Workshop Proceedings: Guiding Principles for Managing the Emerald Ash Borer in Urban Environments

18 November 2009
Royal Botanical Gardens
Burlington, Ontario

Natural Resources Canada | Ressources naturelles Canada

Ontario

Workshop Proceedings:

Guiding Principles for Managing the Emerald Ash Borer in Urban Environments

18 November 2009

Royal Botanical Gardens
Burlington, Ontario

edited by

D. Barry Lyons[1] and Taylor A. Scarr[2]
[1] Natural Resources Canada, Canadian Forest Service
1219 Queen Street East, Sault Ste. Marie, Ontario P6A 2E5
[2] Ontario Ministry of Natural Resources,
Suite 400, 70 Foster Dr., Sault Ste. Marie, Ontario P6A 6V5

2010

Organizing Committee
Dave Kreutzweiser
D. Barry Lyons
Joe Meating
Stan Phippen
Krista Ryall
Taylor Scarr

Library and Archives Canada Cataloguing in Publication Data

Emerald Ash Borer Workshop (2009 : Burlington, Ont.)
Workshop proceedings : guiding principles for managing the emerald ash borer in urban environments

Electronic monograph in PDF format.
Issued also in printed form.
ISBN 978-1-4435-2798-9

1. Emerald ash borer—Congresses. 2. Emerald ash borer—Control—Congresses.
I. Lyons, D.B. II. Scarr, Taylor Adrian, 1963- . III. Ontario. Forest Health and Silviculture Section. IV. Title.

SB945.E48 E43 2010 634.9'7387 C2010-964055-1

OMNR Catalogue Number: 52631

Co-published by Natural Resources Canada, Canadian Forest Service and the Ontario Ministry of Natural Resources, Forest Health & Silviculture Section

Cover: Adult of emerald ash borer (*Agrilus planipennis*) and page ii: adult of emerald ash borer and emerald ash borer infested ash trees in Mississauga, Ontario (photographs by D. B. Lyons).

For more information on forest health in Ontario visit the Ontario Ministry of Natural Resources website: **www.ontario.ca/foresthealth**

You can also visit the Canadian Forest Service website: **www.glfc.cfs.nrcan.gc.ca**

Telephone inquiries can be directed to the Natural Resources Information Centre:
1-800-667-1940
Français: 1-800-667-1840
Email: **mnr.nric@ontario.ca**

Copies of this publication are available at no charge from:

Publication Services
Natural Resources
Canadian Forest Service,
Great Lakes Forestry Centre
1219 Queen Street East
Sault Ste. Marie, Ontario
CANADA P6A 2E5
glfcweb@nrcan.gc.ca

Ontario Ministry of Natural Resources
Forest Management Branch
Forest Health and Silviculture Section
70 Foster Drive, Suite 400
Sault Ste. Marie, Ontario
CANADA P6A 6V5
mnr.nric@ontario.ca

Table of Contents

A Strategic Perspective on Managing the Emerald Ash Borer in Urban Environments

Andy Kenney
Faculty of Forestry, University of Toronto
Toronto, Ontario
a.kenney@utoronto.ca

The programme for the workshop was extremely full and covered a broad range of issues focusing on the biology and control of emerald ash borer (EAB). I was asked to launch the programme with a more general overview of urban forest management. So, my objective for this paper is to set the stage for the discussion of EAB (a tactical view) by presenting a broader perspective of urban forest management planning (a strategic view).

We're all familiar with the many social, environmental and economic benefits that urban forests provide to urban society and to the general environment so I won't go into these here. Suffice it to say that these benefits are all closely related to the leaf area of the forest, so anything we can do to sustain or enhance the leaf area will, in turn, sustain or enhance these benefits. For my own use, I have tried to bring the complexity of urban forest management into a relatively simple but comprehensive definition. To this end, I consider the objective of urban forest management to be:

> *"To optimize the leaf area of the entire urban forest by establishing and maintaining a canopy of genetically appropriate (adapted & diverse) trees (and shrubs) with minimum risk to the public, and in a cost-effective manner."*

So, to come back to the specific objective for this workshop, we should ask ourselves:

1) How will an EAB infestation affect our ability to continue to meet this objective, and
2) How well prepared is our community to deal with an infestation over the long-run, while still addressing the immediate issues of monitoring, control and mitigation of the infestation?

It is my opinion that these two important aspects of EAB management can only be addressed effectively if the specifics of this control are carried out within a broader approach to sustainable urban forest management. To provide some "food for thought" along these lines I will outline a model of strategic urban forest management planning that Philip van Wassenaer and I have been working on for a number of years. As part of that approach, we have expanded on a system of criteria and indicators of success originally proposed by Clark *et al.* (1997).

While this approach to management planning doesn't just focus on EAB or insects more generally, one example might help to illustrate why we should be thinking strategically about the entire urban forest over a long-term while acting tactically to deal with EAB in the immediate term. Based on research he has done in Vancouver, Humble (2004) suggests that other exotic insects are already present near the port area and the potential exists that some of these could reveal themselves to be invasive. This situation may not be unique to the Vancouver area. So, in our planning for EAB control, what are we doing to prepare ourselves for these as yet unknown threats? As we continue to see the impacts of climate change, increasing urbanization, budget challenges and so on, how prepared are we to address challenges similar to, or even greater than, EAB?

While it might be desirable to conduct urban forest planning in a time frame of 50, 75 or even 100 years (ideally something approaching the lifespan of a tree) this is difficult to incorporate into a political realm that is based on four year time horizons or a grey infrastructure lifespan of five to ten years. Similarly, planning in a time frame of 1, 5 or 10 years, when dealing with infrastructure that is just beginning to pay dividends at 15 or so years, does not provide enough time or continuity to make meaningful changes towards improved management and sustainability of the urban forest. We feel that a twenty-year planning horizon is a reasonable compromise.

