Toronto's Forest Health Threats

Parks, Forestry and Recreation

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1 Executive Summary

Forest health care is a dynamic and ever-changing field of urban forestry. Challenges and solutions to address forest health threats are described briefly in *Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan*. The strategic plan recommended sound and proactive forest management planning and implementation to help sustain and expand the urban forest, including mobilizing resources to mitigate public risk, protecting selected trees, planting replacement trees and increasing awareness of forest health threats.

Toronto's Forest Health Threats is a document that provides a framework for effective management of the impacts to Toronto's natural environment, economy and community posed by forest pests. This document includes methods to control the introduction, establishment, spread and impact of current and potential forest pest invasions. The document describes the nature, extent and risk level of the current and potential forest pest threats and proposes specific management responses to minimize their negative impacts. The document sets priorities and describes enhanced programs and required resources for the protection of the urban forest by incorporating integrated pest management programs.

Invasive non-native forest pests (both insects and diseases) have the potential to cause significant damage to the natural environment and the economy, and subsequently, cause indirect harm to human health. If not managed effectively, they can spread rapidly, potentially causing extirpation of native species and loss of biodiversity. Once these invaders become established, control is often ineffective. Managing such threats effectively requires a set of strategies ranging from prevention, to control, to eradication. The cost of managing forest pest invasions, once established, is typically very high. Without dedicated resources to carry out surveillance, monitoring, and public education programs, the City risks far-reaching environmental, social and financial impacts.

Risk assessment for specific forest pests is based on critical parameters such as host species distribution in a given environment, virulence of the pest, impact to host species, the potential spread of the pest, available management options and potential environmental, social and economic impacts.

In Toronto, current forest pest threats include those that are well established and those more recently introduced. In 2017, the City actively manages the following pests:

- European Gypsy Moth
- Dutch Elm Disease
- Emerald Ash Borer
- Asian Longhorned Beetle

Potential forest pest threats are those not yet established in Toronto but that have been identified as an imminent health risk to the city's urban forest. Those considered include:

- Sudden Oak Death
- Oak Wilt
- Asian Gypsy Moth
- Beech Bark Disease
- Hemlock Woolly Adelgid
- Thousand Cankers Disease

Toronto's Forest Health Threats is a document that identifies criteria that will help determine forest health risks and direct appropriate management actions. The document identifies key stakeholders and recognizes the importance of partnerships and community engagement. An adaptive management approach allows for the integration of new information and modification of management practices in order to meet the challenges of forest health threats. Periodic review of this document should include the adoption of new objectives, the identification of funding requirements and a description of proposed management responses.

Management responses to non-native forest pest introductions may have different funding impacts. The current Service Plan for Urban Forestry supports forest health care management programs such as the Emerald Ash Borer management program and the European Gypsy Moth and Dutch Elm Disease control programs. In the case of the Asian Longhorned Beetle, support for City activities is funded by the Government of Canada through the Canadian Food Inspection Agency as this regulated pest remains under a federal eradication program.

Initial efforts to control and eradicate high-risk threats that have yet to enter Canada are often led by the Canadian Food Inspection Agency as these would be considered federally regulated pests. The potential severity of each instance of pest infestation, regulatory requirements and subsequent response plans will determine the overall financial implications to the City. Large-scale tree removals or wide-sweeping applications of pesticides will have a significant impact on overall cost. Program cost estimates are developed at the time of detection based on the estimated scope of the proposed response plan.

2 Introduction

Toronto, as a major urban centre, is at great risk to the introduction of invasive non-native pests. With an increasingly integrated global economy, a busy international airport, and a large number of international importers, the risk of foreign pest introduction has increased in spite of regulations designed to reduce such risks. Native and non-native pests (insects, pathogens, and weeds) have the potential to cause significant damage to urban and rural forests. Many of these pests have already become established in Toronto and continue to have an impact on the city's natural ecosystems, economy, and consequently the quality of life in Canada's largest city.

Not all forest pests require control. Most forest pests are benign, innocuous or minor in character and do not pose a risk to forest health. The interaction of the host, the pest and the environment determine the level of the threat. A susceptible host, a virulent pest and a favourable environment are the necessary conditions for pest establishment and outbreak. Furthermore, host distribution, the nature of pest damage to a host and the available control options are other factors that determine the potential impact of the pest on its host and the environment.

Toronto has more than four million trees growing within ravines, along City streets and in parks. Six million more trees are located on private property. These trees offer numerous direct and indirect benefits to residents and visitors. In recent years, the environmental, economic and social values of Toronto's tree canopy has been recognized, particularly for its role in mitigating the effects of climate change. Toronto has a diverse forest resource with many unique natural forest communities and significant mature trees. Toronto's Forest Health Threats will provide a framework for the effective management of forests pests which threaten the health of Toronto's urban forest.

The document is intended to help set priorities and describe enhanced management program needs in order to optimize resource allocation and minimize the impacts of forest health threats. The document focuses on the management of forest pests, specifically insects and diseases that have the potential to cause serious damage to the urban forest.

The City's Urban Forestry branch is responsible for the identification and management of forest health threats through an Integrated Pest Management model which uses the most appropriate and balanced management practices. Recognizing that forest pests spread across political boundaries, collaboration with other agencies about urgent issues is an important factor in the success of any pest management program.

Recent pest introductions, such as the Emerald Ash Borer and the Asian Longhorned Beetle have accelerated the need for understanding the mechanisms of invasive pest

introduction and spread. The increasing cost of managing forest pest threats has presented significant budget challenges for the City and higher-level governments.

Native pest populations are typically kept in check by natural control factors such as predators found within their natural environment. Native pests have evolved and adapted to their native environment alongside organisms that provide natural control. However, outbreaks can still occur within a forest pest's native range. In these instances, older or weakened trees may succumb to the attacks which healthy trees usually resist or recover from with little lasting damage. All native forest pests are considered low-level threats and are not specifically examined in this document.

Introduced forest pests have a potential to spread uncontrollably if a susceptible host is present, the environment is favourable for the pest and the natural control factors are absent. These forest pests, found outside of their natural range, cause severe damage to individual trees and change the natural biodiversity of local ecosystems.

In this document, forest health threats are categorized as current or potential threats according to their spread.

Emerald Ash Borer, Asian Longhorned Beetle, European Gypsy Moth and Dutch elm disease are examples of current threats. Urban Forestry continues to develop and implement specific management programs for current forest health threats to mitigate their negative impact on Toronto's urban forest.

New forest pest introductions, such as Beech Bark Disease and Hemlock Woolly Adelgid, have the potential to become established in the environment. Management programs for new threats are needed to describe the set of actions requiring further development once these pests become established.

Oak Wilt, Sudden Oak Death, Asian Gypsy Moth, and Thousand Cankers Disease are serious forest health threats that as of 2016 have not been detected in Toronto's urban forest, however the risk of them being introduced and becoming established is considered high.

A broad range of forest health concerns and specific management practices recommended by Urban Forestry are described in the Forest Health Care Fact Sheets listed above.

Toronto's Forest Health Threats document focuses specifically on forest health threats posed by invasive forest insects and pathogens. Although invasive plants present a significant threat to the urban forest, they are not discussed in this document. Since 2000, Urban Forestry has managed invasive plants following site prioritization and target species guidelines outlined in [*Sustaining Biodiversity: A Strategic Plan for Managing Invasive Plants in Southern Ontario, 2002*]. This plan was produced by the Ontario Invasive Plants Working Group in partnership with the City of Toronto. Since

2007, Urban Forestry has participated on the Ontario Invasive Plant Council Board to help guide the creation of best management practices, policies and partnerships related to invasive plant management. The management of invasive plants is also addressed through management of the City's ESA's, ravines and natural areas.

3 Goals and Objectives

Toronto's Forest Health Threats document supports the vision and strategic goals set out in *Sustaining and Expanding the Urban Forest: Toronto's Strategic Forest Management Plan.* The goals of the City's forest management plan are to increase canopy cover; achieve equitable distribution; increase biodiversity; increase awareness; promote stewardship; and improve monitoring. These goals are reflected in the long-term vision statement, "Toronto's diverse urban forest is the vital green infrastructure that creates healthy neighbourhoods, supports habitat and biodiversity, promotes clean air and water, offers opportunities for recreation and education, fosters economic prosperity and enhances quality of life for everyone in the city."

The goal of the City's forest health care program is to maintain a healthy urban forest by implementing effective and sustainable Integrated Pest Management (IPM) practices and increasing public awareness to help preserve biodiversity and ecological integrity of the urban forest. Toronto's Forest Health Threats document is intended to be shared, critically reviewed and updated over time.

Specific objectives of Toronto's Forest Health Threats document are to:

- assess risk of current and potential forest health threats
- identify early detection and survey protocols
- identify survey requirements for the presence and the extent of spread
- describe implementation plans for management of current and potential forest pests
- evaluate the efficacy of applied forest pest management programs
- identify research opportunities in relation to pest ecology and effective control methods
- identify partnerships with government, scientific agencies, and other stakeholders
- identify budget requirements for program implementation

Urban Forestry is developing forest health care programs to align with provincial and federal invasive species management programs including any regulations set by higher levels of government. This document promotes forest pest management programs that are environmentally, socially and economically sound. Systematic surveys, pest monitoring, inventory and data management are important tools in forest health care. These tools enable Urban Forestry to identify geographic areas and vegetative communities at greatest risk within the city.

4 Partnerships

Coordination of invasive species management efforts is critical to effective management of invasive pests. Forest pests do not recognize municipal boundaries which increases their potential to affect a much broader geographic area than any one municipality. Therefore, it is very important that the City of Toronto act within a larger sphere, collaborating and co-ordinating efforts to address forest health threats.

The Canadian Forest Service states: "The responsibility for forest pest management in Canada depends on the nature of the pest and the location of outbreaks. In general, forest ownership determines this responsibility: so, federal, provincial, territorial and municipal governments are responsible for pest management within their specific jurisdictions. Private forest owners are responsible for their own forest pest management."[1] While the ultimate responsibility for managing a pest outbreak is with the landowner, there are agencies that contribute to pest management outcomes.

Environmental organizations around the world are working on strategies to manage invasive non-native species. The creation of the Invasive Species Centre in 2011 is an example of a collaborative initiative to address the threat of invasive non-native species in Ontario. The Centre is supported by the Government of Ontario, Natural Resources Canada, Fisheries and Oceans Canada, and the Canadian Food Inspection Agency. The Invasive Species Centre helps with establishing communication between stakeholders to support the prevention, early detection and rapid response to invasive non-native species throughout the province. Partners include:

- Ontario Invasive Plant Council
- Ontario Parks
- Ontario Streams
- Canadian Wildlife Federation
- Friends of Algonquin Park
- York Region
- Toronto Zoo
- Great Lakes Fishery Commission
- Invasive Species Research Institute
- Ontario Invading Species Awareness Program
- Green Teacher
- North American Invasive Species Network
- Ontario Federation of Anglers and Hunters
- Canadian Aquatic Invasive Species Network
- Canadian Forest Service
- City of Toronto

To understand the context, roles and responsibilities of the public and private stakeholders, a description of some of the key partners involved in forest pest management is outlined below.

[1] Canadian Forest Service. Website accessed July 18, 2016. (Natural Resources Canada - Forest pest management)

4.1 Canadian Food Inspection Agency

The Federal Government is responsible for the management of regulated invasive non-native species wherever they occur in Canada. Prevention is recognized as the most effective solution against pest invasions. To some extent prevention is managed by the Canadian Food Inspection Agency (CFIA), which is responsible for legislation and regulations that are relevant to forest protection, including the Plant Protection Act, Plant Protection Regulations and Introduced Forest Pest Compensation Regulations.

The CFIA is also responsible for identifying import/export requirements for forest products, Canadian wood packaging certification requirements, defining the pests of regulation concern, implementing plant pest surveillance programs and communicating broad issues of concern that apply to pest management objectives, (e.g. the movement of firewood). Below are examples of forest pests regulated by CFIA:

- Asian Gypsy Moth - *Lymantria dispar* L.
- Asian Longhorned Beetle - *Anoplophora glabripennis*
- Brown Spruce Longhorn Beetle - *Tetropium fuscum*
- Citrus Long-horned Beetle - *Anoplophora chinensis*
- Emerald Ash Borer - *Agrilus planipennis*
- Common Pine Shoot Beetle - *Tomicus piniperda*

CFIA regulations help to prevent the establishment of new introductions of forest pests and to slow the spread of those pests that have been introduced, e.g. Emerald Ash Borer. The CFIA has several options when an incursion is detected, ranging from doing nothing to eradication. When eradication is not feasible the CFIA may regulate and establish the area of infestation and define a geographic area for which certain obligations must be met. The responsibility to comply with those obligations lies with the communities and businesses located within the regulated zone. CFIA regulated zones can have economic repercussions as commodities associated with the pest in question, as described in CFIA “D-memos”, must acquire authorization from the CFIA via a phytosanitary certificate in order to pass out of the zone.

