back at the community center with a discussion and question period. All volunteers were given the atlas associated with their neighbourhood and they were given until mid September to complete their surveys and submit the data forms to BioForest (BioForest 2014).

1.4 Volunteer surveys, audits, and data compilation

When volunteers were actively surveying, BioForest staff was available to respond to all inquiries from volunteers. Some questions could be answered via email or phone, others required field visits. When a volunteer finished a cell, the data was submitted either digitally or in person. In order to ensure the quality of data collected, audits were conducted on sample areas surveyed by volunteers. All trees which were reported as having signs and symptoms of invasive insects were also checked. At the end of the season when all data was submitted, BioForest compiled the results. A master database of all the data collected was generated along with maps showing where the volunteers surveyed and associated invasive insect finds (BioForest 2014). Once the data was compiled and results generated, a volunteer appreciation night was held. The results of the work done by the volunteers were presented back to the participants (Figure 12). A follow up question, discussion, and opportunity session was held to provide BioForest with feedback on the program. A voluntary program participation survey was given to each attendee to provide BioForest with feedback on the program. The evening was concluded with a state of the forest report, showing the volunteers how similar forest health issues are being monitored on a provincial level. BioForest compiled the results of the evening and survey to better plan the program for 2015 (BioForest 2014).

Figure 12. Oakville forest health volunteer program appreciation night
(Source: BioForest Technologies Inc)

City of Barrie – Ash inventory and application to community engagement

A sample inventory was the first step in modeling the effectiveness of a community engagement framework. The inventory was completed by Allison Winmill in 2014, and it served 2 purposes. The first was to give the City of Barrie further insight into the extent of the infestation within the city. The second is to model how engaging volunteers from different parts of the city could help in early detection and monitoring efforts of invasive insects.

Five streets with a high component of ash were selected from around the city, ranging from south to north: Taylor Drive, Cheiftan Cres, Kenwell Cres, Shakespeare Cres, Osprey Ridge, and College Cres. The first site to be surveyed was ground zero, where EAB was first detected, at the southern range of the city. The sites continued in a clockwise fashion from west to north (Figure 14).

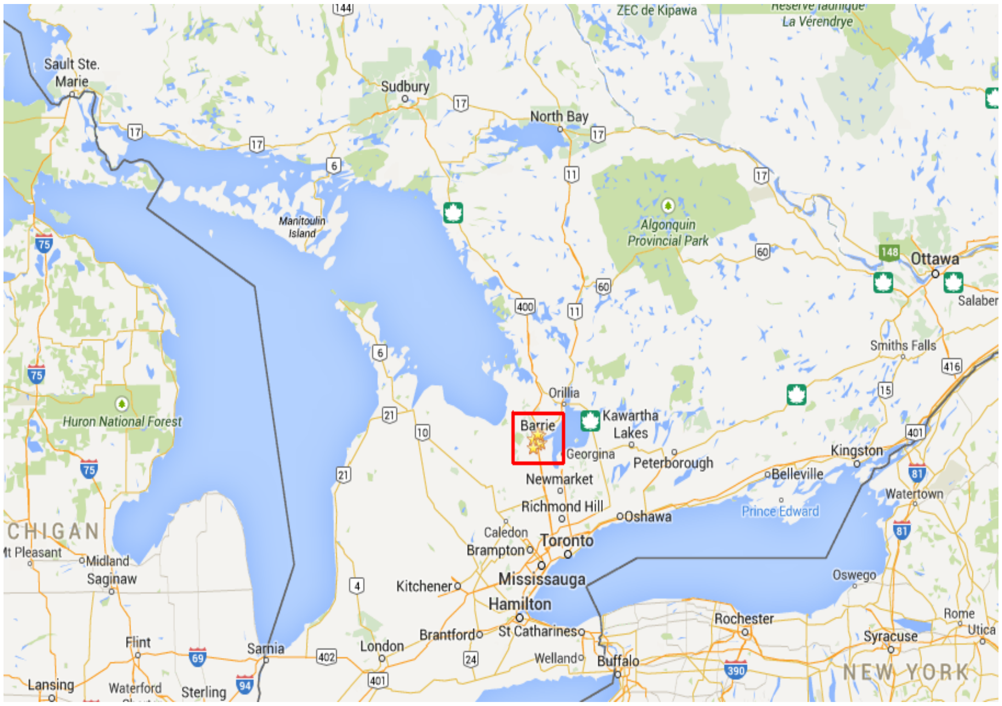


Figure 13. Location of Barrie, Ontario (Source: Google Earth 2015)

Figure 14. Inventory sites in City of Barrie (Source: Google Earth 2015)

The information collected in the inventory can be separated into two parts. The first was a basic health assessment of the tree along with species identification and DBH.

The health assessment was very similar to that of the FHVP, with a stem and crown condition assessment. Damage to the stem was recorded as yes/no, and attributes considered were wounds, cankers, mechanical and cracks. Crown condition was divided into health and deadwood. Health was ranked on the same scale as that of the FHVP from 1to 5 where; 1 = 0 – 5%, 2 = 6 – 25%, 3 = 26 – 50%, 4 = 51 – 75%, 5 = > 75%. Deadwood was divided into branches and twigs, and was a simple presence or absence assessment. The second portion of the data sheet was specific to ash trees, with a visual survey of signs and symptoms of EAB. The signs and symptoms were recorded as presence/absence and were as follows; yellowing of crown, epicormic shoots (stem and branches), cracks (stem and branches), woodpecker damage, exit holes, adult beetle, galleries. An example of the data sheet used can be seen in appendix IV. A GPS waypoint was also collected for each tree to enable mapping (Figure 15).

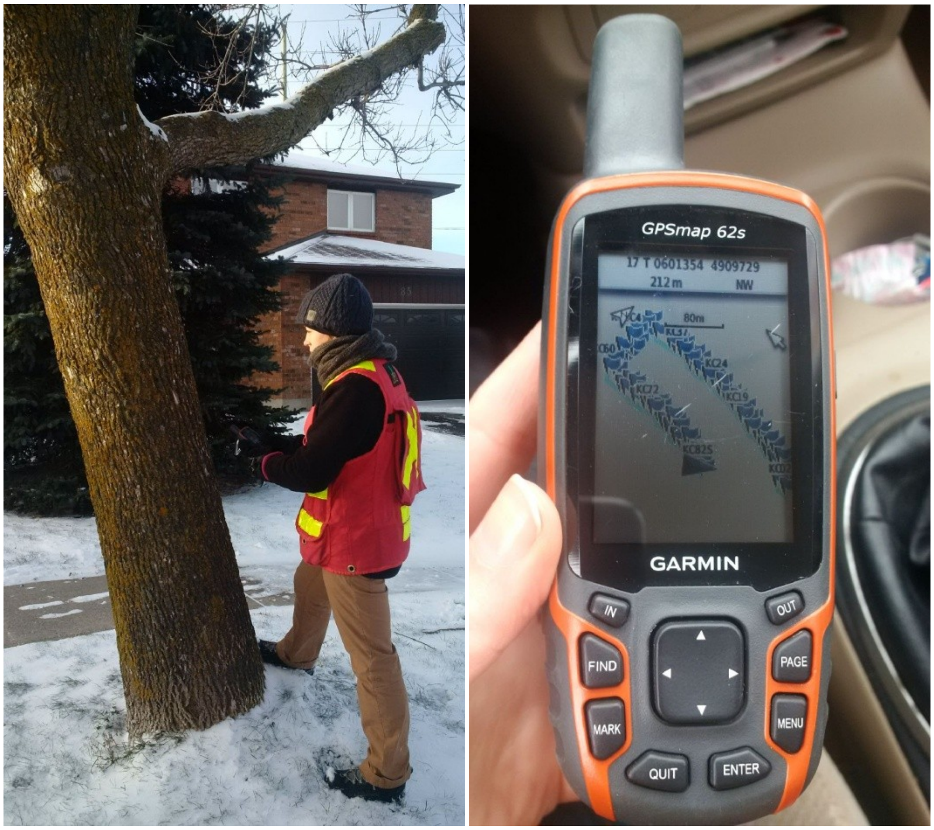


Figure 15. GPS mapping inventoried trees (Source: Winmill 2014)

The data collected from the inventory was compiled, analyzed, and mapped to better understand and visualize the signs of EAB around the city of Barrie.

RESULTS

Town of Oakville - FHVP

The FHVP in the Town of Oakville was a success in its first year running. Advertising efforts for the program resulted in a list 33 people interested in the program, and of that number a total of 23 responded that they would attend the evening. A total of 28 people actually attended and participated in the training session. Of those people, there were eleven submissions of survey data to BioForest from a total of seventeen people (BioForest 2014). The discrepancy in numbers is due to surveys being conducted by individuals, pairs, or groups. This means that 61% of the number of people who attended the training session actively participated in the program and submitted data.

The total number of trees surveyed by the volunteers was 545, ranging across 40 streets in the Town of Oakville. From the total number of trees surveyed Norway maple (*Acer platanoides* L.) was the most common, followed by honey locust (*Gledisia triacanthos* L.), green ash, white ash, and ash species in general. Of the trees surveyed, 60% had normal stem conditions, and 61% had a health canopy (ranking of 1). Only 3% of trees surveyed had a dead top or storm damage. These two categories were particularly important to the Town of Oakville because in 2013 the Town was hit by a major ice storm resulting in heavy damage to many trees. Such a low number of damage recorded in the survey means the Town was successful in their response to cleaning up the damage from the storm.

In total there were 31 reports of signs and symptoms of invasive insects. Eleven of these were for gypsy moth and the remaining twenty were for EAB. Through the auditing process it was determined that all 31 reports were accurate in their assessment (BioForest 2014). The resulting reports of signs and symptoms of invasive insects were incredibly encouraging for two reasons. The first being that since all reports were correct that indicates that training was effective and volunteers gained the knowledge required to correctly identify these insects. The second is that this data proves that volunteers can be effective in early detection and monitoring efforts for invasive insects. A map showing the distribution of survey sites in the Town of Oakville along with positive gypsy moth and EAB findings can be viewed below in Figure 16.

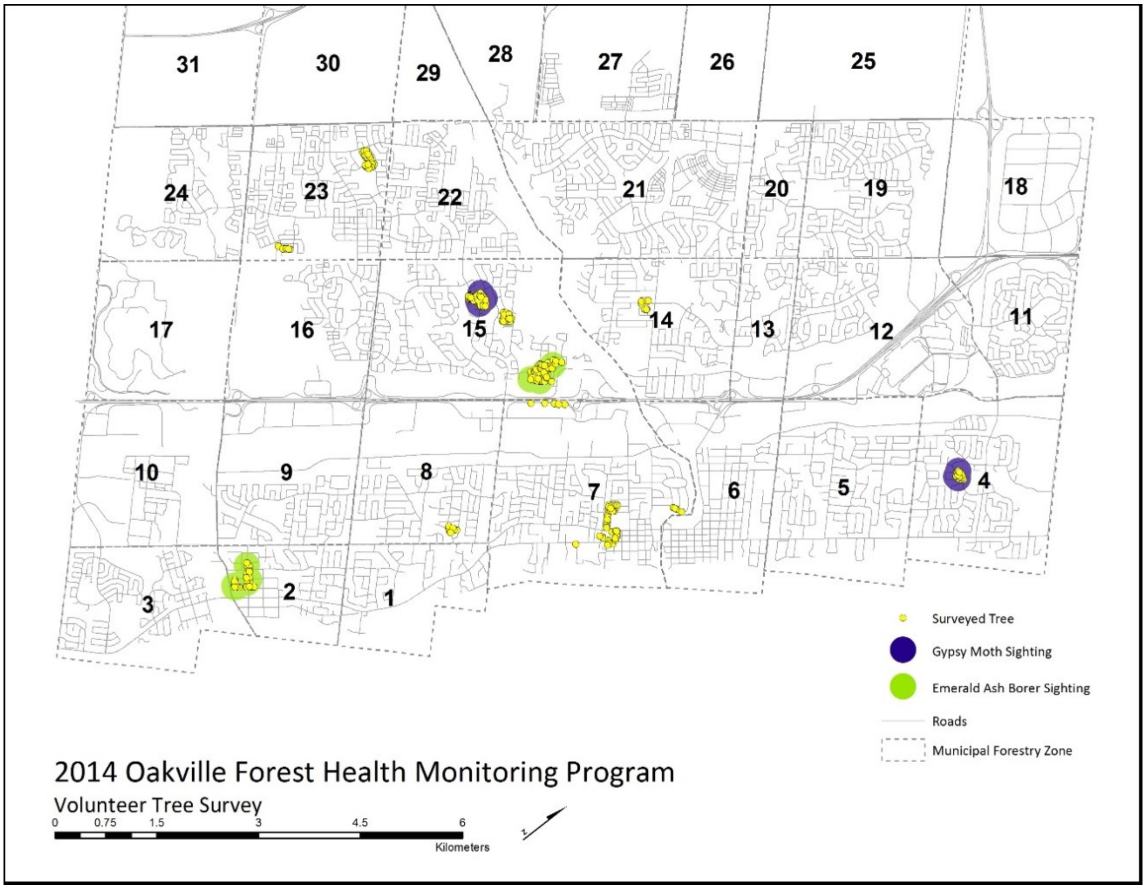


Figure 16. Trees surveyed in Oakville forest health volunteer program 2014
(Source: BioForest 2014)

At the end of the survey season, eleven people attended the volunteer appreciation night. Each of these attendees completed a feedback survey. The results offer strong insight into various aspects of the FHVP including; how they heard of the program, why people volunteered, success of training, strengths and weaknesses, enjoyment of participating, willingness to participate again, and other areas of interest. It was surprising to learn that although the majority of advertising for the program was done through social media, none of the participants found out about the program this way. All responses indicate either by email or word-of-mouth. A very important question on the survey was why people volunteered. There were a wide range of answers to this question but a common theme was concern for the community and the trees, as well as a love of nature and trees. Other people noted that they felt the FHVP was a meaningful way to volunteer and do something good for the community (BioForest 2014). These answers help provide insight on how to target volunteers and maybe even what other community groups would be a good target for advertising. Not only is this helpful for the FHVP in Oakville, but also for places like the City of Barrie when trying to develop ways to engage the community.