Our approach to urban forest planning consists of a twenty year strategic plan that provides the overall guiding objectives and vision for the forest. Within this twenty year planning horizon the actions become more specific through four 5-year management plans. The first management plan will be quite specific while the fourth is substantially less detailed at the outset because of the inherent uncertainty we face over the next 15 years. However, each five year plan is still directed by the overall strategic plan and is informed by the preceding management plan(s).

Because of the complexity of the urban forest (the vegetation, the growing environment, the fragmented ownership, the political background, etc.) and the level of uncertainty mentioned above, how can we plan effectively over a 20-year time frame? This can only be accomplished if we set our broad vision and goals but then track our progress and INTENTIONALLY MONITOR AND TEST THE EFFECTIVENESS of each of our actions. This approach is called "Active Adaptive Management". This is not to be confused with "reactive management", where we simply react to each new challenge that we face, but rather one where we anticipate change and set up our planning to prepare ourselves to adapt to this change.

Our model for strategic urban forest management planning consists of a series of components many of which are repeated at the level of the strategic plan, the five-year management plans and the annual operating plans. Fig. 1 illustrates these components. I'll briefly discuss how EAB infestation and control could relate to some of these planning components and/or how these components could inform the control and mitigation of an infestation.

How will an infestation affect the overall goals for the urban forest of the community? Are there good policies in place to assist with control and mitigation efforts? Having these in place before the infestation begins will facilitate the discussions by the various

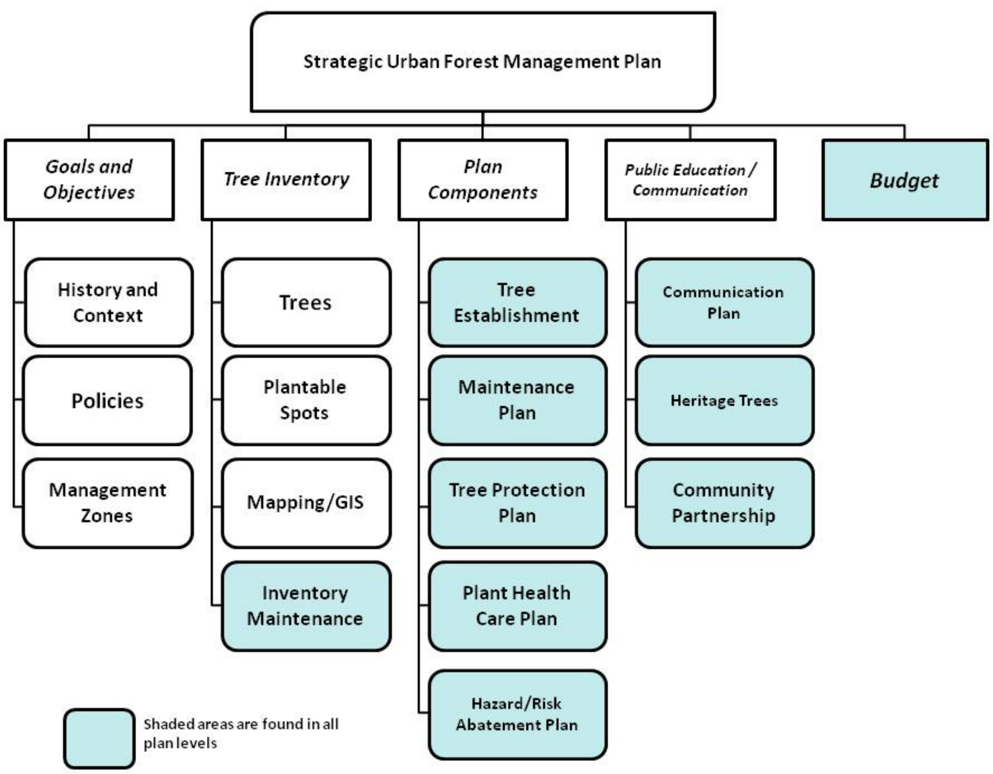

Fig. 1. The structure of a strategic urban forest management plan.

actors. This does not just refer to policies dealing specifically with EAB or pests in general but rather to policies dealing with the urban forest both directly and indirectly. An urban forest inventory is critical to any strategic planning and the implementation of all aspects of that plan. How would an infestation affect the inventory? If the policies mentioned above can be thought of as the "declaration of war" against the invaders (the laws that enable government to take action on behalf of citizens) then perhaps the urban forest inventory is the "intelligence" that is essential to conduct any battle. Part of that intelligence is an understanding of the spatial distribution of the enemy (EAB in this case) as well as the vulnerable and high value targets. In other words, how well is your inventory linked to the municipal GIS?

The linkages between an EAB infestation and many of the items under "Plan Components" in Fig. 1 should be relatively obvious and you are encouraged to consider each of these in detail. However, in the interests of space they will not be discussed here.

If the policies are the "declaration of war" and the inventory is the "intelligence" then a carefully crafted and implemented public engagement/ communications plan is the strategy to "win the hearts and minds" of the public. Keeping in mind that most of the urban forest is on private property illustrates how essential it is to have a well informed public as your ally. As with all other aspects discussed to this point, having this support for the urban forest in place before an infestation is discovered will ensure that these allies are well-informed when you need their support for the specific challenges posed by EAB.

We have expanded and enhanced a series of criteria and indicators for sustainable urban forest management originally proposed by Clark *et al.* (1997). These are outlined in the Urban Forest Strategic Management Plan for Oakville (Urban Forests Innovations Inc. and Kenney 2008). A criterion is characterized by a set of related indicators which are monitored periodically to assess change. "Indicators are measures of an aspect of the criterion. A quantitative or qualitative variable which can be measured or described and which, when observed periodically, demonstrates trends" (Montreal Process 1999). The criteria and indicators we have developed can provide a comprehensive measure of how prepared your community is to deal with an EAB infestation and the more general stewardship and management of the urban forest.