4.2 Canadian Forest Service

The Canadian Forest Service (CFS), part of Natural Resources Canada, is the principal provider of scientific and technological support for all forest pest matters of national jurisdiction including other federal agencies such as Agriculture and Agri-Food Canada (including the Canadian Food Inspection Agency), Environment Canada and Parks Canada. One of the core mandates of the CFS is to conduct scientific research on Canada's forests, providing expertise and tools on topics such as forest fire monitoring,

insect and disease identification, forest monitoring, climate change research, biodiversity, conservation, protection, industry innovation and more.[2]

The CFS works in partnership with researchers in international government and universities to provide basic information on the identity, biology, ecology and management of forest pests. This work includes studying forest pest ecological and assessing potential economic impacts as well as developing expert tools and strategies to support evidence-based decision-making for effective pest management.

The CFS recognizes that while native insects and diseases play an essential ecological role in Canada's forests, native and non-native insects and diseases can become significant pests when infestations are so severe they destroy or damage large areas of commercially valuable forest or infest Canadian forest products bound for export. Mountain Pine Beetle, Spruce Budworm, European Gypsy Moth, and Dutch elm disease are all examples of well-known forest pests that have led to significant economic impacts to Canadian forests. Researchers at the CFS play a vital role in the establishment of eradication protocols. They also assist in the development of pest control products including TreeAzin® and; *Bacillus thuringiensis kurstakii* (Btk). Researchers also contribute to the development of early detection survey tools such as those used to detect the presence of the Emerald Ash Borer.

4.3 Ontario Ministry of Natural Resources and Forestry

The Ontario government is responsible for managing provincial Crown forests, which cover almost two-thirds of the province. In addition to other activities, the Ontario Ministry of Natural Resources and Forestry (OMNRF) has a long history of supporting research and pest monitoring for forest management planning on provincial lands. OMNRF staff implement endangered species protection for butternut trees, undertake invasive species management programs and participate in non-profit organizations such as the Forest Gene Conservation Program and Ontario Invasive Plant Council. The OMNRF also maintains a broad interest in environmental health and forest pest management specifically including:

Asian Long-horned beetle
Winter Browning
White Pine Blister Rust
Spruce Budworm
Snow Damage
Septoria Leaf Spot of Birch
Satin Moth
Pine False Webworm
Large Aspen Tortrix
Larch Casebearer
Jack Pine Budworm
Gypsy Moth
Forest Tent Caterpillar
Emerald Ash Borer

[2] Canadian Forest Services. Website accessed July 18, 2016. Natural Resources Canada - Canadian Forest Service

Eastern Larch Beetle
Dutch Elm Disease
Drought Damage
Dogwood Anthracnose
Cedar Leafminer
Butternut Canker
Brown Spot Needle Blight
Blowdown
Birch Skeletonizer
Birch Casebearer
Beech Bark Disease
Aspen Twoleaf Tier
Armillaria Root Rot

4.4 University of Toronto, Faculty of Forestry

The University of Toronto is a long-standing research partner with the City in the area of forest health threats, particularly Emerald Ash Borer and Dutch elm disease. In recent years, graduate students of the Faculty of Forestry have worked on many projects related to urban forest health including research on the biological control of invasive insects such as the European Gypsy Moth and Emerald Ash Borer.

4.5 Local Enhancement and Appreciation of Forests

Local Enhancement and Appreciation of Forests (LEAF) is a non-profit organization working in the Greater Toronto Area, providing a variety of programs and services designed to protect, restore and celebrate the urban forest. LEAF plays an important role in community outreach, communication and stewardship by raising public awareness, engaging communities and providing educational tools and resources.

With the assistance of the City of Toronto, LEAF has implemented an Emerald Ash Borer Ambassador Program that includes consultation with private property owners regarding the impacts of Emerald Ash Borer, discussions about management options, and the role private landowners play in sustaining the City's urban forest.

4.6 Private Businesses

Where the City of Toronto does not have regulatory authority to manage private property, private businesses can be of assistance by offering forest management services to private land owners. These businesses may also provide scientific and technical expertise to government agencies in the development of pest management programs. Private businesses also perform independent research and develop products for the treatment of invasive pests.

BioForest Technologies Inc. specializes in forest protection strategies and provided Urban Forestry with scientific and technical expertise in the development of European Gypsy Moth and Emerald Ash Borer management programs. BioForest Technologies Inc. also conducted field trials on TreeAzin® treatment efficacy which was later used in the EAB injection program. BioSiIM, a pest surveillance tool developed by BioForest

Technologies Inc., was used by Urban Forestry to determine the optimal treatment time for Emerald Ash Borer and European Gypsy Moth control.

4.7 Community

Community groups often become the liaison between staff and residents. They are very effective at increasing awareness of forest health care threats and encouraging individual homeowners to address these threats along with the rest of the community. The members play a key role in engaging the public about the risks and possible effects on trees within the community. The peer approach works well and the engagement on many occasions has significant impact in the management of the threats.

Past experience highlights the importance of involving, engaging and enabling the residents of a community to address forest health threats. By working with homeowners to educate, support and offer guidance about forest health threats, residents see the value of participating in forest health care programs on both public and private property. This type of partnership highlights the ability and power of an organized group working together to accomplish common goals.

5 Management Strategies

Integrated Pest Management (IPM) is a systematic, ecosystem based process where all pest management components are integrated in eliminating the pest population or suppressing it to tolerable damage levels.

5.1 Native Forest Pests

Outbreaks of native forest pests occur periodically. Potential pest outbreaks are forecasted and assessed through continuous pest monitoring, systematic surveys and data collection with reference to historical patterns. The City of Toronto will continue to administer IPM programs in order to meet forest pest management objectives. Most native tree pests are nuisance in character and do not cause damage to trees but draw great public attention. Raising awareness of native forest pests through effective communication with the public is therefore essential.

Outbreaks of native pests like the Eastern Tent Caterpillar, Fall Cankerworm and various fungal leaf diseases can cause considerable damage to trees over large areas. Typically, the damage is more severe in areas where host species are dominant and species diversity is low. Unfavourable environmental conditions can further stress trees making them more susceptible to pest damage.

Prevention: The first consideration of an IPM program is to prevent pests from becoming a threat. IPM recommends sustainable forest management practices that should prevent or keep the adverse impacts of pests at tolerable levels. These include:

- good arboricultural practices that enhance overall tree health e.g. correct pruning

- planting tree species that are resistant/tolerant to pest infestation
- avoiding the planting of monocultures – plant trees in a diverse species mix so as to not encourage build-up and spread of forest pests associated with a single species
- applying phytosanitary methods, e.g. restricted transport of infested plant material, disinfection of pruning tools, restricted timing of pruning
- avoiding the use of broad spectrum, non-selective pesticides
- avoiding unnecessary tree injury, e.g. mechanical (tree trimmer), chemical (de-icing salt)
- avoiding the planting of introduced species if they are susceptible to native pests e.g. Black Knot of ornamental cherries or plums; Pine Wilt caused by nematodes on Scots Pine and Austrian Pine
- educating staff, contractors and the public

Intervention or Direct Control: When the threshold levels of a pest indicate that intervention is required and preventive methods are no longer effective or available, Urban Forestry will evaluate appropriate control methods both for effectiveness and environmental risk. Effective, less disruptive pest control methods are selected first, including mechanical and biological control practices or the application of highly selective and environmentally-friendly pesticides.

5.2 Non-native Forest Pests

The term non-native usually refers to pests from other countries, regions or continents. Invasive non-native forest pests can be added to the environment by the expansion of their natural range or by introduction through human activity.

Non-native forest pests have the potential to cause significant damage to the native environment, economy, and human health. Once these invaders become established, control is often ineffective. The cost of managing introduced forest pest invasions is typically high. Loss of biodiversity and the potential extirpation or even extinction of native species can result if pests are not managed effectively and are allowed to spread uncontrollably. Managing such threats effectively requires a set of strategies ranging from prevention, to control, to eradication.

Risk Assessment and Prevention of Introduction: Risk assessment is a key tool in the fight against invasive non-native species. It is a vital part of any comprehensive prevention strategy. Risk assessment is used to identify threats, utilize rapid responses, identify management objectives and establish appropriate management practices. Risk assessment aims to identify forest threats and prevent their introduction. Toronto receives a lot of international goods through shipping, rail and truck transport. Imported goods increase the risk of new non-native forest pest introduction. For this reason, detection and public outreach are key priorities.

Risk assessment and prevention is led and coordinated in cooperation with provincial and federal organizations. Urban Forestry collaborates with these government organizations through information exchange, pest monitoring, inventories, invasive non-native species survey programs and outreach efforts.

Early Detection and Prevention of Spread: This includes the detection and identification of invasive non-native species before or immediately after they become introduced. Systematic survey and monitoring, sampling/trapping, creating awareness and public education play important roles in the early detection of forest pests. Current searchable tree species inventories are also crucial as they enable forest managers to identify areas with vulnerable plant communities predisposed to future pest invasions.

Management Objectives: The potential impact and advancement of any given non-native pest invasion determines the objectives of the appropriate response. Management objectives are developed for each pest response program considering the best possible outcomes and what is feasible to achieve. For example:

- Asian Longhorned Beetle
  - eradication of the pest
- Emerald Ash Borer management (early detection)
  - slow the spread of the pest
- Emerald Ash Borer management (active infestation)
  - slow host tree mortality
- European Gypsy Moth management
  - mitigate impact to vulnerable ecosystems
- Dutch elm disease program
  - preservation of remnant, significant host trees

These objectives may change over time as the infestation evolves and new, more effective management practices become available.

Management Practices: In response to invasive non-native forest pest invasions, the following steps will be considered and the most suitable applied to best mitigate the forest health threat:

- systematic survey
- pest monitoring
- data collection and management
- review of scientific research and/or facilitation of research by partners
- sanitation or host management (removal, pruning, planting)
- pesticide treatment
- biological control
- phytosanitary regulations (CFIA ministerial orders)
- awareness, education, stewardship

Forest health care strategies require a detailed understanding of the state of current forest resources. An accurate, up-to-date forest inventory is one of the critical components in the development of an effective pest management program. Urban Forestry is committed to improving and updating the City's electronic tree inventory; applying new geospatial methodologies and data-processing technologies in order to identify the current state of the trees and forests; and describing species distribution, size structure, health condition, and geographic location.

Urban Forestry will continue to monitor and collect data for the target areas city-wide, as well as maintain strong communication pathways for public education and feedback. Staff will align City management plans with federal and provincial agencies.

Effective management of forest health threats from non-native pests requires adequate financial resources to carry out ongoing monitoring, training and outreach initiatives. The development and continued implementation of forest health care response programs must continue to be guided by integrated pest management principles.

5.3 Summary of Recommendations

Based on a review of current and potential forest health threats, a summary of the proposed priority actions is described below under the categories of monitoring and response planning; training and education; and communication and collaboration.

Monitoring and Response Planning

Forest health care monitoring and response planning is included in the Urban Forestry Service Plan. The current funding level supports the Emerald Ash Borer management program and the European Gypsy Moth and Dutch elm disease control programs. Future funding requirements must be developed to address potential forest health threats including pest monitoring, risk assessment and recommended response plans.

City of Toronto Forest Health Care staff will:

- continue to implement existing management programs for current forest health threats including European Gypsy Moth, Dutch Elm Disease, Emerald Ash Borer and Asian Longhorned Beetle
- develop monitoring, training and communication plans for the most imminent potential forest pest risks
- prioritize planning for potential forest pest risks, starting with Oak Wilt and Hemlock Woolly Adelgid, then Sudden Oak Death, Beech Bark Disease and Asian Gypsy Moth
- identify requirements and designate staff to develop and implement specific management programs for these potential forest health threats
- conduct inventories of vulnerable tree species to specific forest health threats
- undertake risk assessment for specific forest health threats
- develop monitoring protocols for specific forest health threats

- develop recommended response plans and programs to address specific forest health threats
- develop tree maintenance protocols to prevent unnecessary injuries that increase risks of pest introduction
- provide input in the development of a geospatially enabled asset and work management program that supports forest health program development and implementation

Training and Education

Staff training and education is critical to the effective management of Toronto's urban forest. Keeping informed of current, emerging and potential forest health threats is crucial to the success of the City's forest health care program.

City of Toronto Forest Health Care staff will:

- keep informed about current, emerging and potential forest pests
- provide regular training to Urban Forestry staff on forest health care issues and forest pest identification
- provide training to Urban Forestry staff on tree maintenance protocols
- promote awareness of forest health care issues in the tree care industry
- support continuous learning and professional development through participation in professional trade organizations, conferences and working groups

Communication and Collaboration

Since forest pests do not recognize organizational boundaries, communication and collaboration are necessary to ensure the effective management of forest health threats. Information-sharing between municipal, provincial and federal agencies is essential to the development of timely and effective response plans needed to maintain a healthy and resilient urban forest.