Feedback on the training night showed that 90% of participants felt that the training adequately prepared them to conduct the survey (BioForest 2014). This is a strong indicator that the methods chosen to communicate and engage the community were successful. It also indicates that the objective of educating the public was successful. In addition, 100% of the volunteers responded that they enjoyed the program and would participate again The most common feedback on other topics of interest were tree identification and insects and disease (BioForest 2014). The interest of the community shows that it is possible to engage, educate, and work with the community to achieve a common goal.

City of Barrie – Inventory

A total of five streets were inventoried in the City of Barrie. These streets all had a high component of ash, and were geographically arranged to give good coverage of the city. Included in the survey is Taylor Drive which is where EAB was first found and confirmed in the City of Barrie, making it ground zero. There was a total of 449 trees inventoried (APPENDIX VI). Of these trees, 295 or 66% were ash (Figure 17).

Distribution of species by street can be seen in Figure 18. Taylor Drive, Kenwell Cresent, and Chieftan Cres had the highest number of ash trees.

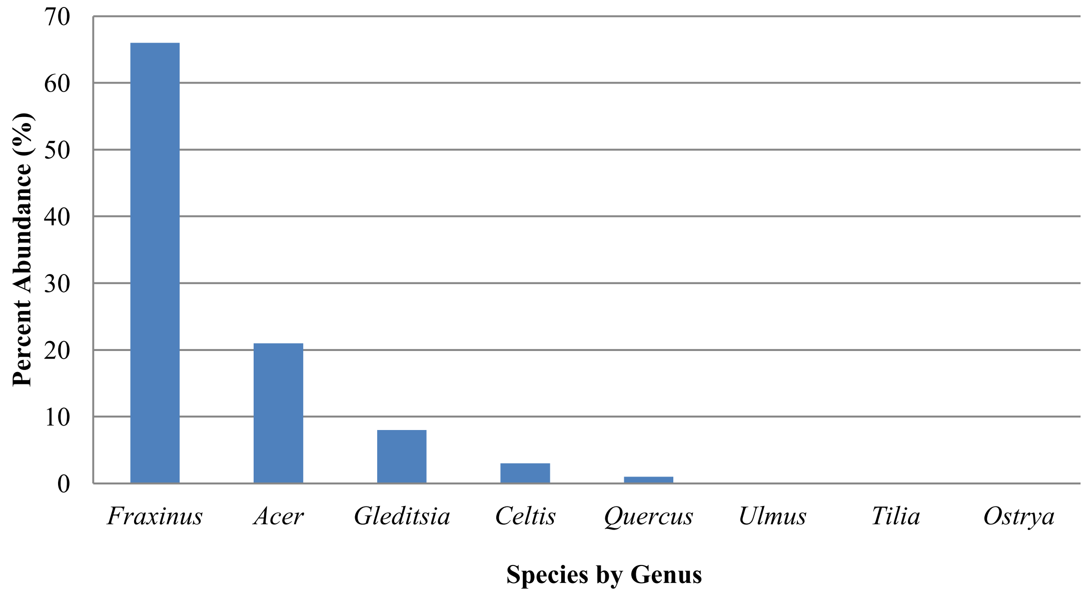


Figure 17. Species composition of six streets inventoried in the City of Barrie

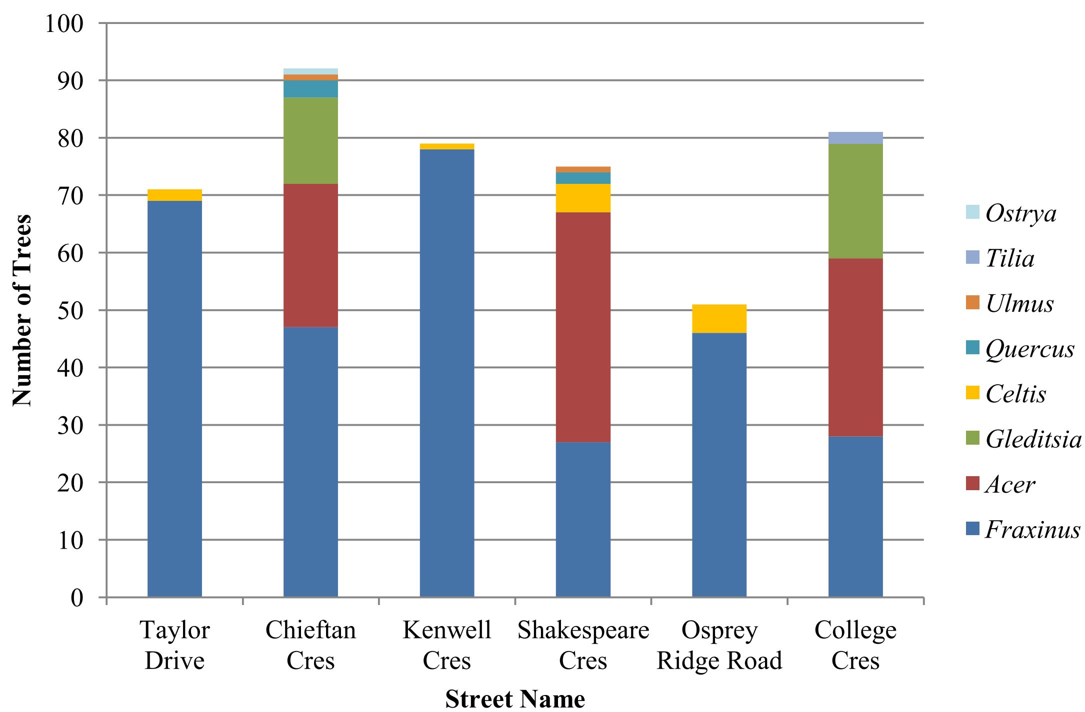


Figure 18. Species distribution by street in City of Barrie

Of the 295 ash trees surveyed in the inventory, 86% of those were green ash (Ag) and the remaining 14% were white ash (Aw) (Figure 19). Just over half of the ash trees (169 or 57%) exhibited signs and symptoms of EAB (Figure 20).

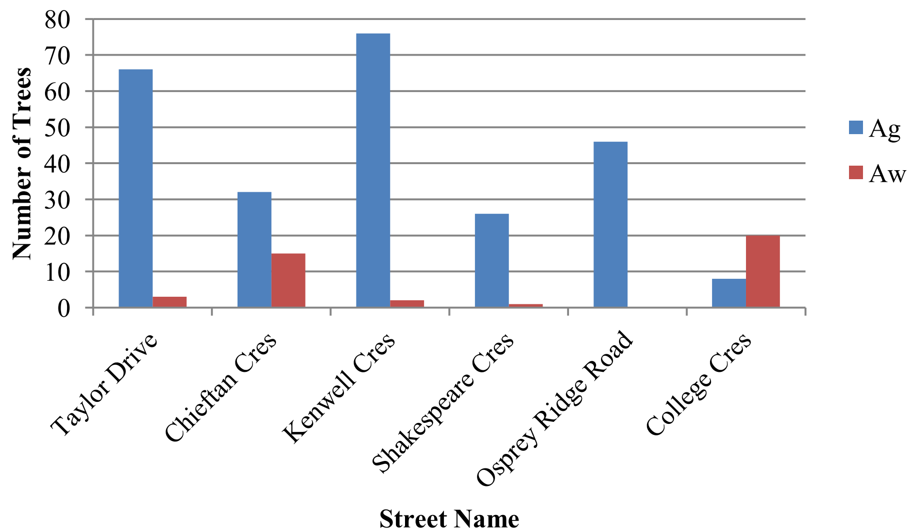


Figure 19. Distribution of green and white ash in City of Barrie sample street tree inventory

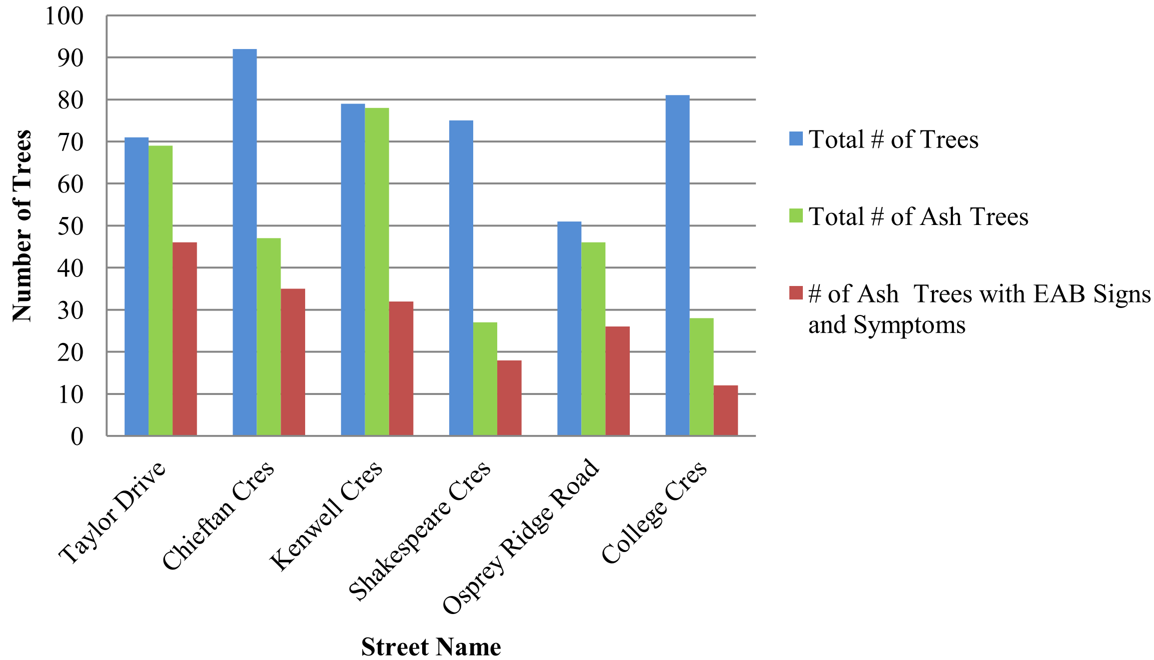


Figure 20. Ash component of inventoried streets in City of Barrie

The most common symptom observed was epicormic shoots, with 115 trees recorded (68%). Following epicormic shoots, yellowing of the canopy, and cracks in stem and branches were the next most common (Figure 21 and Figure 22). Signs of the beetle with exit holes and galleries were only seen on Taylor Drive, which was ground zero of the infestation in the City of Barrie (Figure 23). Four trees were recorded with exit holes and two with visible galleries. Each sign and symptom, save for the adult beetle, were observed and recorded on Taylor Drive. The adult beetle was not seen on any trees during the inventory.