In conclusion, I encourage you to consider these broader scale or strategic approaches to management as you address the tactical challenges the emerald ash borer will pose. In other words don't lose sight of the forest while focusing on the trees.

Acknowledgements

This presentation is based on the collaborative work with Philip van Wassenaer and Alex Satel of Urban Forest Innovations Inc.

Literature Cited

Clark, J. R., N. P. Matheny, G. Cross and V. Wake. 1997. A model of urban forest sustainability. Journal of Arboriculture 23: 17-30.

Humble, L. M. and E. A. Allen. 2004. Alien invaders: non-indigenous species in urban environments. 6th Canadian Urban Forest Conference, Kelowna, B.C. 19-23 October 2004. Available at: http://www.treecanada.ca/cufc6/proceedings/papers/Humble.pdf (accessed 22 December 2009).

Montreal Process. 1999. Criteria and Indicators. Available at: http://www.rinya.maff.go.jp/mpci/criteria_e.html (accessed 22 December 2009).

Urban Forests Innovations Inc. and A. Kenney. 2008. Urban forest strategic management plan Town of Oakville: 2008—2027. Available at: www.oakville.ca/Media Files/forestry/2008UFSMPappendices.pdf (accessed 22 December 2009).

Emerald Ash Borer Biology

D. Barry Lyons
Natural Resources Canada, Canadian Forest Service
Sault Ste. Marie, Ontario
Barry.Lyons@NRCan.gc.ca

Emerald ash borer (EAB), *Agrilus planipennis* Fairmaire was first discovered in North America in the vicinity of Detroit Michigan in 2002 (Haack *et al.* 2002). In the same summer, this invasive beetle was also found in Windsor, Ontario. This beetle probably arrived in North America from its native northeast Asia by hitchhiking in untreated wood-packaging material used for imported trade goods. In Asia, EAB is known from China, Japan, Korea, Taiwan, Mongolia and the Russian Far East (Haack *et al.* 2002). Dendrochronological evidence suggests that it had probably arrived on this continent at least 10 years prior to its discovery (Cappaert *et al.* 2005).

As the common name suggests, host plants for EAB are ash trees (*Fraxinus* spp.). In China, EAB has been reported from *Fraxinus chinensis* var. *chinensis, F. chinensis* var. *rhynchophylla, F. mandshurica, F. pennsylvanica, F. americana* and *F. velutina* (Liu *et al.* 2003). The latter three species are North American species that have been introduced into China. Reported host plants for EAB in Japan include *F. mandshurica* var. *japonica, Juglans mandshurica* var. *sieboldiana, Pterocarya rhoifolia* and *Ulmus davidiana* var. *japonica* (Yu 1992). Consequently, there was some concern that species of *Ulmus* (elms) and *Juglans* (walnuts) might be at risk, but to date these genera have not been attacked by EAB in North America. Possible explanations for these trees being reported as hosts for EAB in Japan may be that EAB in Japan is a different subspecies (i.e., *A. p. ulmi)* or that these records represent collections of adults off of non-host plants. There are 16 species of *Fraxinus* in North America (Farrar 1995). In northeastern North America, EAB has successfully attacked all five species of native ash including: *F. pennsylvanica* (green/red ash), *F. nigra* (black ash), *F. americana* (white ash), *F. quadrangulata* (blue ash) (Haack *et al.* 2002) and *F. profunda* (pumpkin ash) (Czerwinski *et al.* 2007). In Canada, the last two species are uncommon and restricted in distribution to southwestern Ontario. There is mounting evidence that blue ash is relatively resistant to EAB attack. In foliage choice tests, Pureswaran and Poland (2009) found it was less palatable to adults of EAB than green or white ash. European ash, *Fraxinus excelsior* L. is susceptible and has been attacked in Moscow, Russia (Baranchikov *et al.* 2008) and in Toronto, Ontario. Other native ash species are also probably at risk.

The biology of EAB in China was briefly described by Yu (1992) and is similar to what has been observed in North America. In southern Ontario, the majority of the EAB population overwinters as prepupae. These prepupae are mature larvae that have completed feeding, excavated a chamber in which they will pupate and undergone some changes in body structure. Pupal chambers are constructed either in the outer sapwood (xylem) or in the inner bark (phloem), the location depending in part on the thickness of the bark. In thick-barked trees there is a greater tendency to form pupal chambers within the bark. Feeding larvae (Fig. 1) are flattened from top to bottom, but the prepupae constrict in length and become thickened. They also double over on them-

Fig. 1. Early-instar larva of emerald ash borer in feeding gallery in cambial layer.

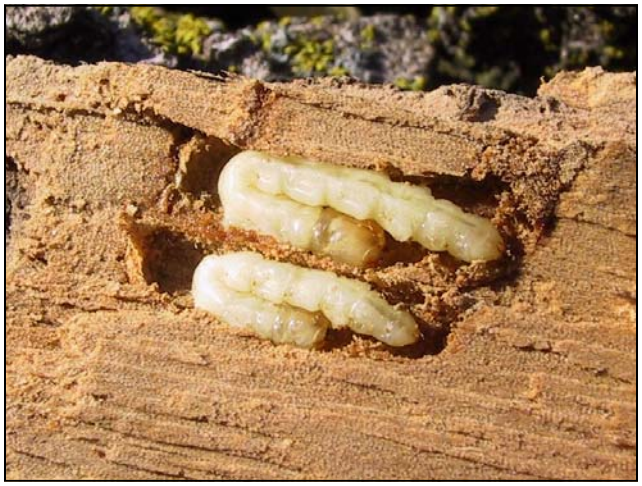

Fig. 2. Prepupae of emerald ash borer in pupal chambers within the bark.