City of Toronto Forest Health Care staff will:

- establish an inter-divisional forest health care working group with representatives from each of the branches of the Parks, Forestry and Recreation division
- work with Urban Forestry staff to identify the collaboration needs and early pest risk assessment of newly introduced species
- advise and promote good arboricultural practices and ground care maintenance practices to other City divisions by inserting guidelines in work practice documents
- liaise and cooperate with government and scientific organizations including the Canadian Food Inspection Agency (Bio-surveillance unit), Invasive Alien Species Survey Program, Invasive Species Centre, Ontario Ministry of Natural Resources and Forestry, Canadian Forest Service, and others
- work to broaden the management of other pests through continued participation in regional working groups (e.g. York Region Emerald Ash Borer working group)

- liaise with partners in the USA to explore opportunities for gaining first-hand identification skills and understanding of management programs required to prevent the spread of Sudden Oak Death, Oak Wilt and other imminent threats managed by urban forest managers in the USA
- use various means to distribute knowledge gained from other jurisdictions to forest health care partners and City staff, including workshops, presentations, and communications materials
- increase internal awareness and improve operational coordination through staff training and the production and distribution of forest health care publications;
- encourage Urban Forestry staff and other City divisions to plant a diversity of tree species, with special attention to tree species most at risk to forest pests
- promote increasing public awareness of important forest health threats and encourage active community engagement in forest health care programs through direct communication, web updates, social media, and news publications
- engage active interest groups through presentations, tours and workshops

6 Management Programs for Current Forest Health Threats

Toronto currently recognizes four current forest health threats: Emerald Ash Borer, Asian Longhorned Beetle, Dutch Elm Disease and European Gypsy Moth. Long term strategies are focused on these four threats. Separate management programs for each one of the four threats are described below.

6.1 European Gypsy Moth

History: The European Gypsy Moth (*Lymantria dispar*) is an invasive non-native pest that has been present in North America since the late 19th century when it was inadvertently released into the environment in the state of Massachusetts. This leaf-eating pest steadily advanced westward through New Brunswick, Nova Scotia, Quebec, and Ontario, as well as to the northeast and the mid-western United States. In 1969, the first population of EGM in Ontario was detected on Wolfe Island near Kingston. Outbreak conditions causing visible damage over large geographic areas occurred in southeastern Ontario during the mid-1980s, early 1990s and early 2000s.

In Toronto, the population of EGM has fluctuated in relation to environmental and biological controls. Outbreaks occurred in the early1990s, and again in 2006, 2007, 2008 and 2013.Surveying and monitoring will continue in order to determine whether the current population levels qualify as an outbreak.

Preferred hosts for EGM include all species of the oak family (*Quercus* sp.), however, it will also attack maple (*Acer* sp.), spruce (*Picea* sp.), birch (*Betula* sp.), aspen (*Populus* sp.), willow (*Salix sp.*) and many other species of deciduous and coniferous trees. About 1.8 per cent of Toronto's 10.2 million trees are oak species,[3] which are the preferred

[3] Every Tree Counts: A Portrait of Toronto's Urban Forest, 2013. Appendix 8, p.92.

host of this pest and the most vulnerable. Stands dominated by white oak are particularly susceptible to EGM attack, especially after repeated seasons of defoliation that lead to overall tree decline and mortality. EGM populations are known to fluctuate over time with long periods of low population levels climbing rapidly to outbreak conditions and then collapsing to pre-outbreak levels. A Forest Insect and Disease Survey[4] from 1989, published by the United States Department of Agriculture Forest Service, continues to provide good information for forest pest managers, with the exception of some of the outdated pesticide treatment options. The cyclical nature of these outbreaks makes control measures difficult as the pattern is unpredictable.

Figure 1: A fully developed European Gypsy Moth larva

Figure 2: Female European Gypsy Moths laying eggs

EGM has four life stages: egg, larva (caterpillar), pupa and adult. The larval stage is the destructive form. Larvae feed on tree leaves for a period of about seven weeks and can quickly defoliate individual trees with potentially thousands of caterpillars feeding on a

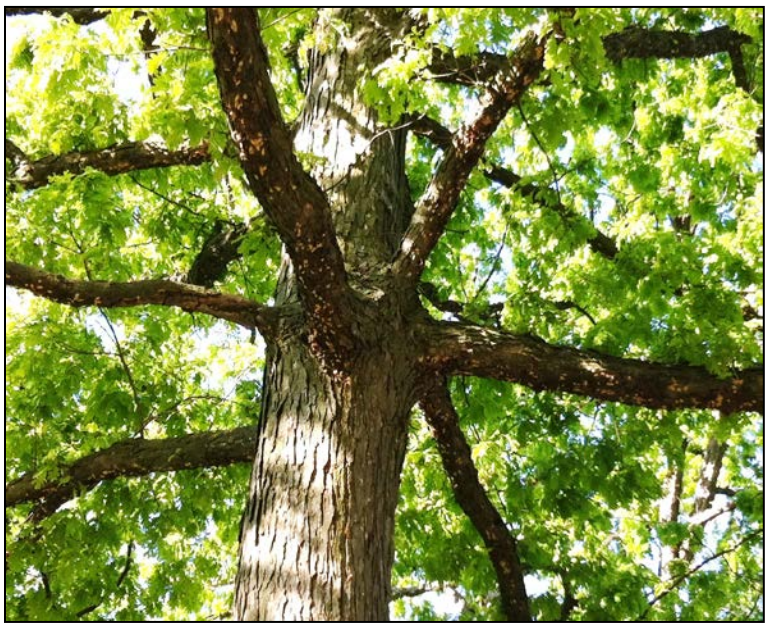
[4] *Gypsy Moth*, Forest Insect & Disease Leaflet 162, U.S. Department of Agriculture Forest Service, 1989.

single tree. Light levels of defoliation (30 to 40 per cent of the leaf area on an individual tree) are noticeable and will cause added stress to the tree. Moderate to severe defoliation (over 50 per cent defoliation) can occur during outbreak conditions, and when repeated, can result in twig, small and large branch death, and/or whole tree mortality.

Prevention: EGM is well established in the Toronto area and eradication of the insect is not possible. However, controlling threshold levels is possible, but needs to be coordinated, both on private and City-owned trees. Homeowner education and continued monitoring of sensitive areas are necessary. The most vulnerable sites are those with mature, continuous oak stands that have a dominant white oak component.

Normally, EGM is present in low numbers, controlled by naturally-occurring fungal pathogens and insect viruses that provide effective biological control. There are two biological controls that kill larvae: a fungal pathogen (*Entomophaga maimaiga),* and a virus nucleopolyhedrosis (NPV). Naturally-occurring parasitic wasps also kill pest eggs while predators such as birds and mice feed on larvae. These natural biological controls help to keep population levels low.

Figure 3: Outbreak levels of European Gypsy Moth egg masses on a white oak tree



When EGM populations increase rapidly, natural biological controls become less effective. As a result, large numbers of larvae can cause repeated defoliation leading to tree mortality. Given time, natural biological controls will bring population levels down. However, it is important that treatment programs be applied strategically to areas with high EGM populations so that susceptible trees are protected from lethal damage. Concurrently, it is important to protect the growing populations of fungi, viruses, and parasitic wasps that depend on EGM for their reproduction. Treatment programs must balance the health of trees against the health of natural biological control populations.

EGM outbreaks may last from 2-4 years before natural biological controls and environmental conditions cause populations to crash. The transition from low-density (innocuous phase) to high-density (outbreak phase) can happen in a few generations before it decreases to an innocuous phase again. The population cycle is typically 8-10 years.[5] At light levels of defoliation, individual trees can respond to early defoliation by producing a second flush of leaves and thus mitigate the effects. However, repeated defoliation, in combination with other stressors, can cause tree mortality.

Figure 4: European Gypsy Moth larvae under burlap

Detection: Detection and monitoring of EGM population levels is critical in managing this pest. Urban Forestry has identified several geographic areas where EGM has developed a consistent presence. Threshold levels are determined through several tests. Pheromone traps are set up in these areas in mid-summer so that male moths can be trapped and counted. Urban Forestry conducts an ongoing program of surveillance for egg masses in areas of potential outbreak. It is important to differentiate between newly laid egg masses and old egg masses, which may remain visible for a few years. A comprehensive egg mass survey must be conducted in order to prepare an effective, site-specific control program for various affected areas in the city. Once areas are roughly delineated, a systematic survey of egg masses is initiated in late fall into winter.

The survey is typically conducted by two survey crews (two surveyors per crew). Fresh egg masses are counted in area survey plots. The survey results are analyzed and the

[5] Sourcebook for the Management of the Gypsy Moth, Chapter 1, V.G. Nealis and S. Erb, Forestry Canada, Ontario Region, Great Lakes Forestry Centre 1993.

calculated egg mass numbers are applied to a given area. Egg mass threshold levels are used to determine the type and the extent of the control methods.

Figure 5: White oak defoliated by European Gypsy Moth

Response: In an effort to protect the tree canopy against EGM damage, the City must continue to implement management programs to control outbreaks. Response to EGM varies and depends on survey results. The primary objective of the control program is to protect vulnerable trees from moderate to severe defoliation. Nuisance issues that this insect may cause are not addressed in this document.

Urban Forestry recognizes the need to protect natural population control agents such as the *Entomaphaga maimaiga* fungus, the nucleopolyhedrosis virus (NPV), parasitic wasps and other naturally-occurring biological controls known to cause EGM population decline. Egg masses are sampled in early spring and analyzed for the presence of the parasitic wasps. The rate of the egg parasitism is calculated into the population level forecast. This and the observed mortality of the larva population in late summer are the determining factors in the decision on how to manage the pest population in the spring.

Table 1: European Gypsy Moth control methods used in years of outbreak

Year	Manual egg mass removal (No. of trees)	Ground spray of *Bacillus thuringiensis kurstaki (Btk)* (No. of trees)	*TreeAzin*® insecticide stem injection (No. of trees)	Aerial spray of *Btk* (ha)
2006	250	-	-	-
2007	3000	101	-	70
2008	200	28	-	250
2013	500	60	25	392
2014	200	14	5 City + 221 private	-

Figure 6: Egg mass removal with portable vacuum

Low-level Outbreaks

Minor or low-level populations may require simple mechanical control methods such as physically scraping off egg masses and destroying them. For small scale outbreaks, Urban Forestry staff recommend and apply integrated pest management techniques to prevent damage to selected trees.

These techniques include:

- burlap wraps around tree trunks, collection and daily removal and destruction of the caterpillars that hide under the burlap
- pheromone traps or lures to catch or confuse male moths
- scraping away or vacuuming and destroying egg masses before the caterpillars hatch

Larger Outbreaks

- Larger outbreaks may require isolated ground spraying of an insecticide containing *Bacillus thuringiensis kurtsaki* (Btk) or injections of systemic pesticides such as TreeAzin®. Outbreak levels over large areas may require an aerial spray of Btk by helicopter. Btk is a biological control agent which results in the death of caterpillars feeding on leaves. It is most effective when applied to the foliage of preferred host plants under proper conditions.

TreeAzin® (active ingredient Azadirachtin), which is a pesticide product also used in the control of EAB, is now available for use to be injected against EGM. TreeAzin® insecticide stem injection was applied to a number of infested trees in 2013 and 2014. This control option is used to strategically protect selected trees in small areas of infestation.

Figure 7: European Gypsy Moth larvae killed by a fungus (right) and a virus (left)

Various treatment options are available based on specific criteria, listed below.

Aerial application of Btk may be selected when:

- the infestation threatens a vulnerable plant community (such as Environmentally Significant Areas and those communities with a dominant white oak population)
- the infestation covers a continuous oak stand with a large number of mature trees
- the infestation has caused past defoliation in at least one season
- the number of egg masses exceeds the threshold of moderate to severe defoliation (over 1,236 egg masses/ha)
- the majority of egg masses are deposited higher in the tree and are inaccessible by manual removal or ground spray
- closed or moderately closed tree canopy exists
- naturally-occurring bio-controls are not present or are forecast to have little impact on the pest population

Note – Aerial spray treatment may require external resources to monitor pest development (timing) and to support helicopter spray operations. Depending on the availability of significant resources, this may or may not be an EGM control option to consider.