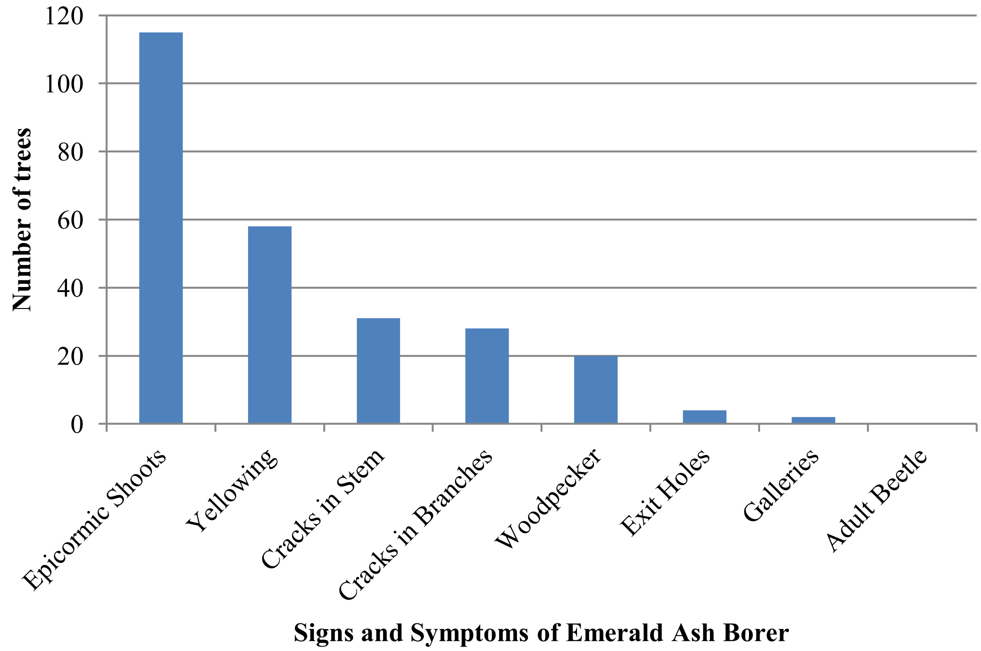


Figure 21. Signs and symptoms recorded on ash trees in City of Barrie

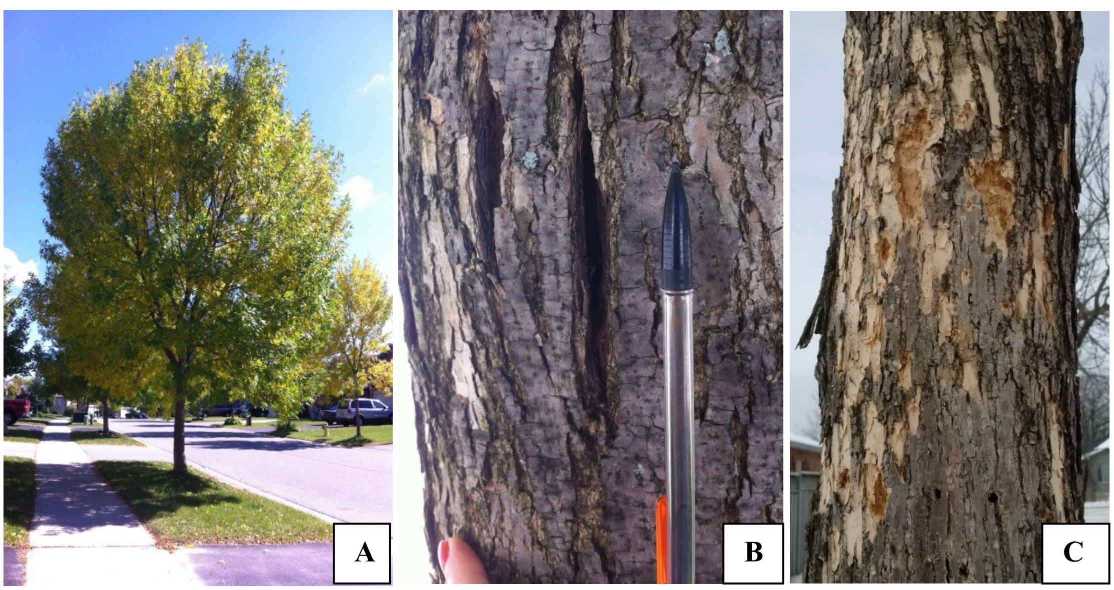


Figure 22. Observed signs and symptoms of EAB: A) yellowing canopy, B) cracks, C) woodpecker damage

Figure 23. Ground zero for EAB infestation in the City of Barrie on Taylor Drive

Signs and symptoms vary in degree of severity in correlation to the level of infestation. At ground zero it was observed that the initial tree of detection and those surrounding showed very late stages of decline (Figure 24). In areas of the city further away from ground zero less obvious symptoms were observed, with minimal epicormic shoots and just the beginning of yellowing of the canopy (Figure 25).

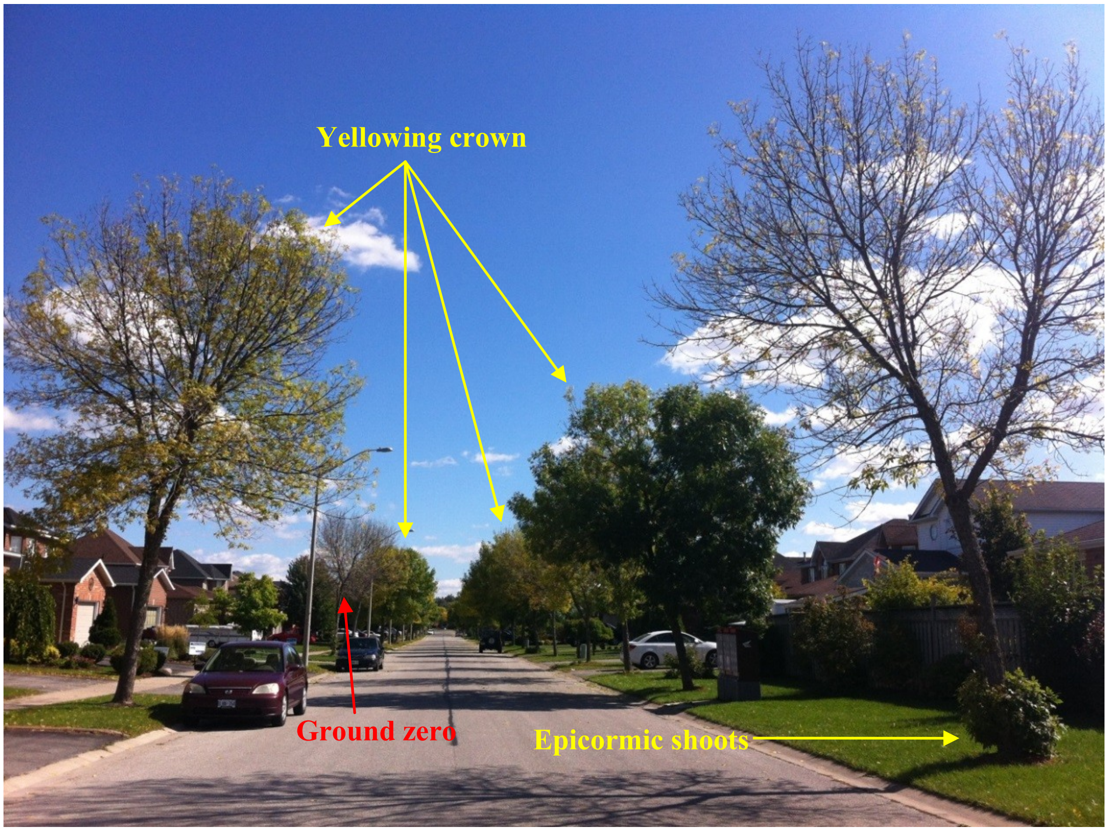


Figure 24. Ground zero for EAB: Taylor Drive, City of Barrie

Figure 25. Early signs of yellowing crowns on Kenwell Cresent, City of Barrie

An aerial view of Kenwell Crescent with the waypoints of trees surveyed can be viewed in Figure 26. The ash trees are depicted by the green tree symbol, and it is clear from the image that the majority of boulevard trees are ash. Way points from other streets surveyed can be seen in Figure 27. As seen in the aerial photograph, the City of Barrie has a major highway running directly through it, highway 400. This highway is very well travelled, especially in the summer by people travelling north for summer activities. Many of these activities include camping and going to a cottage, which often include the need for firewood. As previously discussed in Chapter 4 of the literature review, transporting firewood is one of the main vectors of human assisted migration of EAB. With many people travelling north from Southern Ontario where many cities are experiencing high mortality of ash, it is possible that dead wood may be brought along as firewood. With the City of Barrie being the gateway to cottage country in southern Ontario with highway 400, this makes Barrie and its trees even more at risk with the immense volume of people travelling to and through the city.

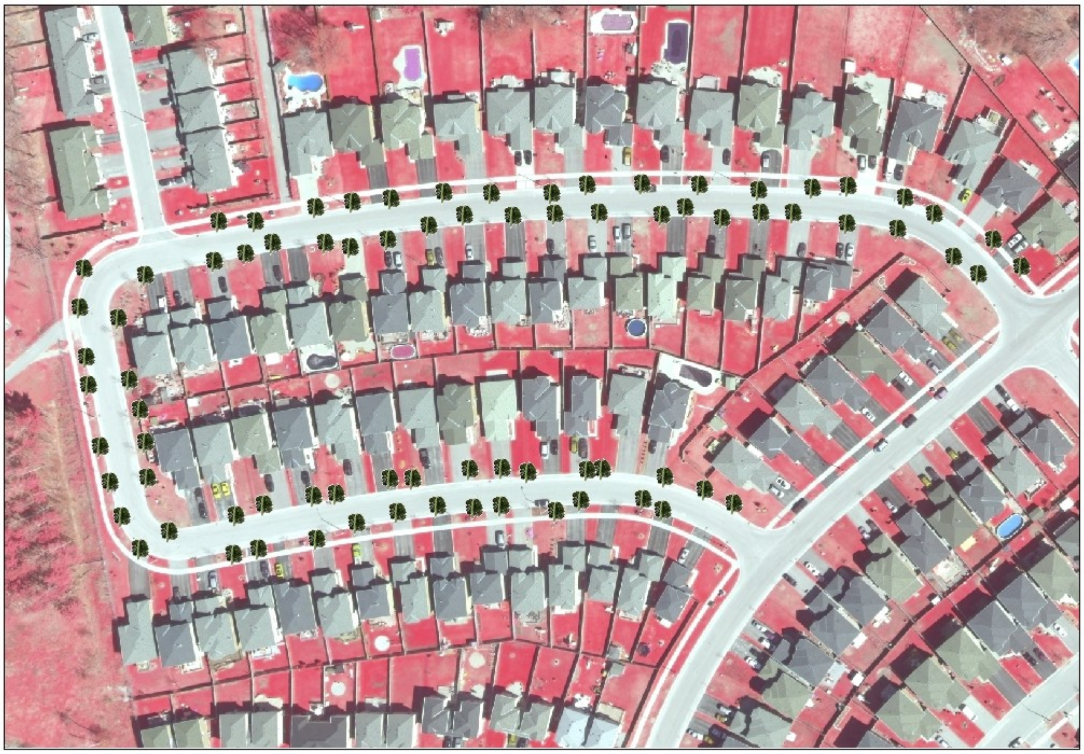


Figure 26. False colour infrared aerial photograph of Kenwell Crescent with surveyed ash trees

Figure 27. Surveyed ash trees in the City of Barrie

DISCUSSION

The devastating effects of ash decline and mortality can be seen in many places across eastern North America. In some places the infestation is old, and others it is just beginning. Communities awaiting or just discovering EAB in their area have knowledge and resources available from communities who have already dealt with EAB to design and implement an early detection and rapid response program. In Canada, the City of

Barrie was considered a fringe community when this thesis project began in 2013. EAB was not yet detected within city limits, but preparations were being made for its imminent arrival. In August 2014, EAB was confirmed in the southern end of the city on Taylor Drive. The galleries present strongly indicate that the population has been present for at least one season. This is one of the classic difficulties with EAB, it can take several years for signs and symptoms to become apparent. With the confirmed presence of EAB, comes the challenge of management. We cannot manage the insect, only the forest it thrives in. The City of Barrie faces the same challenge as all municipalities including Oakville, public versus private tree management. Bridging the theory tested in the Town of Oakville with resources and science available for the City of Barrie, a framework was created to engage the public to report on private trees.