Fig. 3. Pupa of emerald ash borer in pupal chamber within the bark.

selves and become "J"-shaped (Fig. 2). In spring, the prepupae unfold but remain constricted in length and moult into pupae (Fig. 3) within the pupal chambers. The pupae, initially light beige, become progressively darker and start to show the adult coloration as they develop. Adults (Fig. 4) moult out of the pupal skins and remain within the pupal chambers until their exoskeletons harden. Adults then chew their way out of the pupal chamber through the wood and/or bark via "D"-shaped holes. In southwestern Ontario the first adults were observed flying during the last days of May and peak emergence was in mid June (Lyons and Jones 2005). Peak flight activity in southwestern Ontario was in mid July (Lyons and Jones 2005). Insect development or phenology is temperature-dependent. Thus, the date of events in the life cycle of EAB is dependent on the accumulation of enough heat to complete each stage of development, which in turn is a function of local weather. Typically, slower heat accumulation occurs at higher latitudes and altitudes. Consequently, more northerly populations of EAB should emerge later and develop slower through subsequent life stages.

Upon emergence, the EAB adults fly up into the canopy of the ash trees and begin to feed on the edges of the leaves. Beetles are attracted to the host foliage in part by green leaf volatile (GLV's) chemicals (Rodrigues-Saona *et al.* 2008, de Groot *et al.* 2008). Foliage feeding may last for weeks and probably allows for the maturation of the beetles reproductive organs. Mature males seek out females for mating usually on the host foliage. Males detect females visually (Lelito *et al.* 2007), although a short-range pheromone has been implicated (Bartelt *et al.* 2007), and swoop down on the female by what has been described as paratrooper copulation™ (Lelito *et al.* 2007). Mature females produce a contact pheromone (Silk *et al.* 2009, Lelito *et al.* 2009) on their bodies that serves to let the males know they are receptive.

Eggs of EAB are deposited in crevices and under scales of the bark on the host trees. The beetles show a preference for small diameter branches and stems on which to oviposit at low population densities (Timms *et al.* 2006), but as populations build all but the smallest diameters of stems and branches are chosen for egg deposition. Females also show a preference for ovipositing in sunlight, and choose exposed or woodlot edge trees (Lyons et al. 2009). Bark-produced volatile chemicals have been implicated in the detection of oviposition sites by EAB (Crook *et al.* 2008). The small (1.0 by 0.6 mm) eggs are flattened disks that conform to the surface on which they were deposited. Eggs require an average of 18.4 and 36.8 days to complete development at constant temperatures of 24°C and 18°C, respectively (Lyons *et al.* 2004).

When the tiny larvae emerge from the eggs they bore through the bottom of the egg disk and burrow directly into the bark without exposing themselves

Fig. 4. Adult of the emerald ash borer.

Fig. 5. Characteristic serpentine-shaped larval galleries of the emerald ash borer under the bark of the host tree.

to the outside elements. They tunnel through the outer bark (cork) and the inner bark to the cambial layer where they begin to feed. The cambium is a thin layer of cells from which the tree grows producing the wood on the inside and the bark on the outside. The larval feeding damages the outer xylem and inner phloem interrupting the movement of nutrients and water in the tree which ultimately leads to its death. The larval gallery has a characteristic serpentine shape resulting from the larva zigzagging up or down under the bark of the bole or branch of the tree (Fig. 5). Larvae moult three times during their development through four larval instars (Cappaert *et al.* 2005, Lyons and Jones 2005). If the larva is unable to reach the prepupal stage prior to the onset of low temperatures, it passes winter as a earlier instar larva. These larvae continue to feed the following spring but must overwinter once more to complete development, emerging as adults the following year. All four larval instars have been collected in winter. In southern Ontario, about 20% of the population requires two years to complete the life cycle. In more northerly locations, the incidence of two-year life cycle increases in EAB populations.

When populations of EAB are high, signs and symptoms of their attack are readily detected. Signs are physical damage produced by the insect, while symptoms are responses of the tree to attack. Signs of attack by EAB include the “D”-shaped emergence holes produced by the adults, serpentine galleries made by the larvae under the bark and feeding damage by the adults on the edges of the foliage. Symptoms of attack by EAB include thinning, dieback or chlorosis (yellowing) of the crown, production of epicormic shoots from the roots, trunk of branches of the tree and deformities of the bark such as discoloration, cracking or splitting. These symptoms are not positive proof of the presence of EAB, because other biotic and abiotic agents can also cause these symptoms. Secondary signs of attack include woodpecker feeding holes, squirrel feeding damage and attack by secondary insects (*e.g.,* oystershell scale). Two manuals have been developed describing the signs and symptoms of attack by EAB (de Groot *et al.* 2006, Lyons *et al.* 2007).

Literature Cited

Baranchikov, Y., E. Mozolevskaya, G. Yurchenko and M. Kenis. 2008. Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. OEPP/EPPO Bulletin 38: 233-238.

Bartelt, R. J., A. A. Cosse, B. W. Zilkowski and I. Fraser. 2007. Antennally active macrolide from the emerald ash borer *Agrilus planipennis* emitted predominantly by females. Journal of Chemical Ecology. 33: 1299-1302.

Cappaert, D., D. G. McCullough, T. M. Poland, and N. W. Siegert. 2005. Emerald ash borer in North America: a research and regulatory challenge. American Entomologist 51: 152-165.

Crook, D. J., A. Khrimian, J. A. Francese, I. Fraser, T. M. Poland, A. J. Sawyer and V. C. Mastro. 2008. Development of a host-based semiochemical lure for trapping emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestridae). Environmental Entomology 37: 356-365.