Figure 8: Aerial spray block with oak trees

Figure 9: Aerial spray of *Bacillus thuringiensis kurtsaki* with helicopter

Ground application of Btk may be selected when:

- there is the presence of a high number of egg masses (more than 15 per tree)
- there is the presence of vulnerable tree species (white oak group)
- individual oak trees or a group of trees is isolated from continuous stands of vulnerable tree species
- egg mass removal is not feasible due to the high number of egg masses located high in the tree canopy, out of reach and where the rough bark texture makes egg masses difficult to detect
- trees are accessible to ground application equipment
- good canopy coverage is achievable by the ground spraying
- naturally-occurring bio-controls are not present or are forecast to have little impact on the pest population

Insecticide stem injection may be selected when:

- there is the presence of a high number of egg masses (more than 15 per tree)
- trees may not be accessible by ground spray equipment
- individual oak trees or a group of trees is isolated from continuous stands of vulnerable tree species
- egg mass removal is not feasible due to the high number of egg masses that are located high in the tree canopy, out of reach and where the rough bark texture makes egg masses difficult to detect
- naturally-occurring bio-controls are not present or are forecast to have little impact on the pest population

Egg mass removal and other integrated pest management methods may be selected when:

- the infested area is made up of a diverse plant community;
- trees are less vulnerable to repeated defoliation by European Gypsy Moth;
- most egg masses are deposited 0-6 m above ground level;
- naturally-occurring bio-controls are not present or are forecast to have little impact on the pest population

In 2007 the City of Toronto partnered with the City of Mississauga to implement EGM control using BioForest Technologies to schedule aerial spraying and determine application rates, and Zimmer Air to obtain provincial permits and implement the spray program. This cooperative approach was repeated in 2008 when the City of Toronto partnered with the Town of Oakville, Halton Region Conservation Authority, the City of Burlington, the Royal Botanical Gardens and the City of Hamilton to utilize these same private companies to plan and implement the spraying program.

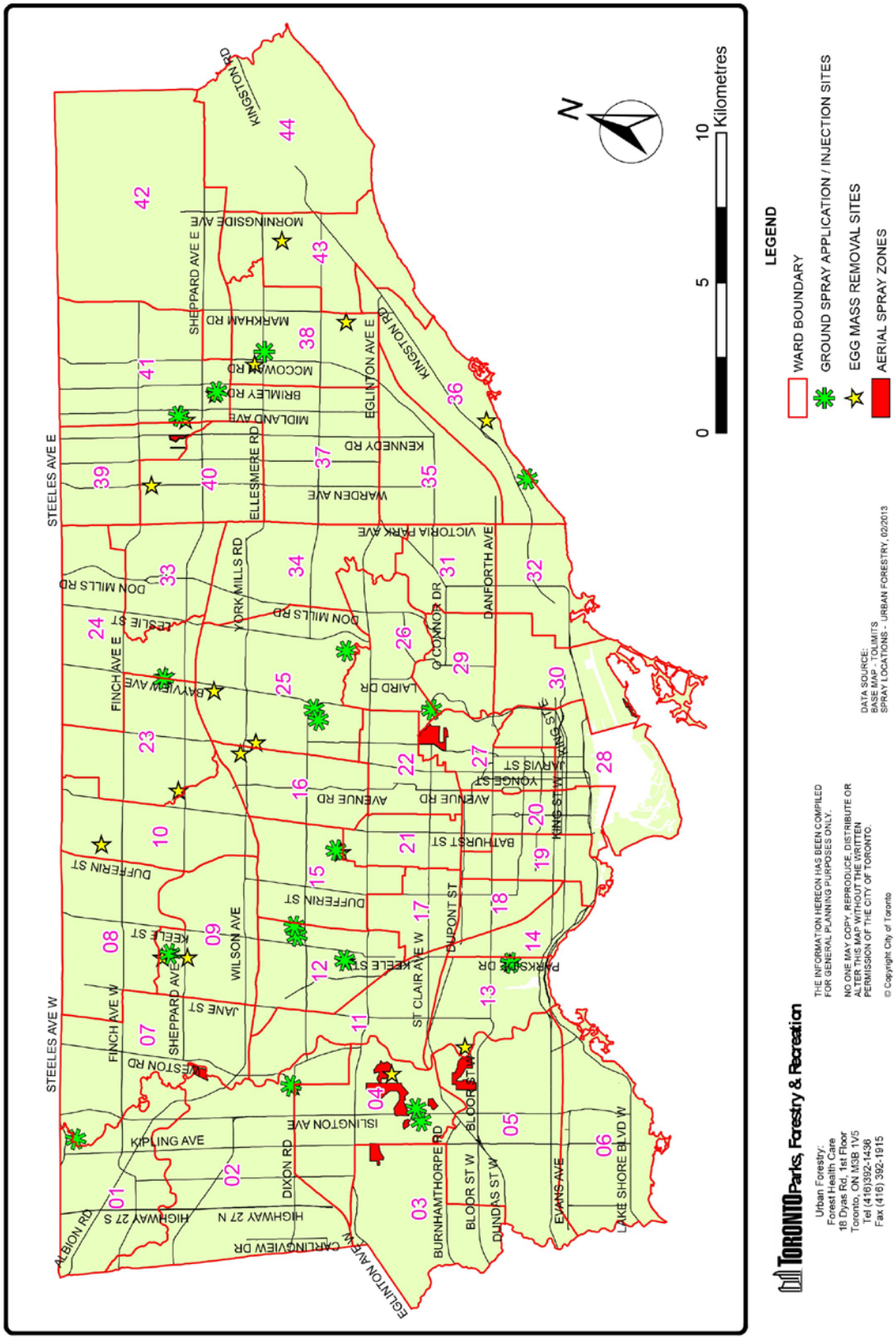
In 2013 a spray program was undertaken by the City of Toronto in partnership with St. George's Golf and Country Club in Etobicoke. In 2014 the City of Toronto initiated a control program in the Princess Margaret neighborhood through the engagement of local residents. These examples are models which will be used to guide future EGM control programs.

Partnership and Engagement: Continuous monitoring for the presence of the EGM both by City staff and the public is important in preventing an outbreak of the EGM population. Establishing communications and educating residents and community groups where EGM is known to be present is vital. Encouraging biodiversity in newly planted tree species within these areas is important to build resiliency in the urban forest and needs to be communicated to landowners.

In severe outbreaks, proposed areas for aerial spray treatments include both City-owned and privately-owned trees. Due to the extent and scope of the infestation in these areas and the availability of a landscape level control option, a program of aerial spraying of Btk is recommended. Because aerial spray operations specifically target defined geographical areas and not individual trees, the treatment of privately-owned trees is unavoidable.

Prior to the implementation of spraying control strategies, consultation with the Ontario Ministry of the Environment, as well as with ward councillors, Toronto Public Health and members of the public is required.

Figure 10: Areas treated for European Gypsy Moth during the 2013 outbreak



6.2 Dutch Elm Disease

History: Dutch elm disease (DED) was introduced to Canada from Europe in 1944. The disease was first detected in Ontario in 1950. Since then it has spread over the entire range of native elm trees (*Ulmus sp.*) in North America. All American and European elm species in Toronto including American elm (*Ulmus americana),* red or slippery elm (*Ulmus rubra)*, rock elm *(Ulmus thomasii),* Scots or Camperdown elms (*Ulmus glabra)*, and English elm (*Ulmus procera)* are susceptible to DED. Some individual trees show a certain level of resistance but are not completely immune to attack. Two non-native species, Siberian elm *(Ulmus pumila)* and Chinese elm *(Ulmus chinensis)* are resistant to DED. In the past 50 years, the city has lost many of its largest elm trees to DED. Recently the City of Toronto has been planting accolade elm (*Ulmus japonica x wilsoniana)* because it's considered to be resistant to DED.

DED is caused by a fungus, *Ophiostoma ulmi,* which attacks the water-conducting vessels in the sapwood of elm trees where the fungal spores are carried by the trees sap. The first symptoms of the disease are wilting, curling, and yellowing of the leaves on one or more of the branches. In some cases, a few branches may wilt and die slowly over a period of years. In other cases, all branches may wilt and die within weeks. Native and European elm bark beetles carry the fungus from diseased to healthy trees. The disease can be also passed through root grafts when healthy trees are situated in close proximity to diseased trees. Various elm species show a certain degree of resistance in the early years of growth. This is known as juvenile resistance which typically disappears after maturation of the elm.

Figure 11: A healthy mature American elm tree

The City's tree inventory database includes 520 City-owned American and European elm trees measuring over 70 cm in diameter. These mature elm trees have resisted the DED infection for approximately 50 years.

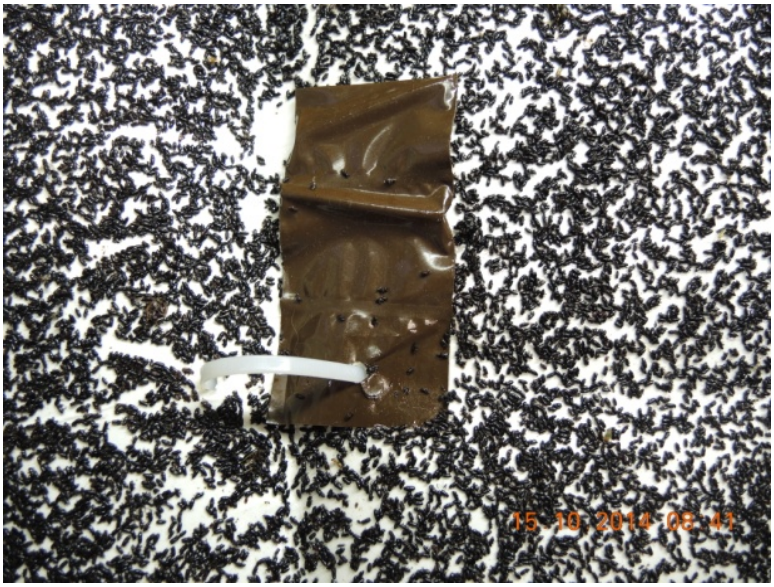
Prevention: DED is firmly established in North America and therefore eradication is not a feasible management option. Preventing the spread of the disease is limited to isolated areas and to select trees. Preventative measures are focused on denying breeding habitat to the vectors (elm bark beetles) and by promptly removing infected trees, and protecting select trees using fungicide injections.

Generally, elm trees that have died as a result of DED are removed before they become a hazard. However at this point mature elm bark beetles have left the tree carrying fungal spores to other hosts subsequently spreading the disease. If infected trees are removed in time, it may be possible to reduce the spread of the disease and extend the life of other valuable elm trees in the area. Removal and disposal of infested stems and branches is an important function of an effective sanitation program. Movement of infested wood offsite and away from neighbouring trees is effective in helping to preserve these trees.

In the past specific trees have been periodically treated. A comprehensive, city-wide program similar to the one carried out in the city of Winnipeg, was not implemented in Toronto prior to 2015. Standard DED management practices were recommended in the past, however, resources were not available to fully implement them.

It is reasonable to expect that some elms will be infected and die despite sanitation and treatment efforts.

Figure 12: Elm bark beetles caught on the monitoring trap



Detection: Early detection of DED is critical in preventing the spread of the fungus further within the tree, and also to other healthy elm trees in the landscape. Early

detection is best accomplished through systematic monitoring of the city's elm tree population and through public awareness. These are integral parts of Toronto's DED management plan.

Figure 13: Mature American elm killed by Dutch Elm Disease

Response: Urban Forestry has initiated a continuous DED monitoring program of all known, City-owned, susceptible elm trees. This management program is planned as a continuing commitment. It is important to weigh the cost of a control program against the value of mature trees (cultural and canopy value) and the cost of removing large dead trees that will occur if the disease is allowed to spread unchecked. The objective of the program is to further protect these large-growing trees from DED.

Elm inventory: There are over 1,200 elm trees listed as susceptible to DED in the City's inventory. The focus of the DED management program is on large, mature specimens; elm trees measuring 70 cm in diameter or larger. City-wide, data has been collected on 520 elm trees of this size class. A selected number of private trees, relevant to the program, have also been recorded. Data is recorded in the City's tree inventory system and selected trees are identified with physical tags. The tree inventory contains the following information:

- Address
- geographic coordinates
- species
- size (dbh)
- condition
- symptoms of DED present
- pending work to be done
- monitoring requirements
- photo of tree in the growing season

Elm bark beetle monitoring: Pheromone traps are set up to monitor elm bark beetle populations. Trapping results determine the level of beetle populations in a given area, and consequently the risk of infection. To date, 18 locations with a large group of valuable elm trees have been identified. Traps will be installed at the perimeter of these areas to compare elm bark beetle populations on a lifecycle basis.

Monitoring for symptoms (early detection): Symptoms of DED can be seen anytime from early June to mid-October. Early detection requires continuous monitoring during this period. There are 1,200 DED susceptible elm trees in the City's tree inventory that require periodic monitoring. Elm trees are inspected by staff twice during the growing season, timed in conjunction with the flight of elm bark beetles, in order to identify any signs of DED.

Maintenance activities (sanitary pruning, removal, and disposal): Data shows that from 316 susceptible mature elm species recorded in 2009, 234 are still alive today. That represents a 5 per cent annual mortality rate. The objective of the DED management program is to preserve remnant host trees.

It is important to identify and remove infected, dying trees before elm bark beetles emerge. In Toronto this typically occurs in late May. Sanitary pruning and removal of diseased trees identified during the flight season of the elm bark beetles (June-September) should be done on a priority basis, and the wood disposed of at a designated disposal site where the wood can be ground within a short period of time. All tree maintenance on selected elm trees must be performed under the supervision of an Urban Forest Health Care inspector. Sanitation work and disposal of diseased trees should be completed before elm bark beetle emergence in late May. Regular maintenance pruning of elm species susceptible to DED should be avoided during the flight season. Elm bark beetles that spread the DED fungus are attracted to fresh pruning wounds and are most active during this period.