It is clear from the literature available that management options for emerald ash borer are limited to treatment with insecticides and/or removal, doing nothing is not an option. Early detection can be done through visual surveys, trap trees, and volatile traps. Many municipalities are actively managing for EAB or planning for its arrival. As municipalities utilize this management knowledge and become more proactive to the insect instead of reactive, it is clear that the inclusion of the public is an absolute necessity if trees on private land are to be incorporated. The first step in doing so is educating the public as to why they should care, and then how to act on that and report.

The FHVP with the Town of Oakville was a successful example of how to engage the public and address the first question of “why should the public care”. Participants in the program were educated on signs and symptoms of invasive insects and how to assess the overall health of a tree. It is one thing to hear about invasive insects in a presentation, in the news, on television or other places, but it is another to be on the ground walking and applying what you learned to the urban forest itself. Getting the volunteers out in the Town looking for these signs and symptoms allowed them to appreciate the vast spread and damage done by these insects. Although the program is focused on municipal trees, it is the long term vision that by educating people on how to and what to look for in terms of invasive insects they can then apply that on their own property. This information can also be shared with friends and family. Participants may even begin to observe signs and symptoms in their daily lives outside of volunteering in activities such as walking the dog or going for a hike.

Feedback from the volunteers was very helpful in learning what was liked and disliked about the program. All of the volunteers indicated that they would like to participate in the same program in future years. They also expressed interest in learning tree identification skills as well as furthering their skills for detection of invasive insects. These are all ways that the municipality can use to create workshops or events to maintain the interest of the volunteers.

The data submission from the program really supported the premise supporting this research in the need for online self-reporting. When the volunteers submitted data, it had to be manually entered into a database for each individual data sheet. This was very time consuming and sometimes difficult for volunteers to scan in or physically drop off their completed data sheets. It was mentioned in the volunteer appreciation night that an online application would be helpful in submitting information. All of the results and feedback from the program were taken into consideration and utilized to build a stronger program for 2015.

The research conducted in the City of Barrie builds upon the idea of an online database or application where resident and private land owners can self report on evidence of emerald ash borer. The inventory provided information on the state of the ash in the urban forest. It also modeled how even just a few volunteers from neighbourhoods around the city could provide effective and very useful information on the ash throughout the city. Figure 24 and 25 are a great comparison of the importance of early detection of EAB but also how difficult that can be. At ground zero many signs and symptoms were observed, with obvious decline in the ash trees. Trees on Kenwell Cres, west of the infestation on Taylor Drive, were showing early signs of yellowing and thinning in the canopy. Although very few other signs and symptoms were apparent, the proximity to ground zero and initial early decline suggest that insect activity is happening in this area. To the untrained eye this slight level in decline may go unnoticed, which is why it is so important to have more eyes on the ground for early detection.

The framework proposed for community engagement would follow a similar protocol as that used for the FHVP in the Town of Oakville. As outlined in the results, with 100% success rate in identifying emerald ash borer signs and symptoms, the program can be deemed a success in addressing the education aspect of the program. Having volunteers train and practice on municipal trees where the urban forester has information and access to the same trees is a benefit. In addition to a PowerPoint™ presentation with pictures and information as used with the Town of Oakville, the city of Barrie could use the converted 3D anaglyphs to help residents visualize the impact of EAB. The figure below is a sample of the aerial photography for the city of Barrie which was converted into an anaglyph. Although the image appears blurry as a two dimensional photograph, when viewed using the blue/red glasses it appears clear in three dimensions.

Figure 28. Anaglyph aerial photo for the City of Barrie

The red blue glasses required to view an anaglyph are easily found for purchase and are inexpensive. Prices can range from one dollar to several dollars depending on the quality of the glasses. As a community outreach tool, this is an affordable way to display high quality imagery to members of the public. One of the main purposes of the three dimensional display is for residents to visualize the impact EAB will have. Many streets in Barrie have a high density of ash trees, as seen on Kenwell Crescent in Figure 26. The anaglyph imagery would allow for residents to view the number of ash trees, their location, and the devastating image if all those trees were to disappear. It is one thing to be told that there will be an impact, and another to visualize and understand how bad that impact will be and how much it will affect you. As discussed in chapter 1, trees provide many ecosystem services both in the commercial and urban forests. Allowing a member of the public to view the city from an aerial perspective can broaden their sense of the urban forest from their small parcel of private property, to the city as a whole. The anaglyphs can be made on a street level, or zoomed out on a more landscape level. They are a great tool for communication and understanding of forest dynamics and the critical role trees play in the urban forest.

The Town of Oakville has been managing for EAB for many years so it is not a new issue. In Barrie however, the beetle has only been confirmed present for less than a year. To help people visualize the impact that EAB will have over time to the urban forest of Barrie they can view their own neighbourhoods online in two and three dimensions. If the City of Barrie were to host a similar workshop or open house as to that held in the Town of Oakville, the anaglyphs could be used as an educational tool to highlight the ash, and subsequently highlight the impact if those were gone. Understanding the devastation and impending loss of canopy cover in the city may encourage people even more to take a look at their trees and report to the city forester. In addition promoting for removal or treatment of private ash trees will help manage the insect population within the City.

It was hoped that the imagery may prove to be useful as an early detection tool, but analysis and research proved that without infrared stress to that level on ash cannot be detected. The aerial imagery available for the City of Barrie can instead be used as a training tool and then be put online for residents to access. The aerial imagery along with the attributes of the municipal street tree inventory would be uploaded to an online database. The vision of the database is one of dual communication. The database will be interactive enabling residents and land owners alike to not only see their land but to also self-report on what is going on there. The urban forester can use the online forum to update and inform residents of management actions for EAB, including tree removals, treatments, and planting locations/programs. The residents in turn can post sightings and information which the urban forester and other members of the public could see.

From the public open houses, individuals of the public should be able to identify if they have an ash tree on their private property. It is then proposed that these individuals can go online and self-report if they have seen evidence of the EAB. An alert will be set up on the database to notify the city forester of reports such as these so that the arrival of the EAB will be found quickly.

Although residents would be asked to self report on private trees, having the street tree inventory would allow them to report on sightings on municipal trees. It would also allow them to check for tree identification. The database could include guides for species identification which are directly tagged to existing trees in the inventory. This way interested residents could practice identification on their own. A key feature to also include in the database would be for people to be able to upload photos of their suspected finds.

The arrival of EAB to a community inevitably means loss in canopy cover. This is the opposite of what most cities are striving for, increasing their canopy cover. The idea of having self reporting residents through an online database could also help urban foresters quantify and reach canopy cover targets. Residents could post their management decision for trees on private property, whether they will treat or remove. Removed trees would be noted in the canopy cover targets with a question of replanting. If residents decide to treat their ash trees than effficacy of treatment could be another application to be explored through the database. Homeowners could indicate which insecticide was used, as well as which tree care company to indicate happiness of service. There are many beneficial implications of having an online database, ranging from community engagement to maintained engagement, to increasing the communication between city planners and residents. The database can also be viewed as a long term proactive management approach for the urban forest post EAB.

The applications of this research go beyond management for EAB. An online interactive database between city planners and residents would allow communication between parties on any future management issue. This could be another invasive insect, or even environmental assessment of urban expansion. An example of a future application could be assessing sites for urban expansion. The imagery can be photo-interpreted to understand species composition of current forest structure occupying the area, as well as sensitive areas the city may want to plan around. If the area is then developed, the urban planners can go back to the imagery to ensure the same tree species are planted in the area. Keeping native trees present is important for sustainable urban planning by reducing the risk of alien pests and ensuring habitat for native species. If residents or stakeholders have concerns regarding a municipal project, the imagery becomes a tool for conversation and problem solving. The idea of the database is one of cohesive management between residents and city managers.

CONCLUSION

The overall significance of this research is to engage the community in conversation amongst themselves regarding the importance of urban forestry, and the very real threat of EAB to the City of Barrie. Engaging the public can have many benefits. They can aid in proactive management through early detection with more eyes on the ground. Education on issues such as EAB allows for residents to make informed decisions on private tree management. When management actions of private and public trees are on the same level, effectiveness of overall urban forest health is strengthened and unified. An engaged community also means a more supportive community. Having people who value the urban forest actively involved with its management allows for a stronger team of people to conserve and grow green infrastructure in our cities

The demonstration of the educational and planning applications of the 3D imagery is also important. The significance of the community outreach portion of the research is not so much for the academic community, but for the community itself. It is to advance the knowledge of members of the public to their own environment. The goal of the research is to create an informed community who will remain engaged in urban forestry and environmental planning even after the time frame for this research project.

The message from this research for policy makers and stakeholders is the importance of community outreach and efficient planning. Sustainable urban forest management is only effective when all groups within a community and between communities are working together towards a common goal. Creating an online database where all members of the public can access the imagery and see management plans allows for openness and cohesiveness on management strategies. It allows the public to feel like they are connected and important in the planning process. This is incredibly important in Canadian municipalities where there is very little support from the provincial and federal levels when it comes to urban forest management. Having municipalities work independently is counterproductive when tackling landscape level issues such as EAB. Having information and management options available for such threats is helpful, but even more so when applied together.

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APPENDICIES

APPENDIX I

TOWN OF OAKVILLE FOREST HEALTH VOLUNTEER PROTOCOL

OAKVILLE

Town of Oakville

Volunteer Forest Health Survey 2014

BioForest TECHNOLOGIES INC.

Welcome! Thank you for agreeing to be a forest health volunteer. This survey includes an assessment of private and municipal street trees. This instruction sheet provides information and definitions that will help you to collect information required for the survey. If you have questions, feel free to email us at **awinmill@bioforest.ca** or phone us at **1-888-236-7378**. Upon completing the survey we ask that you please submit the information collected on the provided field forms through one of the following methods: 1) scanning and emailing them to us at **awinmill@bioforest.ca,** 2) dropping off the data sheets at the **Oakville Central Operations** front desk at **1140 South Service Road West** or, 3) mailing it to us at **BioForest Technologies Inc. #510 – 2275 Lakeshore Blvd West, Toronto, ON M8V 3Y3.**

Equipment

The equipment required for the survey is minimal. We suggest the following:

- Field forms (BioForest to provide via email and website: www.oakville.ca)
- Clipboard
- Pencil
- Tree identification references
- Additional reference materials (e.g. EAB, Gypsy Moth leaflet, etc.)
- Diameter tape or measuring tape
- Binoculars (optional)

Part 1: Individual Tree Assessment

Instructions

*Complete the form for **Part 1: Individual Tree Assessment**. See **Definitions** below for an explanation of the different sections of the form.*

Definitions

Tree Species: Record the kind of tree being surveyed. Common names are fine (e.g. red oak, white pine, etc.) If unsure of species, genus is fine too (e.g. maple, ash,oak)
Visit Explore Oakville website for ID confirmation
(http://maps.oakville.ca/gxmaps/?map=map01)

Diameter at breast height: Measured at 1.3 m above ground level, record in centimeters. Please note at the bottom of the data sheet if this value was measured using a diameter tape or measuring tape and if it was measured in centimetres or inches.

Live/Dead Status: If dead, indicate if it is new dead (died since last assessment) or old dead.

Stem Condition:

Normal: Normal stem, no deformities
Broken main stem: Main stem broken off
Mechanical Damage: Injury on main stem caused by abiotic factors (example: damage from lawn care equipment)

Woodpecker holes: Holes surrounded by light patches or sapsucker holes in regularly spaced rows
Cracks: Deep split through bark (main stem and major branches)
Cankers: Lesions on a stem, surrounded by living tissue
Conks: Fruiting bodies of wood decay fungi

Crown Condition:

Canopy Health: measured by percentage of dieback/thinning ranging from 0 to >75% dieback

1 = 0 – 5%   2 = 6-25%   3 = 26-50%   4 = 50-75%   5 = >75%

Defoliation: % of current years foliage that is defoliated
1 = 0 – 5%   2 = 6-25%   3 = 26-50%   4 = 50-75%   5 = >75%

Discolouration: % of crown that has yellowing or browning leaves

1 = 0 – 5%   2 = 6-25%   3 = 26-50%   4 = 50-75%   5 = >75%

Dead branches present: % of crown with dead branches

1 = 0 – 5%   2 = 6-25%   3 = 26-50%   4 = 50-75%   5 = >75%

Dead top: Top of tree is dead. Note that this would only apply to conifers

Storm Damage: Presence of storm damage YES/NO

Invasive Insects:

Presence or Absence: Are signs and symptoms of EAB, GM, or ALHB present on the tree? Yes* or No

EAB: Emerald Ash Borer (Hosts are all species of ash, primarily green and white)

GM: Gypsy Moth (Preferred host is oak, but can also be found on a variety of hardwoods including basswood, willow, Manitoba maple, birch, apple, tamarack, mountain ash, alder and hawthorn.)