Czerwinski, E. J., L. Tucker, H. J. Evans, W. D. Biggs and D. T. Rowlinson. 2007. Invasive species in Ontario's forests. pp. 23-41 *In* T. Scarr, A. Hopkins and J. Pollard. 2007. Forest health conditions in Ontario, 2006. Ontario Ministry of Natural Resources and Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, ON.

de Groot, P., W. D. Biggs, D. B. Lyons, T. Scarr, E. Czerwinski, H. J. Evans, W. Ingram and K. Marchant. 2006. A visual guide to detecting emerald ash borer damage. Natural Resources Canada, Canadian Forest Service and Ontario Ministry of Natural Resources, Sault Ste. Marie, ON. 16 p.

de Groot, P., G. G. Grant, T. M. Poland, R. Scharbach, L. Buchan, R. W. Nott, L. Macdonald and D. Pitt. 2008. Electrophysiological response and attraction of emerald ash borer to green leaf volatiles (GLVs) emitted by host foliage. Journal of Chemical Ecology 34: 1170-1179.

Farrar, J. L. 1995. Trees in Canada. Fitzhenry & Whiteside Limited and Canadian Forest Service, Ottawa, Ontario. 502 pp.

Haack, R. A., E. Jendek, H. Liu, K. R. Marchant, T. R. Petrice, T. M. Poland and H. Ye. 2002. The emerald ash borer: a new exotic pest in North America. Newsletter of the Michigan Entomological Society 47: 1-5.

Lelito, J. P., K. Boroczky, T. H. Jones, I. Fraser, V. C. Mastro, J. H. Tumlinson and T. C. Baker. 2009. Behavioral evidence for a contact sex pheromone component of the emerald ash borer, *Agrilus planipennis* Fairmaire. Journal of Chemical Ecology 35: 104-110.

Lelito, J. P., I. Fraser, V. C. Mastro, J. H. Tumlinson, K. Boroczky and T. C. Baker. 2007. Visually mediated 'paratrooper copulations' in the mating behaviour of *Agrilus planipennis* (Coleoptera: Buprestidae), a highly destructive invasive pest of North American ash trees. Journal of Insect Behavior 20: 537-552.

Liu, H., L. S. Bauer, R. Gao, T. Zhao, T. R. Petrice, and R. A. Haack. 2003. Exploratory survey for the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), and its natural enemies in China. The Great Lakes Entomologist 36: 191-204.

Lyons, D. B., C. Caister, P. de Groot, B. Hamilton, K. Marchant, T. Scarr and J. Turgeon. 2007. Survey guide for detection of emerald ash borer. Natural Resources Canada, Canada and Forest Service and Canadian Food Inspection Agency, Sault Ste. Marie and Ottawa. iv + 52 pp.

Lyons, D. B. and G. C. Jones. 2005. The biology and phenology of the emerald ash borer. *In* K.W. Gottschalk (ed.) Proceedings 16th U.S. Department of Agriculture Interagency Research Forum on Gypsy Moth and Other Invasive Species, 2005, 18-21 January 2005, Annapolis , Maryland. U.S.D.A. Forest Service, Northeastern Research Station, General Technical Report NE-337. pp. 62-63.

Lyons, D. B., G. C. Jones and K. Wainio-Keizer. 2004. The biology and phenology of the emerald ash borer. *In* K.W. Gottschalk (ed.) Proceedings XV U.S. Department of Agriculture Interagency Research Forum on Gypsy Moth and Other Invasive Species, 2004, 13-16 January 2004, Annapolis , Maryland. U.S.D.A. Forest Service, Northeastern Research Station, General Technical Report NE-332. p. 54.

Lyons, D. B., P. de Groot, G. C. Jones and R. Scharbach. 2009. Host selection by *Agrilus planipennis* (Coleoptera: Buprestidae): inferences from sticky-band trapping. The Canadian Entomologist 141: 40-52.

Pureswaran, D. S. and T. M. Poland. 2009. Host selection and feeding preference of *Agrilus planipennis* (Coleoptera: Buprestidae) on ash (*Fraxinus* spp.). Environmental Entomology 38: 757-765.

Rodriguez-Saona, C., T. M. Poland, J. R. Miller, L. L. Stelinski, G. G. Grant, P. de Groot, L. Buchan, and L. MacDonald. 2006. Behavioral and electrophysiological responses of the emerald ash borer, *Agrilus planipennis*, to induced volatiles of Manchurian ash, *Fraxinus mandshurica*. Chemoecology 16: 75-86.

Silk, P., K. Ryall, D. B. Lyons, J. Sweeney, and J. Wu. 2009. A contact sex pheromone component of the emerald ash borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae). Naturwissenschaften 96: 601-608.

Timms, L. L., S. M. Smith and P. de Groot. 2006. Patterns in the within tree distribution of the emerald ash borer *Agrilus planipennis* (Fairmaire) in young, green-ash plantations of south-western Ontario, Canada. Agricultural and Forest Entomology 8: 313-321.

Yu, C. 1992. *Agrilus marcopoli* Obenberger (Coleoptera: Buprestidae). *In* Forest insects of China (2nd edition). *Edited by* G. Xiao. China Forestry Publishing House, Beijing, China. pp. 400-401.

Emerald Ash Borer Distribution Update and Regulatory Issues

Mary Orr
Canadian Food Inspection Agency
Toronto, Ontario
mary.orr@inspection.gc.ca

The emerald ash borer (EAB), a highly destructive pest of ash trees, was first detected in Ontario, Canada in 2002. As a result, the Canadian Food Inspection Agency (CFIA) established regulated areas via ministerial orders to prevent the movement of regulated materials from infested areas to non-infested areas of Canada.

The map titled “Emerald Ash Borer Regulated Areas of Canada 2009” (dated 3 June 2009) (Fig. 1), shows areas where movement of ash tree material and all firewood is regulated. Items may move freely within a regulated area of the same colour, regardless of the number of counties/municipalities it includes. Updates to this map will be found on the CFIA website at: www.inspection.gc.ca as they become available.