If DED is found within a tree, sanitary pruning may be possible by removing the infected branches. However, elm trees that have a large proportion of the canopy affected will need to be removed. Removed wood is to be ground into chips at designated disposal sites. Timely wood grinding must be employed to prevent bark beetles from emerging.

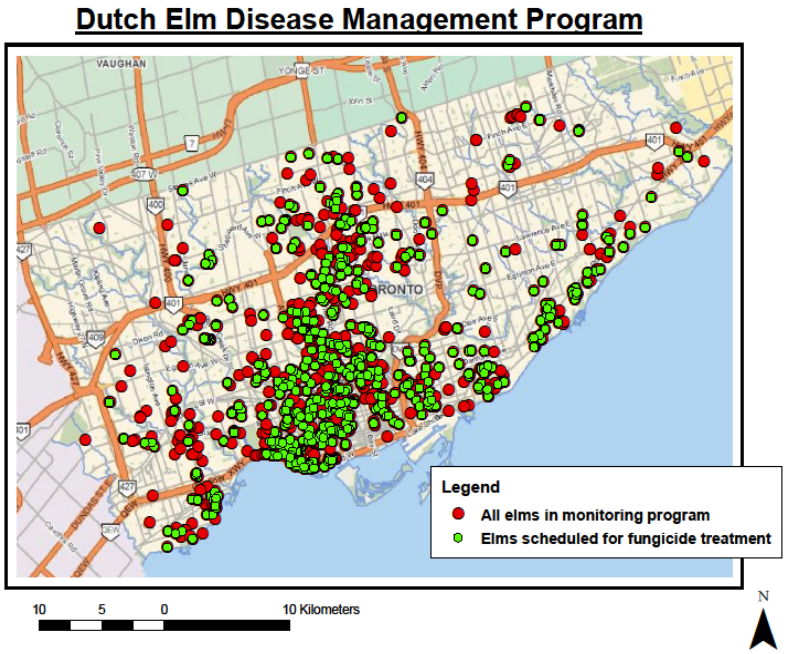
Attention is paid to private elm trees that present an immediate risk of spreading DED to elm trees included in the City's management program. As required, Urban Forestry staff will take reasonable steps to consult with property owners about the work required to save the tree or prevent further spread of the disease. Private land owners are responsible for undertaking any required sanitary pruning or tree removal work.

Figure 14: Removal of an elm killed by Dutch elm disease

Figure 15: Injection of a fungicide in the stem of a mature American elm tree

Fungicide injection: Urban Forestry plans to treat 520 elms over a 3-year period. This number may increase as additional suitable elm trees are identified over the monitoring period. Fungicide injection is recommended for significant trees that show no symptoms of the disease. It is applied as a preventative measure. Tree selection for the treatment will be determined on a case by case basis by staff. Arbortect® 20S is a registered systematic fungicide that is effective in protecting elm trees from DED. If injected in full dosage, the treatment interval is 3 years, currently 175 trees are treated annually to provide protection to 520 trees in the program.

Figure 16: Distribution of elm trees in the Dutch Elm Disease Management Program



6.3 Emerald Ash Borer

History: The Emerald Ash Borer (*Agrilus planipennis*) (EAB) is an introduced wood-boring beetle native to China, Japan, Korea, Russia, and Taiwan that was first discovered in Canada near Windsor, Ontario in 2003. It was first detected in Toronto in 2007 near the area of Hwy 404 and Sheppard Avenue, North York.

Figure 17: Adult Emerald Ash Borer beetle

EAB is a destructive insect that kills true ash (*Fraxinus* sp.) by interrupting the flow of water and nutrients to the upper branches and leaves. In 2010 it was estimated that EAB had the potential to affect 860,000 of Toronto's 10.2 million trees, worth an estimated $570 million in structural value. The loss of these trees is particularly devastating to neighbourhoods that have a high percentage of ash situated on the road allowance, in parks, and on private property.

Figure 18: Ash tree with advanced Emerald Ash Borer infestation

Prevention: EAB is well established within the Greater Toronto Area and most of southern Ontario. Eradication of the insect is not possible. The introduction of the insect to new areas of Ontario and Canada is still possible by natural spread, and through movement of infested ash wood. To slow the spread of EAB to new areas, the CFIA has established regulated areas where the beetle is known to exist. The movement of potentially infested materials is controlled within these areas. The City of Toronto placed a moratorium on the planting of ash trees in order to minimize the impact of EAB on the city's tree canopy and to reduce the potential introduction to nursery stock.

Detection: From 2008 to 2010, Urban Forestry conducted annual surveys to track the spread of EAB and determine the size of the infestation and advancing mortality of trees. The survey included:

- monitoring for visual signs of the beetle
- trapping adult beetles using sticky traps and host plant volatiles
- targeted branch sampling to look for signs or presence of the beetle
- site inspections of non-target areas in response to reports by staff and the general public

Early detection surveys conducted in 2008, 2009, and 2010 confirmed that EAB was firmly established in many areas of Toronto. Detection now consists of monitoring EAB population levels in areas with higher concentrations of protected ash trees that have been infected with insecticide. The objective of this monitoring is to determine the treatment cycle frequency based on the current EAB population pressure.

Figure 19: Emerald Ash Borer larval galleries under bark

Response: There are two main strategies available to manage an EAB infestation:

- remove trees as they die and replace with non-host species
- treat specimen ash trees that are in good condition with insecticide

In 2012 Toronto City Council approved a plan to implement a hybrid strategy targeting up to 16,000 trees for insecticide treatment, in addition to the removal and replacement of dead and dying trees. Unfortunately the speed of spread and delay in available resources required to support this program resulted in fewer trees being protected than originally proposed.

The components of the program included:

- pesticide treatment
- removal of infested trees
- tree canopy replacement
- partnership and public engagement

Pesticide treatment: Research has shown that TreeAzin® injected in the main stem, at full dosage every second year, will inhibit EAB larval development, prevent adult emergence, reduce adult fertility, and provide preventative and curative treatment of EAB. The following criteria have been used by Urban Forestry to select trees for insecticide injection:

- trees that are over 15 cm dbh

- trees that show low-level signs of infestation
- trees with less than 30 per cent loss of canopy
- trees that are in fair or good health

Urban Forestry injected a total of 12,799 ash trees in 2012 and 2013 (4,025 and 8774, respectively) and as of 2016, 9,900 ash trees remain in the injection program. Each tree is assessed for treatment every two years. The goal of this program is the preservation of a number of healthy ash trees and a reduction in the overall number of dead trees requiring removal and replacement across the city over the management plan period. Benefits realized by this program are delayed mortality and the gradual replacement of lost tree canopy.

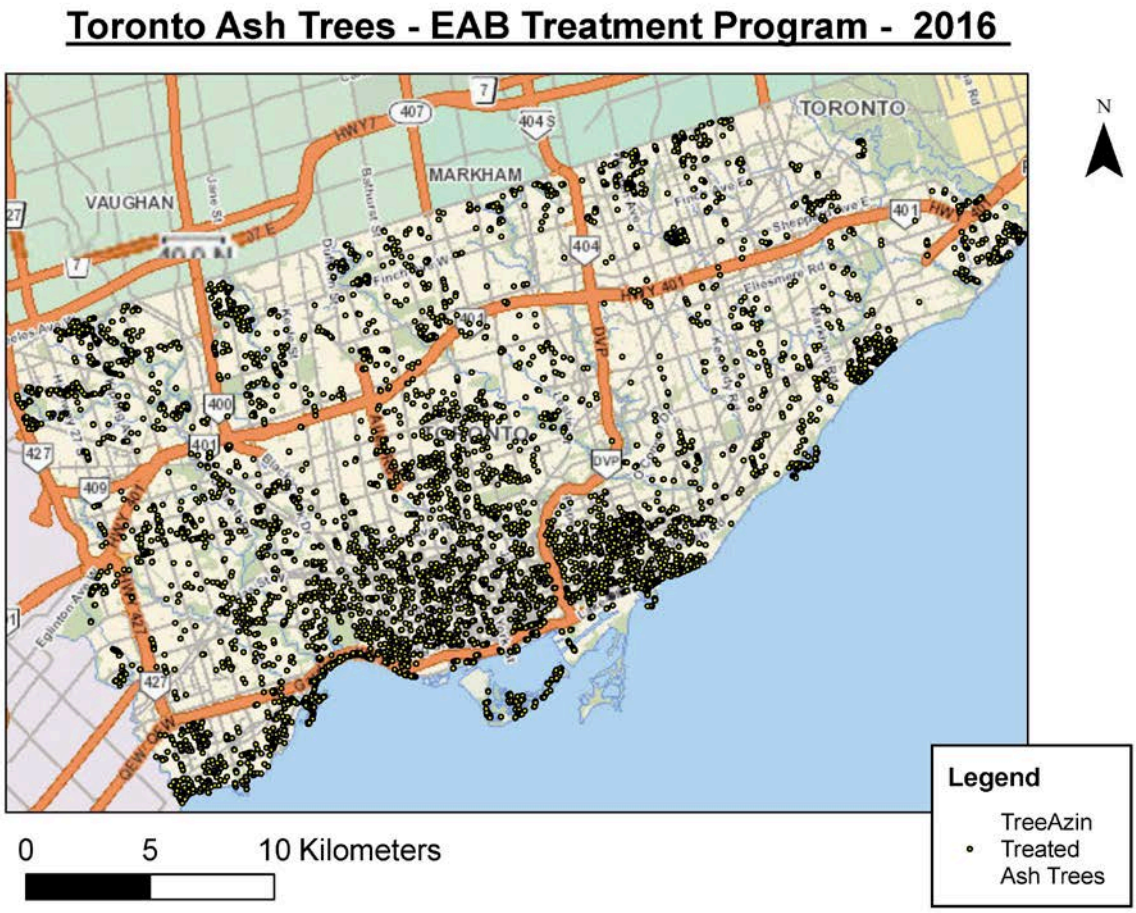
Figure 20: Insecticide stem injection of a mature ash tree

The recommended time interval for the treatment is between June and September. Prior to each injection cycle, staff conduct pre-injection inspections on each tree that is scheduled for injection to determine whether the tree is a good candidate. The inspection is performed in mid to late spring (May/June) when the trees are in full foliage and tree health can be evaluated most accurately. Trees that are no longer suitable for the treatment will be taken off the injection program and scheduled for removal. It is anticipated that 8500 ash trees will remain in the program by 2019.

Continued research is underway regarding the effectiveness of increasing the injection frequency from a 2-year interval to annual treatments in periods when the pressure from EAB population is the highest. In 2015, ash trees were selected across the city for back-to-back yearly injection to compare the effectiveness between these treatments.

The map below shows the distribution and location of City-owned trees injected with TreeAzin® as of 2016.

Figure 21: Map of ash trees in the Emerald Ash Borer Treatment Program



Removal of infested trees: EAB kills ash trees of all sizes. Initial establishment of Toronto's infestation was slow, however, once the beetle was well established, mortality was rapid. It is estimated that most ash trees will be killed by 2017.

Urban Forestry plans to remove and replace dead and dying City-owned trees in areas with the highest mortality. Peak levels of mortality occurred in 2015 and 2016 and are predicted to begin to taper off as the ash population disappears. At this point, most ash trees have been removed and insecticide treatments have stabilized based on the peak years of EAB infestation in the city.

The graph below depicts the cumulative number of ash trees removed and the number of ash trees treated with insecticide beginning in 2011. The number of ash tree removals will drop sharply in 2017, while insecticide treatment is projected to continue at the current level.

Figure 22: Ash tree removal and TreeAzin® injection progress (including projections for 2017-2019)

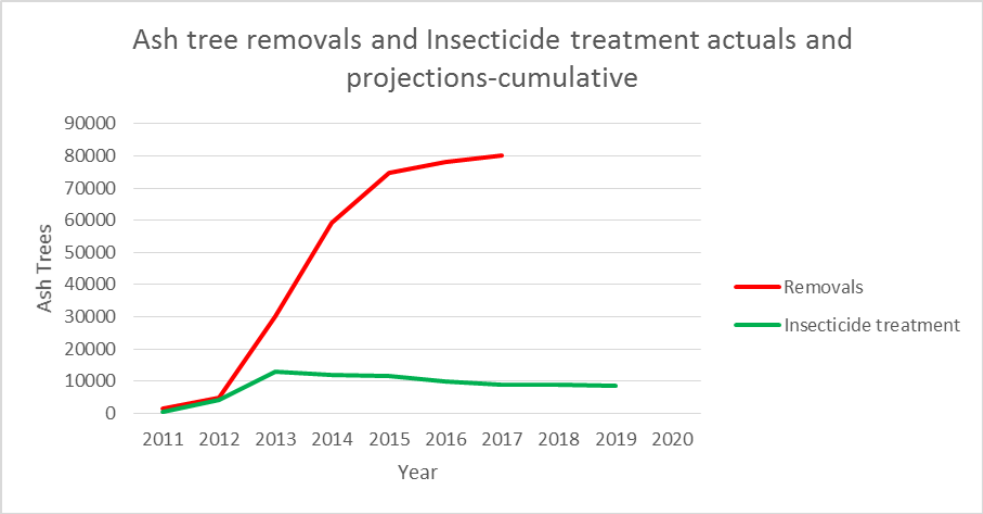


Figure 23: Treated (T) vs. untreated (uT) ash trees

Tree canopy replacement: The loss of tree canopy resulting from ash mortality is significant. As such, tree planting is a major component of the Urban Forestry plan to manage EAB.