ALHB: Asian Long-horned Beetle (Tree species preferred by ALHB is primarily maple. Although a wide variety of hardwoods are suitable host species for ALHB, the focus for searching for this insect should be on maple.)

*If yes, please fill out Data Sheet Part 2: Invasive Insects

Note: If a tree requires a follow up survey for safety concerns or identification of invasive insects, please check the appropriate "Inspection" box. A forestry staff member will then be notified to make a site visit to conduct a secondary assessment.

Comments:

Any other information the volunteer deems relevant to tree health. This may include the presence of native insects, girdling (from vines, cables, swings etc), construction near tree.

Part 2: Invasive Insects

Instructions

*Complete Part 2 according to the invasive insect identified in Part 1. See **Definitions** below for an explanation of the different sections of the form. Please refer to additional educational materials on these insects to provide better guidance in identifying signs and symptoms.*

Definitions

A) *Emerald Ash Borer*

Typically the initial sign of an EAB infestation begins with thinning of the crown, followed by presence of epicormic shoots. Woodpecker damage, exit holes, and adult beetles usually appear in the later stages.

Crown thinning: Yellowing, wilting, dying, and/or missing leaves. Can result in various stages of foliage loss in the canopy leaving bare branches.
Epicormic Shoots: Sprouts normally found on main stem of tree or larger branches.
Woodpecker damage: Holes in bark of the tree surrounded by light coloured patches resulting from feeding on insects.
Exit holes: D-shaped emergence holes in bark from adult beetles.
Adult Beetle Present: Shiny emerald or coppery green coloured body. Body size is usually 7-8mm long, and is bullet shaped.
Larval galleries: An "S-shaped" zig zag or serpentine gallery between bark and sapwood.

B) Gypsy Moth

Egg mass: Creamy beige to brown colour and hairy or velvety.

Caterpillar present: Full grown are hairy and range in length from 35-90 mm. Pairs of 5 blue and 6 red dots on their backs.

Defoliation: Evidence of feeding on leaves.

C) Asian Long-horned Beetle

Exit holes: Circular and 6-14mm in diameter. Can be found on main stem, branches, and exposed roots of the tree.
Adult beetles present: Jet black, glossy, and may have a bluish tinge. Each wing cover has about 20 white or yellow patches. Female is 22-36mm long with antenna of 1.2 to 1.8 times its body length. Male is 19-32 mm long with antenna of 1.6 to 2.1 times its body length.
Oviposition pits or egg laying site: Nearly circular pit with surrounding scratch marks, reddish to brown in colour.
Frass: Can be seen at branch junctions or at the base of an infested tree. Is a mixture of wood shavings and fecal matter from feeding larvae.

Note: If a tree requires a follow up survey for safety concerns or identification of invasive insects, please check the appropriate "Inspection" box. A forestry staff member will then be notified to make a site visit to conduct a secondary assessment.

References:

Explore Oakville

Explore Oakville is the Town's interactive mapping tool that provides users with access to a wide range of geographic data that offers user-friendly functions and simple navigation. Users have the ability to switch to Silverlight (plug-in required) for more options such as links to Google and Bing maps.

http://maps.oakville.ca/gxmaps/?map=map01

Tree Identification Reference Materials

"Trees in Canada" by John Laird Farrar

"Trees in Ontario" by Linda Kershaw

"Ontario Trees and Shrubs" an online reference collection by Walter Muma www.ontariotrees.com

"The Tree Identification Book" by George Symonds

Forest Health Resources

BioForest Technologies Inc. webpage

www.bioforest.ca

Natural Resources Canada: Insects and Disease

http://www.nrcan.gc.ca/forests/insects-diseases/13361

Invasive Insect References Materials

A Visual Guide to Detecting Emerald Ash Borer Damage (2006). Natural Resources Canada, Ontario Ministry of Natural Resources, Canadian Food Inspection Agency.

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How to identify the presence of EAB: Signs and symptoms (2012). Canadian Food Inspection Agency:

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Detecting Signs and Symptoms of Asian Longhorned Beetle Injury: Training Guide (2006). City of Toronto, Natural Resources Canada, Ontario Ministry of Natural Resources, Canadian Food Inspection Agency, United States Department of Agriculture

http://www.glfc.forestry.ca/VLF/invasives/alhbdetecguide_e.pdf.

Ontario Invading Species Awareness Program: Forest Pests (EAB, Gypsy Moth, ALHB) http://www.invadingspecies.com/invaders/forest/.

"A Guide to the Identification and Control of Exotic Invasive Species in Ontario's Hardwood Forests" by Lisa M. Derickx and Pedro M. Antunes.

(Source: BioForest 2014)

APPENDIX II

UFHV DATA SHEETS

Forest Health Volunteer Survey
Data Sheet Part 1: Individual Tree Assessment

Name: ____________________ Date & Visit #: ____________________ Street Name: ____________________

					Stem Condition							Crown Condition									
					check all applicable							Rank 1-5				check all applicable		Invasive Insects			
																		check applicable			
House #	Tree ID #	Tree Species	Dbh (cm)	Live/ Dead Status	Normal	Broken main stem	Mechanical damage	wood-pecker holes	Cracks	Cankers	Conks	Canopy Health	Defoliation	Dis-colouration	Dead branches present	Dead top	Storm Damage	EAB	GM	ALHB	Inspection
Comments:																					

(Source: BioForest 2014)

Forest Health Volunteer Survey
Data Sheet Part 2: Invasive Insects

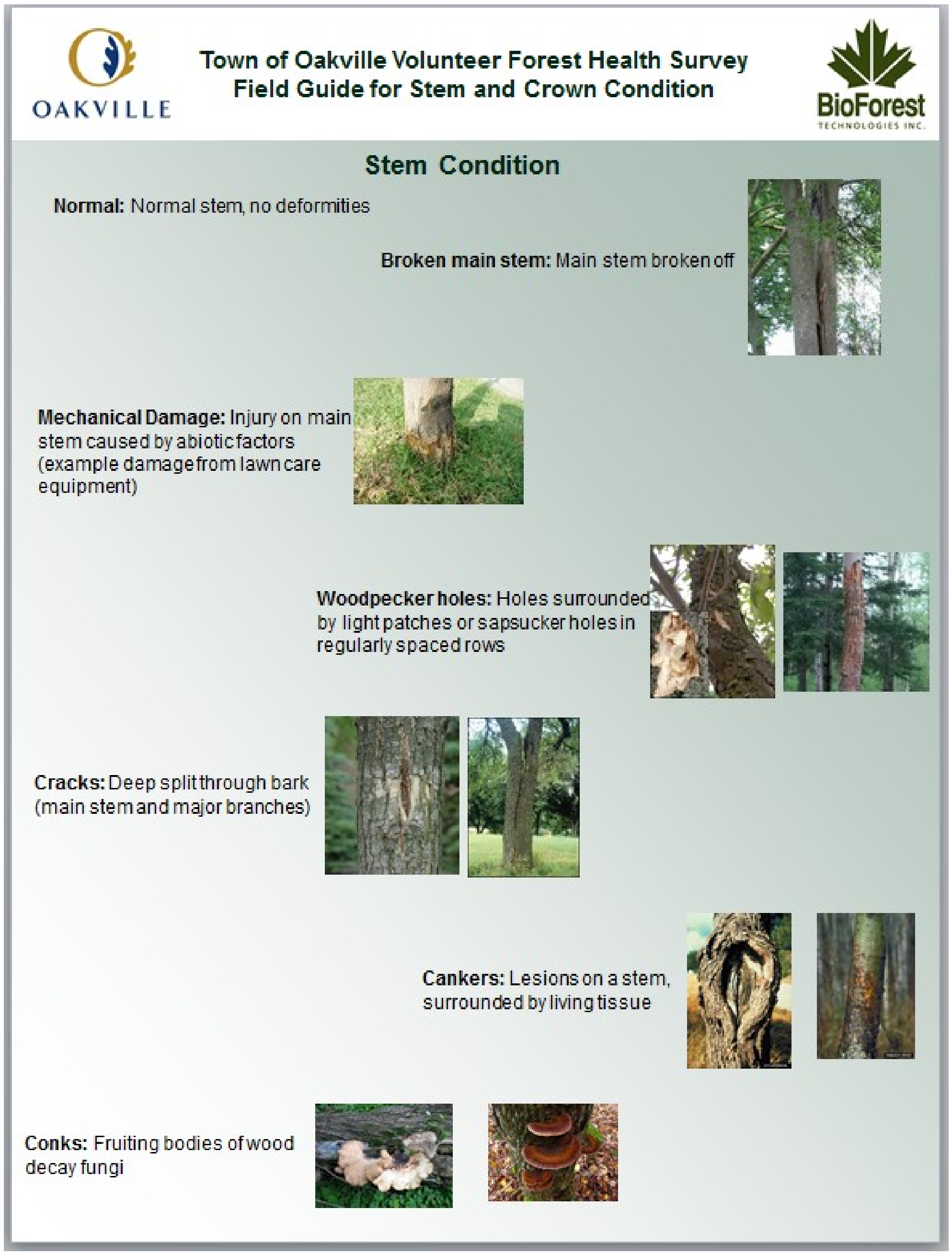
Volunteer's name: ____________ Date & Visit #: ____________ Street Name: ____________

				Emerald Ash Borer (EAB)							Gypsy Moth (GM)				Asian Long-Horned Beetle (ALHB)			
				check all applicable							check all applicable				check all applicable			
Information from Sheet #1																		
House #	Tree ID #	Tree Species	DBH	Crown Thinning	Epicormic Shoots	Woodpecker Damage	Exit Holes	Adult Beetles	Larval Galleries	Inspection	Egg Masses	Caterpillars	Defoliation	Inspection	Exit Holes	Adult Beetles	Oviposition Pits	Inspection
General Comments:			EAB Comments:								GM Comments:				ALHB Comments:			

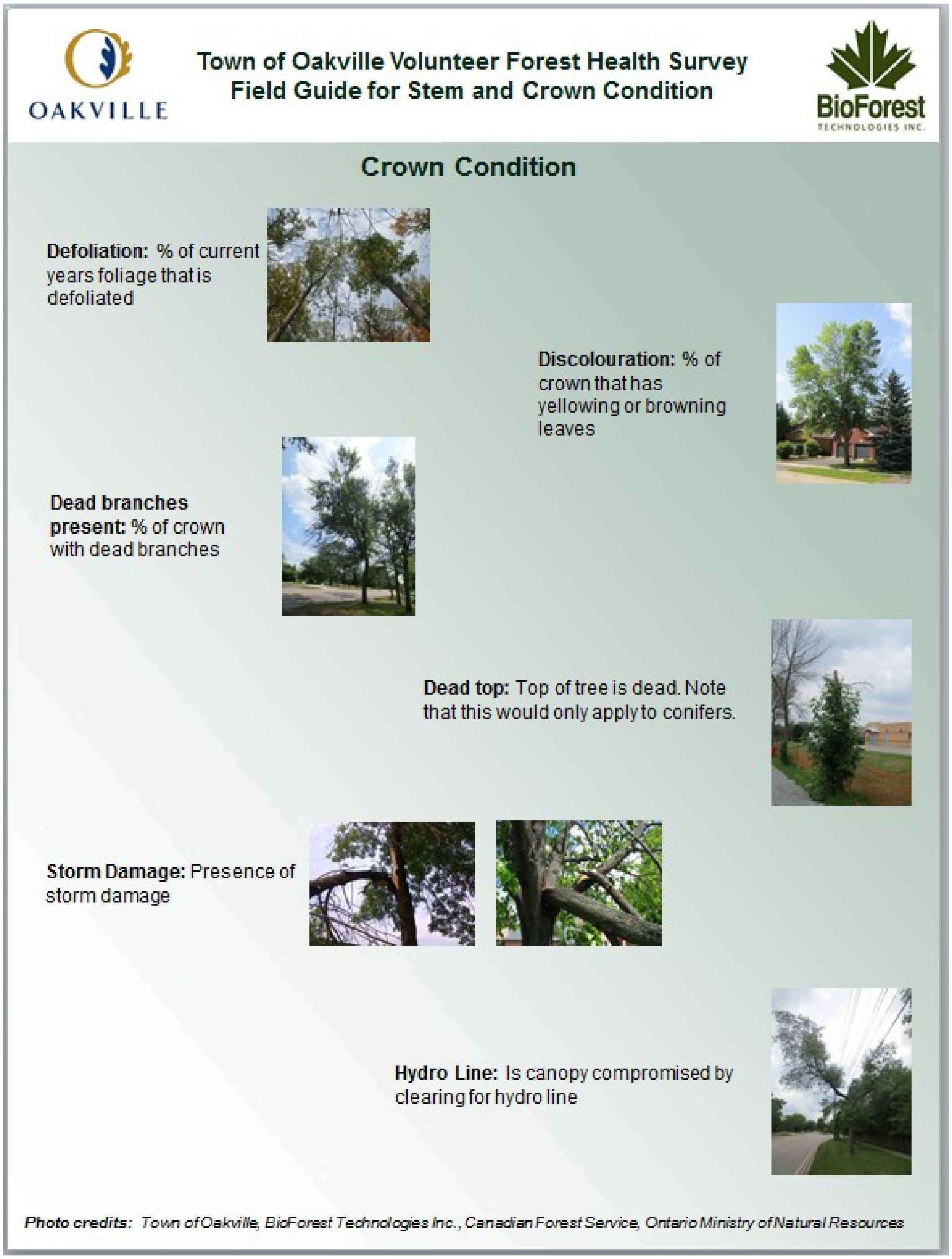
Source: BioForest 2014)