There are two larger contiguous areas: the south western area of Ontario that includes Essex, Chatham-Kent, Elgin, Middlesex and Lambton counties and the Greater Toronto Area which includes the cities of Toronto and Hamilton, as well as York, Durham, Peel and Halton Regions. Norfolk County and Huron County are regulated separately. There are three satellite regulated areas that include a portion of the city of Sault Ste. Marie, a portion of Carignan, Quebec, and portions of the cities of Ottawa, Ontario, and Gatineau, Quebec.

In 2009, two areas were confirmed infested with the EAB. In February of 2009, an infestation was detected in the city of Hamilton and in June 2009 in the city of Welland located in Niagara Region.

In the spring of 2009, the CFIA survey unit made an effort to couple our current survey and detection procedures with the use of traps in non-regulated areas. Purple prism traps baited with a manuka/phoebe oil lures and green prism traps baited with green leaf volatile lures were placed at several locations but were not successful in capturing EAB.

The United States currently has 13 states that are infested with EAB. A map of the current infested areas is located on the following website: http://www.emeraldashborer.info/files/MultiState_EABpos.pdf

The CFIA EAB program is currently engaged in survey, communications, regulation and research.

The CFIA conducts surveys in non-regulated areas to try to determine where EAB is present. When a new EAB infestation is confirmed, regulatory measures are taken to prevent the human-assisted spread of EAB. Regulated ash articles include nursery stock, lumber, wood packaging, logs, wood/bark chips, and firewood of all species. Under the Plant Protection Act and the Administrative Monetary Penalties Act, the CFIA has the ability to prosecute or fine individuals or companies who contravene the Act or Regulations. The CFIA’s policy directive D-03-08 outlines the requirements for movement of regulated articles into and within Canada. A facility may participate on the Emerald Ash Borer Approved Facility Compliance Program, which allows affected parties in regulated and non-regulated areas to ship, access and process ash during low risk periods.

Our communications efforts centre around public awareness and media relations activities. They include presentations, participation at trade/consumer shows, distribution of publications and responding to public enquiries via the CFIA website and EAB call-in line (1-866-463-6017).

The CFIA supports research, particularly in the area of finding improved detection methods and tools. Cooperation with the University of Guelph on

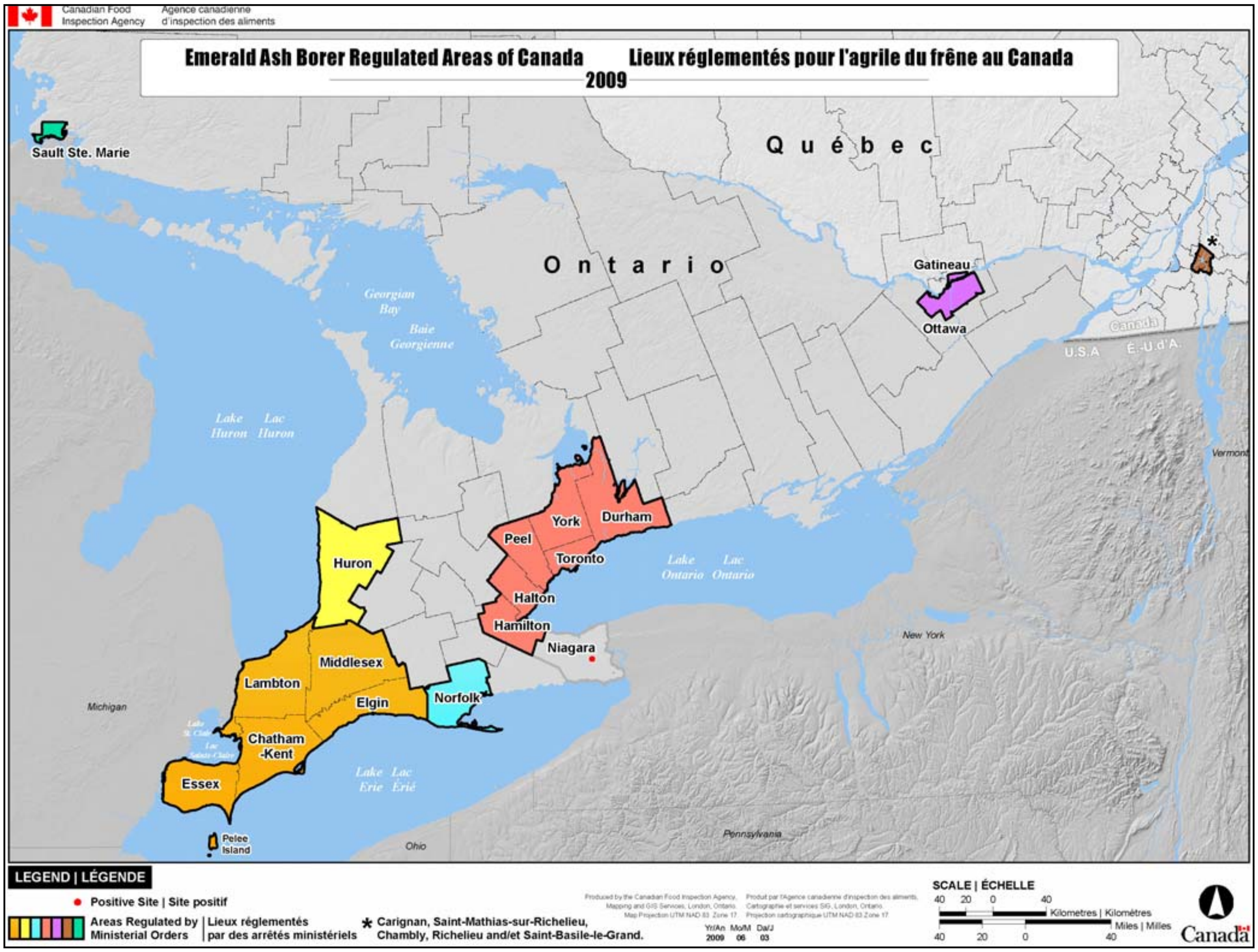

Fig. 1. Distribution of regulated areas for emerald ash borer in Canada as of 3 June 2009.

biosurveillance is one initiative, as well as work with the Canadian Forest Service on trap types.