Urban Forestry will continue to identify and prioritize planting opportunities in those areas of the city with an Emerald Ash Borer infestation and/or areas with high ash tree canopy cover. New and replacement tree planting are necessary to lessen the impact of the inevitable tree loss in these neighbourhoods. Generally, ash trees removed from parks and City-owned boulevards are replaced within two growing seasons.

Public tree planting programs, including ash tree replacement planting, will contribute towards the city's tree canopy cover. However, the most recent tree canopy cover analysis identified that the greatest opportunities for expanding the tree canopy were to be found on private lands. Recognizing that the City has set a target of 40 per cent tree canopy cover, Urban Forestry is developing a tree planting strategy and implementation plan which will include new tree planting and stewardship programs on private lands.

Partnership and Engagement: Urban Forestry has partnered with many groups to deliver the Emerald Ash Borer management program in Toronto.

Canadian Forestry Service: Urban Forestry worked with the Canadian Forestry Service (CFS) to develop early detection tools for Emerald Ash Borer. The protocols developed jointly were used in the 2010 EAB survey program yielding more effective early spatial detection of the beetle. The same tools were also used by other southern Ontario municipalities in their EAB surveys.

University of Toronto – Faculty of Forestry: Urban Forestry has supported research work on the biological control of EAB. In recent years, the University of Toronto has been conducting a study on the parasitism of the native parasitic wasps. The study is continuing and logs containing EAB parasitoids will be placed into multiple sites across several city parks (Centennial Park, West Deane Park, and Poplar Park) over the next few years. American and Canadian researchers are working on parasitoid wasps from the native habitat of EAB, including one, *Tetrastichus planipennisi*, recently released into Canada during 2013 and 2014. Canada does not have permission to rear these wasps and the supply must come from rearing facilities in the USA. The release of parasitoids for biological control is considered a long-term solution for EAB and greatly relies on the success of the establishment of these species into their new environment.

University of Toronto -- St. George Campus: A pilot project was developed in 2013 aimed at bringing together interested members of the community and institutional landowners to discuss management measures, Urban Forestry staff met with representatives from the University of Toronto – St. George Campus and neighbouring residents to discuss combating Emerald Ash Borer in the local area. The meetings afforded the opportunity for participants to present information regarding the scope of the EAB problem around the university campus and to discuss possible management strategies. The results of this initiative included some City-owned ash trees being added to Urban Forestry's pesticide treatment program.

Ministry of Natural Resources and Forestry: A brochure entitled "What you need to know about the Management of Emerald Ash Borer" was developed by Urban Forestry, in partnership with the Ontario Ministry of Natural Resources and Forestry and the Ontario Commercial Arborist Association. The brochure has been widely distributed within Toronto and throughout the Province of Ontario. The brochure includes information on how to identify ash trees and the beetle, symptoms of

Emerald Ash Borer infestation, treatment options, tips for hiring a tree care professional, and recommendations for replacement planting. A copy of the brochure is available on the City's website (www.toronto.ca/EAB).

Local Enhancement and Appreciation of Forests (LEAF): Urban Forestry has collaborated closely with the non-profit organization LEAF on the Emerald Ash Borer issue. With the assistance of the City of Toronto, LEAF has implemented an "EAB Ambassador Program" that includes; consultation with private property owners regarding the impacts of EAB, discussions about management options, and the role private landowners play in sustaining the city's urban forest. This program uses volunteers (Ambassadors) to spread the message about EAB through a variety of networks, including; a door-to-door campaign, presentations at community schools or club meetings, distribution of information and materials at events, and through individual social media networks (e.g., Facebook and Twitter). Urban Forestry's support of this program includes assisting in training LEAF staff and volunteers, providing information and feedback on proposed programming, and providing information material for distribution.

Public engagement has been a critical part of the EAB management program. Regular and consistent communication:

- improves public understanding of how to respond to the EAB threat
- educates private landowners of potential costs they will face to maintain trees affected by EAB
- encourages and promotes replacement tree planting in the event of tree removal on private property

Urban Forestry has prepared several staff reports about the Emerald Ash Borer since 2003. Staff have taken proactive steps to share information and to educate residents about EAB and the implications of this pest to ash trees, on both public and private property, by posting information on the City's website and by conducting periodic public meetings and workshops. Urban Forestry will continue to make staff available to meet with interested parties as required. In addition to regular website updates, Urban Forestry staff publish numerous media releases and participate in numerous interviews with print, radio, and television media to raise the local and national profile of the pest, including EAB awareness posters displayed in TTC shelters throughout the city.

6.4 Asian Longhorned Beetle

History: The Asian Longhorned Beetle (*Anoplophora glabripennis*) is a wood-boring insect native to China and Korea. The beetle poses a great risk to Canada's hardwood forests and shade trees, attacking multiple host species. With no known natural predators in North America, ALHB is a serious threat with the potential to destroy up to 70 per cent of the trees and canopy of not only the urban forest but the natural deciduous forests throughout Ontario and Canada. In Toronto, 42 per cent of the street

trees are preferred host species for ALHB, with 33 per cent being maple that are particularly susceptible to infestation. As a result, the potential for a devastating impact on Toronto's forest canopy from ALHB is high, if allowed to become established.

Between 1996 and 2002, populations of ALHB were found in several cities in the USA. In 2003, an established population was discovered in an industrial park, on the border between Toronto and Vaughan. The Canadian Food Inspection Agency, in partnership with the City of Toronto, the City of Vaughan, the Ontario Ministry of Natural Resources and Forestry, the Canadian Forestry Service, the Toronto and Region Conservation Authority and other stakeholders, implemented an immediate eradication program.

The eradication was declared successful in 2013. Unfortunately, a new infestation was detected in Mississauga and in the northwestern corner of Toronto later that same year resulting in a second eradication program being initiated.

Figure 24: Adult Asian Longhorned Beetle

Prevention: Prevention of ALHB introductions are possible with tighter Canadian Food Inspection Agency (CFIA) phytosanitary regulations on the importation of wood and wood products (especially solid wood packing materials) from Asia into North America. These regulations, in combination with elevated awareness, have significantly reduced new introductions, although a number of interceptions are still being recorded. Phytosanitary experts in North America are working on improving inspection protocols and the enforcement of phytosanitary measures and standards.

Figure 25: Ground survey of Asian Longhorned Beetle

Figure 26: Aerial survey of Asian Longhorned Beetle

Detection: Early detection of ALHB is critical for any successful eradication program. The beetle has a relatively slow reproduction rate and naturally congregates in a localized area, but in the urban environment, there is a high risk of human-assisted

spread over longer distances. Once ALHB is discovered, a delimiting survey led by CFIA is carried out to quickly establish the boundaries of the infested area and to determine where and when the species first established. If detected in the early years of spread, eradication is a feasible management option. In conjunction with the CFIA and other municipalities, Urban Forestry staff continue to look for signs of ALHB throughout the city and to respond to suspected sightings or concerns addressed by the public. Urban Forestry staff will continue investigations of ALHB presence in the regulated area in the northwestern corner of the city for the next five years.

Response: Confirmed findings of any new ALHB infestations will trigger an eradication program, led by the CFIA. The City of Toronto has supported this program since 2003 given the shared interest in eradication.

An eradication program involves removal and sanitary disposal of all host trees within a radius of 800 m from the epicenter of the detection site. Parallel with this is a systematic survey protocol developed by CFIA and scientists from the Canadian Forest Service and the Ontario Ministry of Natural Resources and Forestry. The survey is carried out for five years from the date of the most recent detection in a given location. The goal of CFIA and its partners, including the City of Toronto, is to implement the most appropriate actions aimed at containing and eradicating ALHB from the urban environment as quickly and efficiently as possible. Eradicating the ALHB is a long, difficult and expensive process requiring significant resources.

For the current infestation, quarantine zone(s) have been established in the area of the most recent spread, and movement of wood material is prohibited as enforced by CFIA. Inspections of all host trees in the defined area will be done with the assistance of Urban Forestry staff as well as other affected municipalities and government organizations. Quarantine areas will be defined with signage posted by CFIA.

Eradication of the previous Canadian infestation in Toronto and Vaughan took 10 years. Research to find more effective detection, control, and eradication methods is ongoing, and success requires co-operation and co-ordination among many partners. New host trees should not be planted within the 5-year monitoring period for areas where the beetle has been found.

Partnership and Engagement: Partnerships are critical to successful implementation of the programs led by the Canadian Food Inspection Agency (CFIA), to contain and eradicate the beetle. Urban Forestry staff have taken an active role on science panels, committees, technical working groups, and will continue to assist in the scientific data collection, research and host tree removals.

Urban Forestry has been a significant partner in the implementation of surveys to detect ALHB. The City has provided staff resources, contractor resources and equipment to support the CFIA in these activities since 2004. These contributions have been funded by the Government of Canada through the CFIA. Battling the beetle is not the work of

government alone. Support from residents, tenants, property owners, employees, arborists, landscapers and naturalists is essential. An informed and active community is a critical element in this battle.

Figure 27: Asian Longhorned Beetle regulated area in 2013

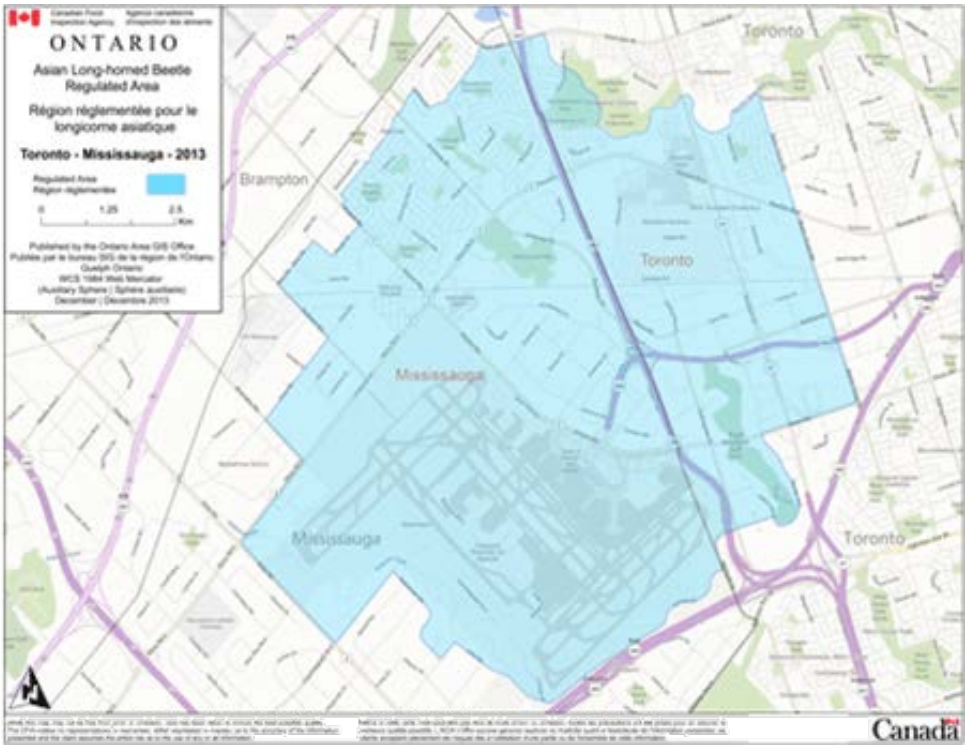
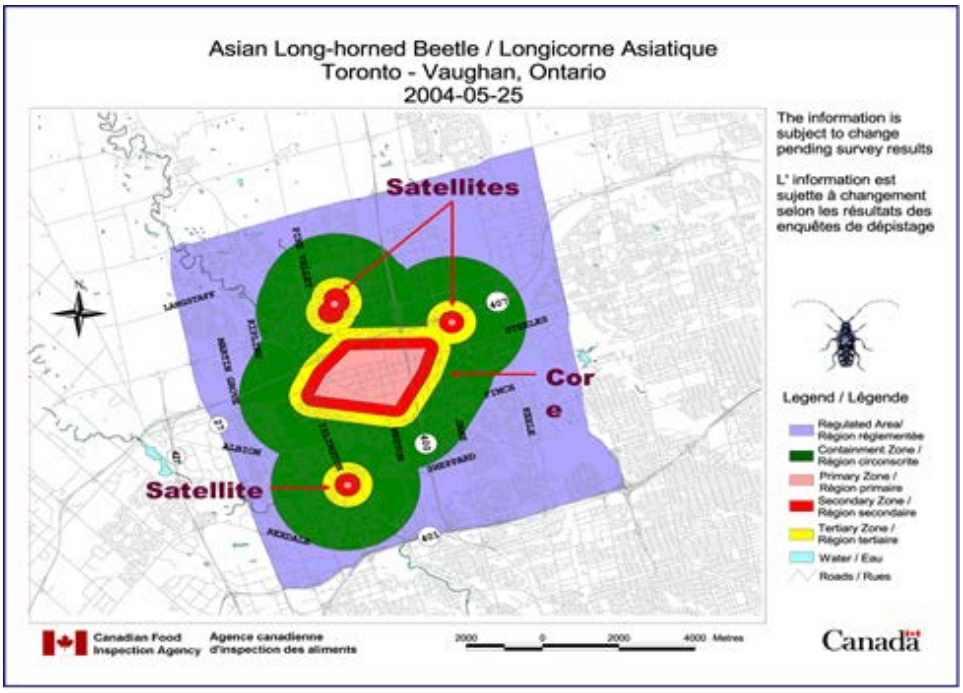


Figure 28: Asian Longhorned Beetle regulated area in 2004



The importance of public support in helping to spot ALHB has been recognized since this insect was first identified by a member of the public. Urban Forestry undertook to expand public awareness and understanding through participation in public meetings led by the CFIA as well as through publication of the document, "Trees Under Threat: The Asian Long-horned Beetle In Greater Toronto" in 2004. This information guide has been modified over the years and continues to be used as a basis for web communications.