APPENDIX III

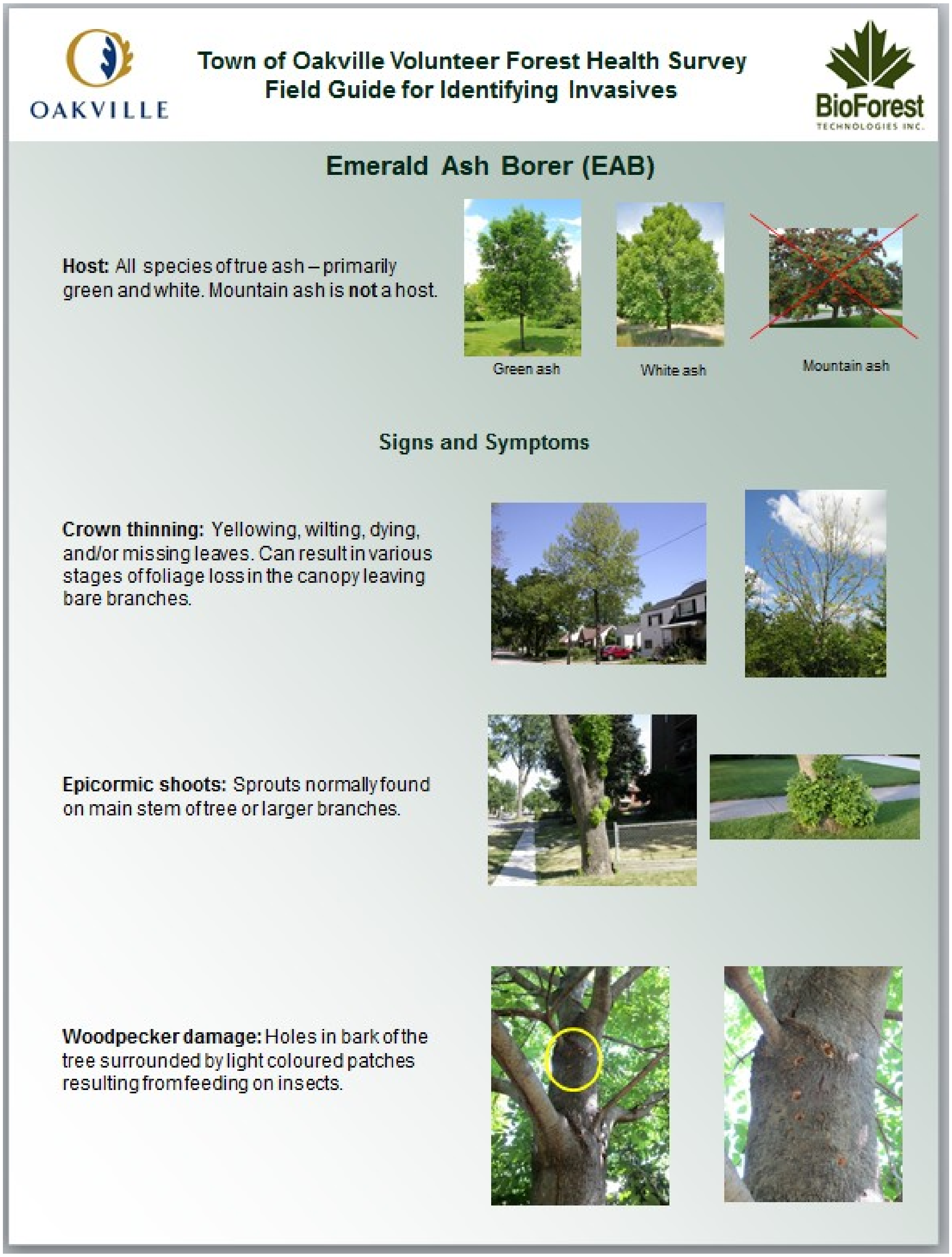
FIELD GUIDES FOR FHVP



(Source: BioForest 2014)



(Source: BioForest 2014)



(Source: BioForest 2014)

OAKVILLE

Town of Oakville Volunteer Forest Health Survey
Field Guide for Identifying Invasives

BioForest
TECHNOLOGIES INC.

EAB (cont'd)

Signs and Symptoms (cont'd)

Exit holes: D-shaped emergence holes in bark from adult beetles.

Adult Beetle Present: Shiny emerald or coppery green coloured body. Body size is usually 7-8mm long, and is bullet shaped.

Larval galleries: An "S-shaped" zig zag or serpentine gallery between bark and sapwood.

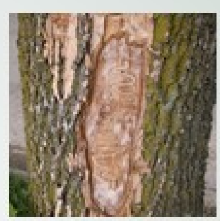


***Photo credits:** Town of Oakville, BioForest Technologies Inc., Canadian Forest Service, Ontario Ministry of Natural Resources, Canadian Food Inspection Agency*

(Source: BioForest 2014)

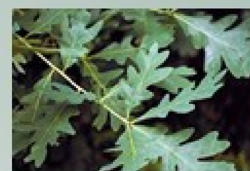
Town of Oakville Volunteer Forest Health Survey
Field Guide for Identifying Invasives

OAKVILLE

BioForest TECHNOLOGIES INC.

Gypsy Moth

Host: Preferred host is oak, but can also be found on a variety of hardwoods including basswood, willow, Manitoba maple, birch, apple, tamarack, mountain ash, alder and hawthorn.



White oak

Red oak

Signs and Symptoms

Egg mass: Creamy beige to brown colour and hairy or velvety.

Caterpillar present: Full grown are hairy and range in length from 35-90 mm. Pairs of 5 blue and 6 red dots on their backs.

Defoliation: Evidence of feeding on leaves.

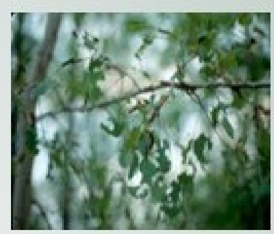


Photo credits: *Town of Oakville, BioForest Technologies Inc., Canadian Forest Service, Ontario Ministry of Natural Resources, Canadian Food Inspection Agency*

(Source: BioForest 2014)

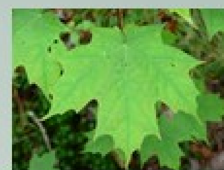
Town of Oakville Volunteer Forest Health Survey
Field Guide for Identifying Invasives

OAKVILLE

BioForest TECHNOLOGIES INC.

Asian Long-horned Beetle (ALHB)

Host: Tree species preferred by ALHB is primarily maple. Although a wide variety of hardwoods are suitable host species for ALHB, the focus for searching for this insect should be on maple

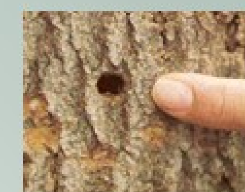


Sugar maple

Red maple

Signs and Symptoms

Exit holes: Circular and 6-14mm in diameter. Can be found on main stem, branches, and exposed roots of the tree.



Adult beetles present: Jet black, glossy, and may have a bluish tinge. Each wing cover has about 20 white or yellow patches. Female is 22-36mm long with antenna of 1.2 to 1.8 times its body length. Male is 19-32 mm long with antenna of 1.6 to 2.1 times its body length.

Oviposition pits or egg laying site: Nearly circular pit with surrounding scratch marks, reddish to brown in colour.

Frass: Can be seen at branch junctions or at the base of an infested tree. Is a mixture of wood shavings and fecal matter from feeding larva.

(Source: BioForest 2014)

APPENDIX IV

DATA SHEET FOR CITY OF BARRIE INVENTORY

Date: ______________ Street: ______________________ Surveyor: ______________

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments

(Source: Winmill 2015)

APPENIDX V

FHVP FEED BACK SURVEY

Town of Oakville

Volunteer Forest Health Survey 2014

Thank you again for your participation in the volunteer program this season! We would appreciate your feedback in the following survey in order to continue to improve and update the program for next year. Please return the survey as soon as possible. If you choose to take home the survey for completion, you may scan and email it to awinmill@bioforest.ca, drop it off at the Town of Oakville Central Operations Office located at 1140 South Service Road West, or mail it to us at BioForest Technologies Inc. #510 – 2275 Lakeshore Blvd West, Toronto, ON M8V 3Y3.

1. How did you first hear about the Volunteer Forest Health Program in Oakville?

   Email Facebook Twitter Reference (Word of Mouth)

2. What prompted you to take part in the program?

3. Was email an effective form of communication during the program?

   Yes No

   If no, please specify how you would like to be contacted.

4. When speaking with members of the public while conducting the survey, did you use the Ambassador card?

   Yes No

5. Did the initial information session provide you with adequate information and training to comfortably complete the surveys?

   Yes No

   If no, please specify which elements of the training were unclear (circle all applicable) and provide details on how to improve these areas.

   Deliverables of the survey

   Definitions of forest health indicators

   Reading the maps and corresponding atlas

   Sign and symptoms of invasive insects

   Other:

6. In general, what were the strengths and weaknesses of the program?

   Strengths: Weaknesses:

7. Overall, did you enjoy the program?

Yes No

8. Would you like to be involved in the program next year?

Yes No

9. What other forest health topics would you like to learn more about through workshops in the future?

10. Do you have any additional comments?

Thank you for your feedback!

APPENDIX VI

STREET TREE INVENTORY DATA FORMS FOR CITY OF BARRIE

Date: September 8 2015 Street: Taylor Drive Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicormic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
2	Ag	25.8	x						x		x				x	x		x	x		x		x		x			
6	Ha	5.4	x		x					x																		skeletonizer
10	Ag	16.5	x						x					x	x	x	x	x			x		x		x			Ground 0
12	Ag	20.1	x		x									x	x	x	x	x		x		x			x		x	
16	Ag	22.6	x		x					x							x			x		x						
18	Ag	21.2	x		x					x										x		x						
22	Ag	23.9	x		x					x							x		x	x		x			x			
24	Ag	18.8	x		x					x						x					x	x					x	
28	Ag	20.7	x		x						x					x	x		x			x						
30	Ag	26.1	x		x					x									x									
34	Ag	29.0	x		x					x																		
36	Ag	21.1	x						x	x								x			x							
42	Ag	22.4	x		x						x				x	x	x							x				
44	Ag	21.0	x			x				x						x	x	x										
48	Ag	17.8	x		x					x						x		x		x				x				
50	Ag	14.0	x		x							x			x	x		x	x									
52	Ag	15.3	x		x					x						x	x		x									
54	Ag	19.2	x		x					x										x								
56	Ag	20.0	x		x					x																		
60	Ag	18.7	x		x						x				x	x												
62	Ag	21.9	x		x					x																		
64	Ag	18.7	x		x							x					x											

(Source: Winmill 2015)