Canada has an international obligation to undertake efforts to control EAB as a quarantine pest. Canada's long-term competitiveness and trade relationships depend on the CFIA working to prevent invasive alien species and other pests from entering Canada and to manage them when they are detected here to prevent further spread.

Emerald Ash Borer Surveys, Detection, and Monitoring

Krista L. Ryall
Natural Resources Canada, Canadian Forest Service
Sault Ste. Marie, Ontario
Krista.Ryall@NRCan.gc.ca

Sampling tools and techniques are urgently required to increase our ability to detect emerald ash borer (EAB) infestations earlier, delimit known populations, and assess their density. However, due to the cryptic life stages of EAB, with larvae creating galleries under the bark (Haack *et al.* 2002), its propensity to attack an individual tree over several successive years, and the lack of obvious visual symptoms during this period (de Groot *et al.* 2006), it is difficult to detect low-density infestations. In this abstract, survey methods and guidelines used by the federal governments of Canada and the United States will be outlined, followed by methods used by the Ontario Ministry of Natural Resources. Next, an overview of sampling methods currently in use, as well as those in development, will provide forest managers with options to consider when trying to detect and delimit EAB populations.

In Canada, the Canadian Food Inspection Agency (CFIA) has the mandate to survey and regulate areas infested with EAB. In 2009, CFIA's EAB detection survey targeted high-risk sites in unregulated counties in close proximity to known infested areas. The surveys are based primarily upon visual inspections of host trees (CFIA 2009). In the United States, the detection and delimitation survey is comprised of three main sections: 1.) a national survey to detect new pockets of infestation; 2.) a grid-based survey around the periphery of the known infested area; and 3.) a targeted survey of high risk sites around the leading edge of the known infestation (USDA-APHIS 2009). High-risk sites in both countries include campgrounds, cottage areas, nurseries, sawmills, firewood dealers and areas of high human activity. For 2008 and 2009, USDA-APHIS utilized sticky purple prism traps, baited with manuka oil and manuka:phoebe oil (80:20) lure, respectively. Within the province on Ontario, aerial mapping of ash decline and mortality was conducted from 2005-2007 and again in 2009 over south-western Ontario. Low level flying was tested in 2008 over urban areas to detect ash decline. With experienced field technicians, ash decline and mortality was readily detected from the air, allowing the geographical location of affected stands to be pinpointed; however, ground-truthing methods are still needed.

Sampling methods available for use with EAB include visual surveys, the use of trap trees, branch sampling, and trapping. The "Survey Guide for Detection of Emerald Ash Borer" provides extensive information on signs and symptoms of EAB infestation (Lyons *et al.* 2007) that should be referred to for images of crown dieback and chlorosis, epicormic shoot production, woodpecker feeding activity, bark cracks and deformities associated with EAB infestation. For the 'trap tree' method, a band of bark and phloem is removed from the bole of the tree in the spring to induce stress (MSU 2006). These trees are highly attractive to EAB and were used as part of the USDA-APHIS EAB sampling from 2005-2008 and in CFIA's survey in 2007. Sampling procedures using branches are being developed to detect low-density infestation by EAB attacking ash trees, *Fraxinus* spp., particularly in urban environments. We currently recommend sampling two branches from the middle of the live crown of the tree, having a minimum diameter of 5-7 cm; whittling of the bark from the branch can reveal the presence of any EAB infestation. This branch sampling technique can detect infestation by EAB in trees exhibiting few or no external signs of symptoms. Detailed publications and further information regarding branch sampling is forthcoming.

Considerable research is being conducted to develop an effective and reliable trap-lure combination for monitoring of EAB populations. A three-sided sticky trap is currently the most effective trap available for use; hanging of baited traps up in the canopy and on edges or in sunny locations increases trap catches (Lance *et al.* 2007, Francese *et al.* 2007, 2008a,b, McCullough *et al.* 2008, Poland *et al.* 2005, Lyons *et al.* 2009). Several studies report the effectiveness of purple traps baited with bark sesquiterpenes (compounds released from the stem of stressed ash; *e.g.*, Manuka and/or Phoebe oil) at capturing more EAB than unbaited traps (Crook *et al.* 2008, Francese *et al.* 2005, 2008a,b, Marshall *et al.* 2010). This was the trap and lure chosen for use in the U.S. EAB survey program. However, other results indicate that green traps baited with green leaf volatiles (GLVs, compounds released from the foliage of stressed ash) capture greater numbers of EAB (Poland *et al.* 2006, Poland and McCullough 2007, Rodriguez-Saona *et al.* 2006, de Groot *et al.* 2008, Grant *et al.* 2010) and may be more effective at low-densities.

To complement surveys being conducted at the large-scale by federal and provincial governments, forest managers may decide to employ one or several of the above-mentioned sampling tools and techniques to conduct more-specific smaller-scale surveys. A detection survey can assist in locating new EAB infestations, followed by a delimitation around a known outbreak to assess its size and extent; next, it is important to evaluate EAB density (numbers of trees infested and at what intensity). Forest managers in rural areas may want to utilize locations identified through aerial mapping as potentially infested with EAB and include them in their ground surveys. These various survey designs could be conducted with one or several of the sampling methods as described above. For example, baited traps may be deployed to detect a new outbreak, followed by branch sampling to delimit and assess EAB infestation levels. Visual surveys, along with branch sampling, could focus on locations where ash decline and mortality has been observed from aerial surveys. This information will hopefully assist forest managers in making decisions regarding EAB management and control.