Urban Forestry staff collaborated in the writing of the "Detecting Signs and Symptoms of Asian Longhorned Beetle Injury" training guide.[6] This publication has been used as a reference tool in the ALHB eradication programs throughout North America and Europe.

Continued public interaction and education will be important in detecting new infestations. In addition, continued education of City staff is necessary to ensure diligence in detecting possible outbreaks. To create awareness and educate the public about ALHB, Urban Forestry, in cooperation with the CFIA, set up eight locations across the city with simulated ALHB infestation signs on the most common host tree species.

Figure 29: Example of Asian Longhorned Beetle public information sign

7 Management Programs for Potential Forest Health Threats

Potential forest health threats are threats that are not yet established in Toronto but that are identified as contributing to the imminent health risk to the urban forest. Toronto's Forest Health Threats document identifies the risk management criteria, potential

[6] Jozef Ric, et. al. Sault Ste. Marie: Great Lakes Forestry Centre, 2007

impacts and proposed management programs to address the risks and potential impacts.

7.1 Beech Bark Disease

History: The fungus (*Nectria* sp.) works in tandem with a scale insect *(Cryptococcus fagisuga*) seen on the trunks of beech trees as woolly, white tufts that harbour colonies of the scale. The scale creates small feeding wounds that allow the fungus to enter a tree. After introduction of the beech scale insect to Nova Scotia in 1890, the *Nectria* fungus began infecting wounds opened up by the insect. Beech Bark Disease spread through the Maritimes, Quebec, and the northeastern United States. It has been detected in southern Ontario.

Figure 30: On the left, beech scale on beech stem; on the right, Nectria fruiting bodies on beech stem

BBD infection leads to multiple canker development and eventual death of American beech trees (*Fagus grandifolia*). European Beech (*Fagus sylvatica*) is not susceptible to this disease. The fungus can be carried by wind and animals, and tends to be much more devastating to stands of beech trees rather than to individual trees.

Toronto does not have many dominant stands of beech. Beech species represents only 0.9 per cent of the total tree population. The overall threat of this disease to Toronto's forest canopy can be considered at medium level (representing a potential loss of 91,800 trees). Beech trees are significant in contributing to biodiversity within the climax forest community in which they are found (associated with sugar maple, yellow birch, white pine and oaks). They also provide crucial wildlife habitat, where the nuts are an important food source for wildlife. Beech trees develop large numbers of root suckers, contributing to successful spread and regeneration of young trees. The success of natural regeneration also contributes to the importance of beech species in Toronto forests where regeneration of nut trees from seed is more limited. Finally beech trees have an aesthetic beauty that has inspired many tree lovers to grow the species in manicured landscapes. However, light coloured bark and shallow roots result in frequent damage meaning beech trees tend to do better in natural forest conditions.

Prevention: BBD is quite difficult to control and is most devastating in stands of mature beech trees where the scale and fungus can spread quite easily. BBD has already been identified in many areas of Ontario where beech trees can be found. Avoiding the movement of firewood from areas where BBD is known is the best prevention. The scale insect itself is very difficult to control on larger trees but on individual, high-value beech trees, it may be possible to control using dormant oil and the mechanical removal of the scale from trees using pressurized water hoses.

Detection: Urban Forestry needs to determine whether any stands of mature, dominant beech exist within the city. Asset mapping was initiated in 2016. Currently, solitary beech trees have been noted throughout the Toronto area and may be monitored for scale at the same time as European Gypsy Moth data is collected. If beech stands are noted and accessible, annual monitoring programs should be introduced to detect the scope of infestation. Over 400 American Beech trees have been inventoried at five woodlots where beech trees are found in large numbers. The presence of scales and the Nectria fungus has been recorded in order to further monitor the development of the disease at these locations.

Figure 31: Beech Bark Disease monitoring site at the Warden Woods beech stand

Response: BBD could have devastating effects on stands of large, mature beech trees. Individual trees may be affected as well. However, there have been instances where some beech trees appear resistant to the disease. Maintenance of these resistant trees, as well as replanting of beech with seedlings reared from these trees, may be a way of retaining beech in forest stands for future generations. In cases where

there is early detection of scale on individual, high-value beech trees, chemical and mechanical control may be used.

Partnership and Engagement: Engaging the public is critical to control the spread of BBD. Urban Forestry provides educational information to the public regarding identifying signs and symptoms of BBD and about the restrictions of movement of wood to control the spread of the disease. The Ontario Ministry of Agriculture and Food and Rural Affairs provides periodic updates about the status of the disease in Ontario, along with recommendations for its management. Urban Forestry maintains contact with the provincial forest pathologist to exchange scientific information about this forest pest.

7.2 Hemlock Woolly Adelgid

History: The Hemlock Woolly Adelgid (*Adelges tsugae*) is an insect of Asian origin and a serious pest of hemlock species (*Tsuga canadensis*) native to Ontario. Large areas of hemlock throughout the eastern USA have already been killed or severely damaged by this pest. Damage to hemlock trees has had serious environmental consequences, including habitat loss and degradation of watersheds. HWA typically spreads via wind, birds, deer, and other forest-dwelling animals. The risk of long distance dispersal primarily comes from the movement of infested nursery stock. In addition, the movement of logs and other unprocessed forest products present a risk of spreading the insect. Hemlock represents 0.2 per cent of the total tree population in Toronto. The greatest threat is to woodlots and ravines since hemlock is not a common street tree.

Prevention: HWA was detected in Ward 13 in 2010 on a small number of newly-planted hemlock trees on private property. The Canadian Food Inspection Agency (CFIA) ordered the destruction and sanitary disposal of those trees. Currently, the most effective form of preventing new introductions of this pest is to regulate or monitor the movement of nursery stock from infested areas. By designation, this is the role of CFIA.

Detection: Urban Forestry staff created an inventory of hemlock trees on city streets and in parks using data taken from previous tree inventories and the City's database. Trees were inspected to confirm their location and evaluate their health. In addition to this, approximately 100 plots of hemlock tree stands consisting of 30 or more hemlock trees were identified in ravines and woodlots using data from the Toronto and Region Conservation Authority. The plots were inspected to confirm their existence and evaluate their health. At least 10 sample trees in each plot are surveyed annually for the presence of HWA. City staff working in close proximity to hemlock trees should be trained in identification of the pest, as well as trained in the inspection of material proposed for planting in natural areas.

Figure 32: Hemlock Woolly Adelgid on hemlock tree at Toronto site

Urban Forestry has initiated workshops to engage staff who manage natural areas to educate them on what early signs or symptoms may look like. Early detection is crucial in any successful eradication of this pest and is best achieved by constant field observation of the existing hemlock within the city. Continued awareness about the current spread and new detections of HWA from the surrounding environment is also important. Careful inspection of nursery stock prior to planting is critical. Urban Forestry staff involved in tree planting will be trained to recognize signs of the HWA.

Response: It is anticipated that the initial response will involve CFIA assistance and may take the form of removals, sanitation, and/or chemical control. The most likely outcome will be the removal of affected trees and replanting in areas where tree loss is significant. A number of valuable trees may be selected for pesticide injection or foliar spray application.

Partnership and Engagement: The greatest potential for loss in Toronto will be in the natural areas and ravines of the city where hemlock are present. Diligent observations by staff already working in those areas will be implemented to achieve early detection. The Canadian Forest Service led several field sessions in which an early infestation of HWA was simulated. Urban Forestry staff attended one of these sessions in Guelph Ontario in the fall of 2015. The simulations allowed participants to experience the difficulty in identifying of an early HWA infestation as well as developing observational skills and processes to look for the signs and symptoms of HWA.

7.3 Sudden Oak Death

History: Sudden Oak Death (SOD) is a condition that leads to the death of oak species caused by a fungus (*Phytophthora ramorum*) that is associated with numerous plant diseases throughout the USA. SOD has not been identified yet in Canada but is considered a high risk due to the movement of nursery stock between the two countries

and the fact that it can be carried by numerous plant species. Oak species including the northern red oak *(Querus rubra)* are highly susceptible to this disease. According to recent canopy analysis, 1.8 per cent of the City's 10.2 million trees are oak species.[7]

Impacts of SOD on Toronto's oak trees would be devastating, especially in oak-dominated areas such as the Beach and High Park neighbourhoods. Oaks are an important species contributing to biodiversity in Toronto's urban forest. Oaks are frequently planted both on street boulevards and in parks, given their contribution to wildlife habitat as well as their value in forming large canopy trees that are less susceptible to ice damage and drought than many other tree species. Oak trees conjure descriptions such as "majestic" and are valued for their beautiful architecture.

Prevention: Early detection and sanitary removal and disposal may be a way of controlling the spread of SOD. The CFIA conducts annual surveys for the presence of the disease in Canada with attempts at linking it back to nurseries within the United States. Distribution of this information to Urban Forestry staff is highly valuable if the disease has been detected. Toronto plants many trees that originate from nurseries in the USA, and knowing how to identify the disease is essential and needs to be passed on to City staff and the public.

Detection: Early detection of SOD is crucial and is best done through constant field observations by staff. Knowledge of signs and symptoms of the disease is critical. Possible sightings need to be reported immediately to Urban Forestry staff for confirmation.

Response: Positive identification of SOD by the CFIA needs to be prompt and infected trees removed and destroyed. Thorough investigations and monitoring of nearby oak trees need to be done if SOD is positively identified.

Partnership and Engagement: SOD has not yet entered Canada, therefore it may still be possible to prevent its introduction. If the disease is found in Ontario, the effects could be devastating to Toronto’s urban forest. Identification and early detection are a top priority and need to be undertaken in conjunction with federal and provincial agencies.

7.4 Oak Wilt

History: Oak Wilt, caused by the fungus *Ceratocystis fagacaerum*, is a serious disease of oak trees *(Quercus sp.*). It attacks the water-conducting system, causing branch wilt and tree death. The oak Wilt fungus can infect trees through roots that are grafted between infected and healthy trees, but can also be spread by two groups of sap-

[7] Every Tree Counts: A Portrait of Toronto's Urban Forest, 2013, Appendix 8, p.94

feeding and bark-feeding insects attracted to fresh wounds during spring and early summer.

Figure 33: On the left, symptoms of Oak Wilt on red oak leaves; on the right, Oak Wilt on a red oak tree

Prevention: Oak Wilt has not been identified in Canada but has been identified nearby in forests of the north-central United States. If the disease is reported and confirmed, an eradication program will be initiated by the CFIA in co-operation with provincial and municipal authorities. Early detection is the most important step to prevent the spread of this disease, as well as avoiding the pruning of oak trees during the growing season when sap and bark-feeding beetles are active.

Detection: Early detection of Oak Wilt is critical and is best be done through consistent field observations by City staff. Knowledge of signs and symptoms of the disease are critical and possible sightings need to be reported to Urban Forestry for inspection.

Response: Oak Wilt has the potential to be a devastating disease within Toronto. Stressed oak trees in an urban environment are vulnerable to infection and Toronto has several oak-dominated neighbourhoods. Confirmation of Oak Wilt will trigger an eradication program of affected trees and establish a monitoring program of oaks in the vicinity. This action will most likely be done under the guidance of the CFIA. Wood will need to be destroyed and quarantine boundaries established to restrict further movement of wood. Public awareness and internal staff education would be a priority component of the response plan.