Date: September 8 2015   Street: Taylor Drive   Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
68	Ag	21.3	x		x					x																		
84	Ag	21.7	x		x					x																		
86	Ag	19.4	x		x						x				x	x	x					x						
88	Ag	23.7	x		x					x																		
90	Ag	19.7	x		x						x							x	x									
92	Ag	24.2	x		x					x							x		x									
96	Ag	23.6	x		x					x						x												
99	Aw	22.5	x		x					x																		
97	Aw	19.5	x		x					x							x											Thin
95	Ha	17.7	x			x				x																		
93	Aw	8.4	x		x					x																		
91	Ag	22.0	x		x					x										x				x				
89	Ag	24.1	x			x				x																		
87	Ag	24.6	x		x					x						x	x											
85	Ag	25.0	x		x					x								x	x									
83	Ag	18.8	x		x						x				x	x	x											
81	Ag	21.0	x		x					x																		
79	Ag	24.7	x		x					x																		
77	Ag	23.7	x		x					x																		
75	Ag	22.5	x		x						x					x	x											Thin
73	Ag	24.4	x		x					x						x												
71	Ag	23.7	x		x					x																		
69	Ag	16.0	x		x					x							x											Thin
67	Ag	15.6	x		x						x					x			x									Thin
65	Ag	26.9	x		x					x																		
63	Ag	15.4	x					x		x						x	x											

(Source: Winmill 2015)

Date: September 8 2015 Street: Taylor Drive Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
61	Ag	24.6	x		x					x								x										
59	Ag	21.8	x		x						x					x	x											
55	Ag	25.9	x		x					x																		
53	Ag	21.1	x		x					x						x												
51	Ag	17.8	x		x					x									x									
49	Ag	23.0	x		x					x								x										
10 Manor	Ag	20.5	x		x					x								x										Side Blvd
10 Manor	Ag	15.5	x		x						x				x	x	x											
31	Ag	22.3	x		x					x						x		x										
29	Ag	18.4	x		x					x						x	x											
27	Ag	22.3	x		x					x																		
25	Ag	15.2	x		x					x						x												
23	Ag	21.5	x		x					x						x	x											
21	Ag	19.3	x		x						x				x	x	x	x										
19	Ag	23.0	x		x					x																		
17	Ag	24.5	x		x					x								x										
15	Ag	27.4	x		x					x												x						
13	Ag	18.8	x		x					x												x						
11	Ag	16.7	x		x								x			x	x	x		x		x						
9	Ag	17.0	x		x							x					x	x		x		x						
7	Ag	20.8	x		x							x			x	x	x				x	x						
Kingsridg	Ag	22.7	x		x					x																		Side Blvd
Kingsridg	Ag	20.8	x		x								x				x	x										Side Blvd

(Source: Winmill 2015)

Date: September 10 2014 Street: Chieftan Cres Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition: Health					Crown Condition: Dead wood		EAB Signs and Symptoms	Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
121	Ag	34.3	x		x					x									x									
119	Ag	34.4	x		x					x						x			x									Bark peeled off
117	Ag	39.2	x		x					x						x												
115	Ag	37.1	x		x					x						x								x				
113	Ag	29.9	x		x					x						x	x		x									
111	Ag	29.7	x		x					x																		thin
109	Mn	22.6	x		x					x						x												
107	Ag	36.7	x		x					x						x			x			x						
105	Mn	21.8	x			x	x				x					x												took picture
103	Ag	25.4	x		x					x						x												
101	Ag	35.8	x		x							x			x	x			x					x				frost crack
99	Mn	27.3	x						x		x					x												
97	Ag	33.2	x		x					x						x			x	x								
95	Ag	30.2	x		x					x						x			x									
93	Ag	34.2	x		x					x						x			x	x								thinning in crow
91	Ag	34.7	x		x					x						x								x				
85	Ag	43.7	x		x						x				x	x			x	x								thinning in crow
81	Mn	28.0	x		x					x																		
79	Ag	28.2	x		x					x								x										
77	Ag	28.7	x		x					x							x											
75	Ag	31.1	x		x					x						x	x											
73	MnCK	22.0	x		x						x					x												
71	MnCK	42.2	x		x					x																		
69	Ag	42.9	x		x					x						x	x											
67	Aw	51.0	x		x							x								x		x						Bad shape
65	Or	5.4	x		x							x																

(Source: Winmill 2015)

Date: September 10 2014 Street: Chieftan Cres Surveyor: Allison Winmill

House #	Species	DBH	Live Status L	Live Status D	Stem Condition Normal	Wound	Canker	Mechanical	Cracks	Crown Condition Health 1	2	3	4	5	Dead wood Branches	Dead wood Twigs	EAB Signs and Symptoms Yellowing	Epicor-mic Stem	Epicor-mic Branches	Cracks Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
63	Lh	42.6	x		x					x																		
61	MnCK	35.9	x		x					x																		Severe girdling roc
51	Lh	48.2	x		x					x						x												
55	Aw	43.5	x		x							x			x	x			x									
53	Mn	30.3	x		x					x																		tar spot
51	Aw	52.6	x		x							x			x	x			x									
49	Lh	38.0	x		x					x																		
47	Aw	56.5	x		x							x																very thin, bark on main stem and bra
45	Lh	43.0	x		x							x				x												
4	Aw	45.3	x		x					x												x						
37	Lh	28.3	x		x					x																		
35	Aw	40.0	x		x							x			x	x		x				x						loss of bark on main
33	Lh	35.1	x		x					x						x												
31	Aw	35.5	x		x						x				x	x							x					loss of outer barl
27	Lh	48.3	x		x					x																		
25	MnCK	6.2	x		x					x																		
21	Lh	41.0	x		x					x																		
19	Aw	42.7	x		x								x		x	x			x			x						
17	Lh	42.3	x		x					x																		
15	Aw	48.2	x		x							x			x	x			x									carpenter ant exit h
13	Mn	33.4	x		x					x																		tar spot
11	Aw	34.3	x		x							x			x	x								x				
9	Lh	45.9	x		x					x																		
7	Aw	45.0	x		x						x					x												
2	MnCK	40.2	x		x					x																		
4	Ag	52.3	x		x							x			x	x			x									

(Source: Winmill 2015)

Date: September 10 2014 Street: Chieftan Cres Surveyor: Allison Winmill

House #	Species	DBH	Live Status: L	Live Status: D	Stem Condition: Normal	Wound	Canker	Mechanical	Cracks	Crown Condition: Health: 1	2	3	4	5	Dead wood: Branches	Twigs	EAB Signs and Symptoms: Yellowing	Epicor-mic: Stem	Branches	Cracks: Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
6	Lh	40.1	x		x					x						x												
8	Ov	32.2	x		x					x																		
18	Aw	39.9	x		x					x						x												
20	Lh	42.1	x		x					x																		
22	Aw	45.0	x		x						x				x	x						x						
54	Mn	12.3	x		x					x																		side blvd
46	MnCK	34.5	x		x					x																		side blvd
46	Mr	13.3	x		x					x																		side blvd
46	Ea	18.2	x		x					x																		spindle gall
50	Lh	52.1	x		x					x						x												
52	Aw	49.9	x		x							x			x	x												foliage present only on ou
54	MnCK	35.3	x		x					x																		
56	Mn	25.9	x		x					x																		polarded, tar spot, powde
58	Lh	52.1	x		x					x																		
60	MnCK	5.7	x		x					x																		
62	MnCK	4.8	x		x					x																		
62	MnCK	37.1	x		x					x						x												
64	Aw	57.7	x		x					x									x									
66	Lh	54.7	x		x					x																		
66	Ag	32.6	x		x							x			x	x												ash flower gall
26 Marsha	Oe	12.4	x		x					x																		side blvd, anthracn
26 Marsha	Ob	5.9	x		x						x																	
88	Ag	35.3	x		x					x										x								side blvd
88	Ms	9.2	x		x					x																		side blvd
88	Ag	31.2	x		x					x								x										
90	Ag	44.7	x		x					x																		

(Source: Winmill 2015)

Date: September 10 2014 Street: Chieftan Cres Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms												
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
92	Ag	41.8	x		x					x																		
94	Ag	43.5	x		x					x					x	x			x									
96	Ag	39.8	x		x					x									x									
98	Ag	32.4	x		x					x						x												
100	Ag	13.8	x		x					x																		
102	Ag	42.6	x		x					x																		
104	Ag	33.6	x		x					x						x			x									
106	Ag	25.1	x		x					x									x									
108	Ag	30.1	x		x					x						x												
112	MnCK	27.6	x		x					x					x													
114	MnCK	29.1	x						x	x																		frost crack
116	MnCK	25.7	x		x					x																		
118	MnCK	21.0	x		x					x																		
120	MnCK	21.8	x		x					x																		

(Source: Winmill 2015)

Date: September 22 1014 Street: Kenwell Cres Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
82	Ag	19.9	x		x					x																		side blvd
82	Ag	13.9	x					x			x					x		x										side blvd, epicormic from m
87	Ag	22.7	x		x					x																		
85	Ag	23.0	x		x					x																		
83	Ag	21.1	x		x					x																		
81	Ag	16.7	x		x					x						x												
79	Ag	16.9	x		x					x						x												
77	Ag	16.8	x		x					x						x												
75	Ag	17.4	x		x					x																		
73	Ag	17.7	x		x						x				x	x												
71	Ag	24.1	x		x					x						x												
69	Ag	22.1	x		x					x																		
67	Ag	23.3	x		x					x								x	x									
65	Ag	18.9	x		x					x									x									
63	Ag	19.0	x		x					x									x									
63	Ag	17.6	x		x					x																		side blvd
63	Ag	21.8	x		x					x						x												side blvd
63	Ag	20.9	x		x					x																		side blvd
43	Ag	19.1	x		x					x						x			x			x		x				side blvd
43	Ag	21.8	x		x					x														x				side blvd
43	Ag	20.6	x		x					x																		
41	Ag	21.3	x		x					x																		
39	Ag	17.0	x		x					x																		ants
37	Ag	17.5	x		x					x									x									
35	Ag	19.9	x		x					x																		
33	Ag	23.1	x		x						x								x									ants

(Source: Winmill 2015)

Date: September 22 1014 | Street: Kenwell Cres | Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition: Health					Crown Condition: Dead wood		EAB Signs and Symptoms	Epicormic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
31	Ag	20.0	x		x					x									x									
29	Ag	21.9	x		x					x								x	x	x				x				
27	Ag	21.2	x		x					x																		
25	Ag	22.5	x		x					x																		
23	Ag	17.7	x		x					x																		
21	Ag	20.5	x		x					x									x									
19	Ag	15.9	x		x						x				x	x												
17	Ag	21.9	x		x					x																		
15	Ag	16.5	x		x					x																		
13	Ag	21.0	x		x					x																		
11	Ag	17.8	x		x					x																		
9	Ag	15.8	x		x						x				x	x												ants
9	Ag	13.8	x		x					x										x				x				
70	Ha	5.8	x		x					x																		side blvd Hollymea
70	Ag	18.9	x		x					x									x	x								side blvd Hollymea
2	Ag	16.2	x		x					x						x												
4	Ag	25.4	x		x						x					x												
6	Ag	21.2	x				x				x					x			x					x				
8	Ag	15.9	x		x								x		x	x												
10	Ag	22.8	x		x					x										x								
12	Ag	20.4	x			x				x										x				x				
14	Ag	20.7	x		x					x																		patchy bark on main
16	Ag	20.5	x		x					x														x				
18	Ag	21.9	x		x					x										x								
20	Ag	21.6	x		x					x											x							took pictures of cra
22	Ag	19.5	x		x					x																		

(Source: Winmill 2015)

Date: September 22 1014 Street: Kenwell Cres Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
24	Ag	23.1	x		x					x																		
26	Ag	19.8	x		x					x																		ants
28	Aw	15.3	x		x					x						x				x								
30	Aw	20.4	x		x					x								x		x		x						
32	Ag	13.0	x		x							x																
38	Ag	16.5	x		x					x																		
38	Ag	18.5	x		x					x														x				
school	Ag	13.5	x			x		x	x	x																		
school	Ag	10.3	x				x	x			x				x	x												
woodlot	Ag	12.9	x		x					x																		
woodlot	Ag	16.8	x		x					x																		
woodlot	Ag	17.2	x		x						x					x			x									
woodlot	Ag	19.1	x		x						x					x		x	x									
woodlot	Ag	16.3	x		x						x					x		x	x									
60	Ag	21.3	x		x					x						x			x									
64	Ag	24.1	x		x					x									x									
66	Ag	21.1	x		x					x																		picture of yellow cate
68	Ag	19.3	x		x					x														x				
70	Ag	19.8	x		x					x						x												
72	Ag	17.9	x		x					x																		
74	Ag	18.6	x		x						x					x												
76	Ag	22.9	x		x					x									x									ants
78	Ag	19.9	x		x					x																		
80	Ag	19.8	x		x					x																		
82	Ag	22.2	x		x					x																		
84	Ag	25.4	x		x					x										x								
86	Ag	24.1	x		x					x									x									