Partnership and Engagement: The United States Department of Agriculture has published documents on Oak Wilt that will be useful as educational tools and will assist in the development of documents that relate to Toronto's urban forest. Forest Health Care staff will visit jurisdictions in the U.S. where Oak Wilt is established to gain first-hand knowledge of the disease and management strategies to control it.

7.5 Asian Gypsy Moth

History: The Asian Gypsy Moth (including *Lymantria dispar asiatica, Lymantria dispar japonica, Lymantria albescens, Lymantria umbrosa,* and *Lymantria postalba*) is an

exotic pest not known to occur in North America. AGM larvae feed on more than 600 plant species, covering over 100 botanical families. Significantly, female AGM, unlike female EGM, are strong fliers capable of flying up to 40 kilometres. The broad range of host plants, combined with the female's ability to fly, could allow AGM to spread rapidly. Large infestations of AGM have the potential to completely defoliate trees, leaving them weak and susceptible to disease or attack by other health threats. Several risk assessments over the years have concluded that due to the similarities between Asian and North American ecosystems, the AGM has great potential for colonization in North American forests.

Prevention: Any introduction and establishment of AGM in North America would pose a major threat to the natural environment in the city of Toronto. Since 2009, the CFIA in partnership with the United States Department of Agriculture, has worked with foreign trading partners to monitor populations of AGM and inspect ships at the ports of departure and destination to certify that they are free of AGM life stages. Although these preventive measures are effective, occasional introductions of AGM have occurred.

Between 1991 and 2012, the AGM was detected and eradicated on at least 20 occasions in locations across North America. The most recent AGM detection occurred in 2013 when a single male moth was caught in a survey trap in Pittsburgh County, Oklahoma. United States Federal and State officials conducted a wide spread survey, using pheromone traps to determine whether an infestation was present. No further detection has been reported since.

Detection: Systematic surveys help detect any possible introductions at an early stage when eradication efforts are most effective and least costly. Early detection relies on a systematic monitoring program using pheromone traps to locate and estimate the size of recently introduced populations of AGM. The monitoring program is conducted by the CFIA, who place traps throughout the province. If male moths are trapped, the trap density in the following year is increased. This is commonly known as delimiting trapping. Traps containing a synthetic female pheromone are placed in the field during early summer, well before the expected flight period in late July through August in order to monitor populations of male moths. Traps are collected in the late fall and data summarized by the CFIA to establish further detection and treatment efforts.

Response: Several treatment options are available to eradicate AGM. The most common treatment for AGM is the application of Btk. The other treatment is mating disruption, using a pheromone emitted by female AGM to attract mates. This pheromone is released at high levels in and around infested areas, overwhelming the natural signal emitted by female AGM and, as a result, making it difficult for male moths to locate females and mate. Every effort needs to be made to eradicate this pest at early stages of introduction. A population is considered to be eradicated after two years has passed without any moths being trapped. After the area has been declared free of AGM, the trapping density returns to former monitoring levels. If AGM were to become

established in Toronto, the damage could be more extensive and costly than the damage caused by European Gypsy Moth.

If eradication is no longer an option, the alternative approach would be similar to European Gypsy Moth management, with an objective to prevent damage to vulnerable plant communities, by controlling outbreak levels of AGM.

Partnership and Engagement: It is critical to maintain the information flow between CFIA and other stakeholders. Urban Forestry will exchange information about the existing European Gypsy Moth monitoring program, and participate in an AGM eradication program. Education and public engagement in the monitoring programs can increase the chances for the early detection of this invasive pest. This can be done through parallel monitoring of the European Gypsy Moth.

7.6 Thousand Cankers Disease

History: Thousand cankers disease is a relatively new threat introduced to North America and linked to mortality of black walnut trees. The disease has been detected in the northeastern United States and has the potential for introduction into southwestern Ontario. The invasive fungus (*Geosmithia morbida*) is carried by the native walnut twig beetle (*Pityophthorus juglandis*). Currently, there are no reported cases of the disease in Ontario, but the impact of the disease on walnut trees in Toronto could be very damaging. Walnuts are an important food source for wildlife in parks and ravines. Black walnut trees tend to die one to two years after infection. Butternut (*Juglans cinerea)*, another member of the walnut family, listed as Endangered under the federal Species at Risk Act (SARA)[8], is also susceptible to the thousand canker disease. Species of the walnut family represent 0.4 per cent of the City's tree population.

Prevention: This disease has yet to be reported in Ontario so early detection is important. Urban Forestry staff who work in the field need to be trained in the identification of the disease by attending Ministry of Natural Resources and Forestry workshops. Communication with CFIA is also critical in determining the proximity of the disease. Movement of wood and lumber must also be controlled to limit the spread of the disease. Sanitization of tools used for tree maintenance work between jobs is also a key component in helping to limit the spread of the disease. Communication with the public and stakeholders needs to be established through workshops, web information and other publications.

Detection: City staff must be trained to identify the signs and symptoms of the disease. Taking inventory and mapping black walnut trees is essential to estimate the volume and the dispersal of susceptible trees within the city. Systematic surveys will enhance

[8] Species at Risk Act, S.C. 2002, c.29, Part 2.

the probability of early detection. Trapping of the walnut twig beetle may assist in determining threat levels.

Figure 34: Exit holes of walnut twig beetle, vector of thousand canker disease

Response: A confirmation of the disease may trigger a sanitation removal program of walnut trees. The CFIA has several options if presence is detected, ranging from doing nothing to eradication. If the eradication is not feasible, the area of infestation may be regulated by the CFIA in partnership with the City of Toronto. CFIA has the mandate and the authority to extend control programs to privately owned trees. They can also "deputize" other jurisdictions to do so as well.

Partnership and Engagement: Cooperation with CFIA, Ontario Ministry of Natural Resources and Forestry, Canadian Forest Service and other stakeholders will raise public awareness of the risk posed by this disease. Communication with the public will increase the chance for early detection of this disease and the implementation of an effective management program.

7.7 Butternut Canker

History: Butternut, *Juglans cinerea L*. is a member of the walnut family and is native to eastern Canada. It grows in southern Ontario and Quebec, as well as New Brunswick. It is a small to medium-sized deciduous tree. The species is relatively short-lived, rarely living longer than 75 to 100 years. Butternut is intolerant of shade, meaning it does not grow or reproduce under a forest canopy. Butternut can be found scattered individually or in small groups within mixed hardwood stands, along fence lines or in open fields. Currently, the butternut is listed as an endangered species under the federal *Species at Risk Act*. In Ontario, it is designated as an endangered species under the provincial *Endangered Species Act*[9].

[9] Endangered Species Act, 2007, S.O. 2007m c, 6, Schedule 2.

The butternut tree is fast fading from our woodlands, field edges and backyards. The Butternut Canker fungus *Sirococcus clavigignentijuglandacearum* is causing the butternut's decline throughout its native range. The fungus can infect and kill healthy trees of any age and size. Infection usually occurs through buds, insect wounds or other openings in the bark. The fungus kills the cambium in elongated patches called cankers. The cankers expand to encircle branches and stems and cut off the flow of water and nutrients. As the disease progresses, branch dieback in the sunlit part of the crown becomes visible. As the cankers increase in number and size, crown die-back accelerates. In early spring and summer, cankers may begin to exude a blackish fluid which dries to form sooty patches.

Since its discovery in 1967, the fungus has spread rapidly and efficiently throughout the range of butternut. Methods of dissemination can range from wind, insects, birds and rain splashes. Some insects, like the butternut curculio beetle (*Conotrachelus juglandis*), create egg laying sites that act as possible sites of infection for the fungus.

Origins of the canker are currently unknown but it is believed to have originated in Asia since Asian walnuts are relatively resistant.

Prevention: Control of the Butternut Canker is very difficult since it is already widespread. Most butternut retention plans now focus on identifying true butternuts that show some genetic resistance to the canker. Natural Resources Canada suggests conserving all butternut trees with a canker-free stem and less than 50 per cent crown dieback, as well as those with less than 20 per cent crown dieback and less than 25 per cent of the circumference of the main stem affected by cankers. Any tree with at least 25 per cent crown dieback and at least 20 per cent of the circumference of the main stem affected by cankers should be removed, as should trees with more than 50 per cent crown dieback, even if the stems are canker-free. High-value trees that are severely infected can be conserved by pruning the affected branches and excising trunk cankers.

Another challenge is the presence of butternut hybrids. The presence of hybrids makes the identification of true butternuts challenging. Hybrids of butternut and Persian or English walnut (*Juglans regia*) are known as *Juglans x quadrangulata*. They can form spontaneously but are uncommon, probably because *J. x quadrangulata* trees produce few fruit. *J. x bixbyi* is the hybrid of butternut and Japanese walnut (*J. ailantifolia*). Heartnuts are a horticultural variety of Japanese walnut. Hybrids can be known to have signs and symptoms of the canker but show resistance to mortality and are not protected under the *Endangered Species Act* in Ontario.

Detection: Creation of an inventory including GPS location, size, and health of both hybrid (*Juglans x quadrangulata, Juglans bixbyi*) and true butternut (*Juglans cinerea*) needs to take place across the city. Inventorying will consist of street, park and ravine trees, where accessible. The collected data will be used to aid in the management of

natural areas where butternut is present, and as a tool for seed collection of possible resistant trees to butternut canker.

Through compilation of existing data from the Toronto and Region Conservation Authority, Toronto Maintenance Management System, Davey Resource Group and historical data indicating locations of butternut, an initial list of approximately 500 butternuts has been established. Urban Forestry staff will inspect each of these sites to determine if these trees are still present, if they are butternuts (hybrid or true), the relative health of each tree and whether cankers are noticed. Although there is a high potential for further butternut discoveries is ravine settings, there is also a high probability that many of these would be declining or dead.

Response: Hybridization of native butternuts with English/Persian walnut and/or Japanese walnut is quite common and further complicates identification of true butternuts in the field. At various points in the season tree identification features can assist in verifying a hybrid compared to a pure native. After an initial sweep for butternuts is made using the current inventory, continued visits will help to further confirm possible hybrids in the inventory. Using i-pads and mapping applications in the field, trees will be scored in 11 categories. If a tree attains a total score higher than three, it will be deemed a hybrid; scores below three could possibly be pure butternuts. Possible "pure" butternuts may then be lab screened to ascertain their genetic qualities.

Butternut trees that can't be identified by the morphological characteristics and that are in good health may be lab tested to confirm DNA. Lab screening will only be done when needed or when true, high-value butternuts are strongly believed to exist in an accessible area, or when work in an area that may result in damage to a true butternut is to be done. Screening can be done on leaves or terminal buds (three healthy samples are required for either leaves or buds). Screening is done by the Ontario Forest Research Institute in Sault Ste. Marie, Ontario.

Private trees (especially in ravines) will be identified when easily accessible. Lab screening will not be done on private trees by Urban Forestry staff. Private butternuts will be noted in the City's tree database as possible hybrids if not confirmed using the butternut ID scoring key.

Partnership and Engagement: Within approximately three years of starting the project in 2014, reliable data has been collected with regards to location, health and genealogy of butternuts. Data collection through site visits will be ongoing and an up-to-date workable list will be maintained. This information will readily be shared with any interested groups with a focus to support Urban Forestry, Toronto and Region Conservation Authority and the Forest Gene Conservation Association.

Knowledge of exact locations of true butternuts and hybrids will greatly benefit work related to maintaining and protecting areas where true butternuts are known to exist as well as provide a possible seed source for canker resistant butternut trees.

8 Conclusions

Toronto's Forest Health Threats document recognizes the threats from non-native forest pests as a key challenge to maintaining and expanding Toronto's urban forest. This document promotes forest pest management programs that are environmentally, socially and economically sound. Systematic surveys, pest monitoring, inventory and data management are identified as important tools in forest health care. This document outlines a comprehensive approach to urban forest management related to pest invasion and outbreak.

This document sets out program objectives, a prescribed course of action and recommended best management practices to address current and potential forest pest invasions. Historical movement of forest pests and risk assessment can provide a strong indication of future introductions and spread. Once established in the new environment, the likelihood of the pest invasion spreading is high. However, there are many ways to mitigate the destructive impact of old and new pest invasions. Advanced planning and assessment of urban forest composition and potential risks to threats, combined with other forest management strategies such as enhancing biodiversity, increasing awareness of the urban forest, reducing stressors associated with climate change and promoting stewardship have an important role in protecting the urban forest from destructive non-native forest pests.

Toronto's Forest Health Threats document recognizes the important role of key stakeholders in the effective management of forest health threats. The implementation of the recommendations outlined in the document relies on the support and cooperation of various City divisions, partners in the public and private sectors, and members of the community. Dedicated federal, provincial and municipal government leadership, and coordination among non-government organizations and private stakeholders is crucial to the successful management of invasive forest pests. Urban Forestry is committed to an ongoing collaboration on invasive forest pest issues by enabling stakeholders to become actively involved in projects that address forest health threats and by improving public understanding and awareness.