(Source: Winmill 2015)

Date: September 10 2014 | Street: Shakespeare Cres | Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
132	MnCK	26.4	x		x					x						x												
130	MnCK	31.4	x		x					x																		
128	MnCK	25.5	x						x		x				x	x												frost crack
126	Mn	15.3	x			x			x	x																		tar spot
124	MnCK	23.7	x		x					x																		
120	MnCK	19.2	x		x						x					x												terminal is dying
118	MnCK	24.0	x		x					x						x												
116	Mn	30.5	x		x					x																		
114	Oe	8.0	x		x					x																		Powdery mildew
112	MnCK	21.7	x			x			x		x				x	x												
102	Ag	27.0	x		x					x						x						x						thin
100	MnCK	16.2	x		x					x																		
98	Ag	27.7	x		x					x																		thin
96	Ag	34.4	x		x					x																		
90	Ag	31.9	x		x					x						x	x											thin
88	Ag	34.6	x		x							x				x	x											thin
80	Ag	20.5	x		x					x									x			x						
78	Ag	25.3	x		x					x																		
74	Ag	24.6	x		x					x						x	x											
68	Mn	14.8	x		x							x			x	x												
64	Mn	14.7	x		x						x				x	x												
62	Mn	15.9	x		x						x				x	x												
60	MnCK	24.6	x		x					x																		
56	MnCK	22.1	x		x					x						x												
54	Mn	23.0	x			x					x					x												frost crack
52	Mn	21.7	x		x							x				x												tar spot

(Source: Winmill 2015)

Date: September 10 2014 Street: Shakespeare Cres Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms												
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
46	Mn	27.1	x		x					x																		
44	Ha	8.9	x		x					x																		skeletonizer
42	Mn	21.2	x		x							x			x	x												tar spot
38	Mn	22.6	x		x						x				x	x												
36	Mn	27.2	x		x					x																		
32	Mn	20.1	x		x					x																		
30	Ea	15.5	x		x					x																		
28	Mn	21.9	x		x					x																		tar spot
22	Mn	22.4	x		x					x																		tar spot
20	Mn	23.2	x		x						x				x	x												tar spot
18	Mn	18.9	x		x						x				x	x												
14	Mn	15.0	x		x							x			x	x												rust on outer edge of
12	Mn	12.7	x		x						x																	rust on outer edge of
10	Mn	17.7	x		x					x						x												rust on outer edge of
8	Mn	20.3	x		x					x						x												tarspot
1	Mn	26.1	x		x						x																	tarspot
3	Mn	26.5	x		x					x																		
5	Mn	24.0	x			x			x	x						x												
7	Mn	23.6	x		x					x																		tarspot
142	Mn	28.8	x		x					x																		rust on outer edge of l
138	Mn	21.4	x		x						x																	rust on outer edge of l
136	Mn	17.6	x		x					x																		rust on outer edge of l
136	Mn	19.3	x		x						x				x	x												side blvd
119	Ag	20.8	x		x					x							x											side blvd
119	Ag	30.1	x		x					x									x					x				
117	Ag	36.4	x			x					x								x									thin

(Source: Winmill 2015)

Date: September 10 2014 Street: Shakespeare Cres Surveyor: Allison Winmill

			Live Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					Dead wood			Epicor-mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
115	Ha	18.6	x		x					x																		Skeletonizer
113	Or	5.5	x		x					x																		
103	Ag	31.8	x		x					x							x		x					x				
101	Ag	28.2	x		x					x							x		x									
99	Mn	36.9	x		x					x																		
97	Ag	29.7	x		x					x					x	x	x		x					x				
95	Ag	27.9	x		x					x																		
63	Ag	23.5	x		x					x									x									side blvd
63	Ag	23.1	x		x					x					x	x			x									thin
61	Mfr	5.3	x		x					x																		maple gall mite
59	Ag	6.5	x		x					x																		veg sprouts
57	Ag	24.3	x		x					x																		
55	Aw	8.1	x		x					x																		
53	Ag	31.9	x		x					x																		ash flower gall
51	Ag	40.8	x		x					x							x		x									thin
49	Ag	31.8	x		x					x							x		x									
47	Ag	30.9	x		x					x							x											thihnn
45	Ag	33.7	x		x					x																		
43	Ag	39.1	x		x					x									x									
37	Ha	14.4	x		x					x																		skeletonizer
35	Ha	11.1	x		x					x																		skeletonizer
29	Ag	37.9	x		x					x									x									
27	Ha	8.7	x		x					x																		skeletonizer

(Source: Winmill 2015)

Date: September 10 2014 Street: Osprey Ridge Road Surveyor: Allison Winmill

					Stem Condition					Crown Condition							EAB Signs and Symptoms											
			Status							Health					wood			mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
56	Ag	27.4	x			x				x																		Majour wound from borke
54	Ag	17.8	x		x					x							x											
52	Ag	23.0	x		x					x																		
50	Ag	27.3	x			x				x																		Broken limb
48	Ag	21.4	x		x					x							x											ash flower gall
46	Ag	27.6	x		x					x																		
44	Ag	27.6	x		x					x																		
42	Ag	22.2	x		x					x							x											
40	Ag	25.7	x		x					x						x												
38	Ag	25.9	x		x					x									x	x								major wound on limb overh
36	Ag	22.5	x		x					x						x												
34	Ag	23.2	x		x					x																		
32	Ag	20.8	x			x		x		x									x									
30	Ag	23.6	x		x					x					x	x												
28	Ag	21.6	x		x					x									x									
26	Ag	20.5	x		x					x							x		x									
24	Ag	26.8	x		x					x																		
22	Ag	19.7	x		x					x									x									
20	Ag	20.2	x		x					x						x	x											
18	Ag	27.0	x		x					x																		
16	Ag	26.6	x		x					x								x	x									
14	Ag	27.5	x		x					x									x									
12	Ag	24.8	x		x					x						x												
8	Ag	21.5	x		x					x									x									
6	Ag	21.0	x		x					x							x											
4	Ag	18.1	x		x					x						x	x											

(Source: Winmill 2015)

Date: September 10 2014 Street: Osprey Ridge Road Surveyor: Allison Winmill

			Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					wood			mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
Peregrin	Ag	12.4	x							x							x											side blvd
Peregrin	Ag	18.0	x							x					x	x	x	x		x								side blvd
11	Ha	6.7	x							x						x												nipple gall
11	Ha	7.3	x							x																		skeletonizer
13	Ha	10.3	x							x																		
15	Ha	4.9	x									x				x												
17	Ag	18.2	x							x									x									
19	Ag	21.5	x							x									x									
21	Ag	20.1	x							x																		
23	Ag	18.3	x							x							x											
27	Ha	8.8	x								x					x												
29	Ag	22.4	x							x													x					
31	Ag	23.2	x							x									x									
33	Ag	23.5	x							x																		
35	Ag	20.6	x							x																		
37	Ag	19.4	x							x																		
39	Ag	15.2	x							x																		
41	Ag	15.5	x								x																	tufty (clumps at end of branches
43	Ag	29.4	x							x									x									
45	Ag	20.8	x							x									x									
47	Ag	20.0	x							x									x									
49	Ag	19.8	x							x								x	x									ash flower gall
53	Ag	25.5	x							x							x											
55	Ag	21.2	x							x																		
57	Ag	18.5	x							x																		

(Source: Winmill 2015)

Date: September 8 2014 | Street: College Cres | Surveyor: Allison Winmill

			Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											Comments
										Health					wood			mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	
4	Ag	43.9	x		x							x					x											
6	Lh	51.2	x		x					x																		
12	Lh	8.6	x		x					x																		
14	Lh	39.2	x		x					x																		
16	MnCK	39.2	x			x	x	x		x								x										
28	MnCK	27.8	x					x	x	x																		frost crack, powdery m
36	Aw	47.0	x		x					x						x	x											thin
38	MnCK	34.5	x			x			x	x																		
40	Lh	30.8	x		x					x																		
42	Tc	32.3	x		x					x								x	x									
44	MnCK	25.0	x			x	x		x	x						x												
46	Lh	37.4	x		x					x						x												
48	Aw	43.4	x		x					x					x	x								x				lots of outer bark peel
50	MnCK	29.4	x			x	x	x	x	x																		
52	Lh	36.1	x		x					x																		
54	MnCK	35.8	x		x					x																		
56	Mn	29.4	x		x					x						x												big crack in upper br
58	MnCK	31.3	x				x			x						x												frost crack
60	Mn	23.6	x		x					x																		tar spot
64	Mn	27.1	x			x			x	x						x												wound as if hit by c
66	Ag	46.5	x		x					x																		bark peeled off
78	Aw	51.4	x		x					x																		thin
80	Ms	8.5	x		x					x						x												
90	MnCK	34.5	x				x			x																		frost crack
92	Lh	26.5	x		x						x				x	x												
94	Aw	54.2	x		x					x					x	x												thin

(Source: Winmill 2015)

Date: September 8 2014 Street: College Cres Surveyor: Allison Winmill

			Status		Stem Condition					Crown Condition							EAB Signs and Symptoms												
										Health					wood			mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
96	MnCK	27.5	x		x					x						x												
98	Lh	32.4	x		x					x						x												
100	Aw	48.8	x		x					x													x					
110	Mn	30.7	x		x					x						x												
112	Aw	45.1	x		x					x						x												lots of peeled off b
113	MnCK	49.0	x		x					x																		
111	Aw	42.8	x		x							x			x	x	x		x			x						
109	Lh	49.4	x		x					x																		
107	MnCK	40.2	x		x					x																		
105	Aw	33.3	x		x									x			x	x										
103	Lh	50.8	x		x					x																		
101	MnCK	36.2	x		x					x									x									
97	Ll	22.2	x		x					x																		skeletonizer
97	Lh	45.3	x		x					x																		
95	Ms	24.1	x		x					x																		
93	Aw	41.8	x		x						x				x	x												lots of peeled off bark, carp
91	Lh	37.4	x		x					x																		
89	MnCK	41.0	x		x					x																		
87	Aw	41.9	x		x						x				x	x	x											thin
85	Ag	52.1	x		x					x									x									
83	Ag	57.6	x		x					x					x	x												carpenter ants
81	Aw	42.2	x		x					x																		
79	Lh	40.8	x		x					x																		
77	MnCK	22.7	x			x					x					x												frost crack
75	Aw	51.1	x		x					x					x	x												
73	Ag	37.6	x		x					x					x	x												

(Source: Winmill 2015)

Date: September 8 2014 Street: College Cres Surveyor: Allison Winmill

			Status		Stem Condition					Crown Condition							EAB Signs and Symptoms											
										Health					wood			mic		Cracks								
House #	Species	DBH	L	D	Normal	Wound	Canker	Mechanical	Cracks	1	2	3	4	5	Branches	Twigs	Yellowing	Stem	Branches	Stem <5	Stem >5	Branch <5	Branch >5	Woodpecker	Exit holes	Beetle	Galleries	Comments
71	Lh	32.6	x		x					x						x												
69	Aw	48.5	x		x					x						x												thin, missing bark
67	Lh	34.3	x		x					x																		
65	MnCK	27.7	x			x	x			x																		frost crack
63	Aw	46.7	x		x					x									x									
61	Lh	28.9	x		x						x				x	x												
59	MnCK	25.6	x		x					x																		
57	Aw	35.1	x		x						x				x	x												
55	Ag	36.5	x		x					x																		bark peeled off
53	Mn	51.5	x						x	x						x												frost crack, included bark
51	Aw	42.1	x		x					x						x	x											thin
51	MnCK	29.9	x		x					x						x												
37	Mn	21.2	x		x					x																		
35	MnCK	30.2	x			x	x		x	x						x												frost crack
33	Aw	43.6	x		x						x				x	x												bark peeled off, carpenter ants, thin, bir
31	Mn	41.5	x		x					x						x												
29	Mn	25.5	x		x					x																		
27	Aw	48.9	x		x					x						x			x									peeling bark
25	Lh	34.5	x		x					x																		
23	Ag	42.4	x			x				x																		
21	Lh	40.4	x		x						x					x												
19	Aw	45.8	x		x						x					x	x											peeling bark
17	MnCK	29.9	x			x	x	x		x																		
15	Lh	31.0	x		x					x																		
13	Aw	27.9	x		x					x																		
11	MnCK	42.4	x		x					x						x												
9	Lh	37.1	x		x					x						x			x									
5	Mn	39.9	x		x					x																		
3	Ag	45.6	x		x					x																		carpenter ants

(Source: Winmill 2015)