Literature Cited

CFIA. 2009. www.inspection.gc.ca/english/corpaffr/newcom/2009/20090915e.shtml

Crook D. J., A. Krimian, J. Francese, I. Fraser, T. M. Poland, A. J. Sawyer and V. Mastro. 2008. Development of a host-based semiochemical lure for trapping emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae). Environmental Entomology 37: 356-365.

de Groot P., G. G. Grant, T. M. Poland, R. Scharbach, L. Buchan, R. W. Nott, L. MacDoanld and D. Pitt. 2008. Electrophysiological response and attraction of emerald ash borer to green leaf volatiles (GLVs) emitted by host foliage. Journal of Chemical Ecology 34: 1170-1179.

de Groot P., W. D. Biggs, D. B. Lyons, T. Scarr, E. Czwerwinski, H. J. Evans, W. Ingram, K. Marchant. 2006. A visual guide to detecting emerald ash borer damage. Natural Resources Canada and Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, Canada

Francese J. A., V. C. Mastro, J. B. Oliver, D. R. Lance, N. Youssef and S. G. Lavalee. 2005. Evaluation of colors for trapping *Agrilus planipennis* (Coleoptera: Buprestidae). Journal of Entomological Science 40: 93-95.

Francese J. A., I. Fraser, D. R. Lance and V. C. Mastro. 2007. Developing survey techniques for emerald ash borer: the role of trap height and design. pp. 72-73 *In* V.C. Mastro, D.R. Lance, R. Reardon and Parra G. (compilers). Emerald ash borer and Asian longhorned beetle research and technology development meeting. USDA Forest Health Technology Enterprise Team FHTET-2007-04, 29 October - 2 November 2006, Cincinnati, OH.

Francese J. A., D. J. Crook, I. Fraser, D. R. Lance, A. F. Sawyer and V.C. Mastro. 2008a. Further investigations in developing a trap for emerald ash borer: how trap height affects capture rates. pp. 79-80 *In* V. Mastro, D. Lance, R. Reardon and G. Parra (compilers). Emerald ash borer research and development Meeting FHTET 2007-08. USDA, Forest Service, Morgantown, WV.

Francese J. A., J. B. Oliver, I. Fraser, D. R. Lance, N. Youssef, A. F. Sawyer and V. C. Mastro. 2008b. Influence of trap placement and design on capture of the emerald ash borer (Coleoptera: Buprestidae). Journal of Economic Entomology 101: 1831-1837.

Grant, G. G., K. L. Ryall, D. B. Lyons and M. M. Abou-Zaid. 2010. Differential response of male and female emerald ash borers (Col., Buprestidae) to

(Z)-3-hexenol and manuka oil. Journal of Applied Entomology 134: 26-33.

Haack, R. A., E. Jendek, H. Liu, K. R. Marchant, T. R. Petrice, T. M. Poland, and H. Ye. 2002. The emerald ash borer: a new exotic pest in North America. Newsletter of the Michigan Entomological Society 47: 1-5.

Lance D. R., I. Fraser and V. C. Mastro. 2007. Activity and microhabitat selection patterns of emerald ash borer and their implications for the development of trapping systems, pp 77-78. *In* V. Mastro, D. Lance, R. Reardon and G. Parra (eds.), Emerald ash borer and Asian longhorned beetle research and technology development meeting. U.S. Department of Agriculture Forest Health Technology Enterprise Team, 29 Oct-2 Nov 2006, Cincinnati, OH.

Lyons, D. B., C. Caister, P. de Groot, B. Hamilton, K. Marchant, T. Scarr and J. Turgeon. 2007. Survey guide for detection of emerald ash borer. Natural Resources Canada – Canadian Forest Service and Canadian Food Inspection Agency, Sault Ste. Marie, Ontario, Canada.

Lyons D. B., P. de Groot, G. C. Jones and R. Scharbach. 2009. Host selection by *Agrilus planipennis* (Coleoptera: Buprestidae): inferences from sticky-band trapping. Canadian Entomologist 141: 40-52.

Marshall J. M., A. J. Storer, I. Fraser and V. C. Mastro. 2010. Efficacy of trap and lure types for detection of *Agrilus planipennis* (Col., Buprestidae) at low density. Journal of Applied Entomology 134: 296-302.

McCullough, D. G., A. Agius, D. Cappaert, T. M. Poland, D.L. Miller, and L.S. Bauer. 2003. Host range and host preferences of Emerald Ash Borer. *In* Mastro, V., Reardon, R. (eds.), Abstracts of Emerald Ash Borer Research and Technology Development meeting. Forest Health Technology Enterprise Team. USDA FHTET-2004-02.

McCullough, D. G., T. M. Poland and D. L. Cappaert. 2006. Attraction of emerald ash borer to trap trees: effects of stress agents and trap height. *In V.* Mastro, R. Reardon and G. Parra (compilers). Emerald ash borer research and technology development meeting. FHTET-2005-16. Forest Health Technology Enterprise Team, Morgantown, WV, pp. 61-62.

MSU. 2006. Michigan State University, USDA Forest Service. Using girdled trap trees effectively for emerald ash borer detection, delimitation and survey. http://www.emeraldashborer.info/files/handoutforpdf.pdf

Poland T. M., C. Rodriguez-Saona, G. Grant, L. Buchan, P. de Groot, J. Miller and D. G. McCullough. 2006. Trapping and detection of emerald ash borer: identification of stress-induced volatiles and tests of attraction in the lab and field. pp. 64-65 *In* V. Mastro, D. Lance, R. Reardon and G. Parra. Emerald ash borer research and development Meeting FHTET 2007-08. Ed. By , USDA, Forest Service, Morgantown, WV,

Poland T. M. and D. G. McCullough. 2007. Evaluation of a multicomponent trap for emerald ash borer incorporating color, silhouette, height, texture, and ash leaf and bark volatiles, pp. 74-76. *In* V. Mastro, D. Lance, R. Reardon and G. Parra (eds.), Emerald ash borer and Asian longhorned beetle research and technology development meeting. U.S. Department of Agriculture Forest Health Technology Enterprise Team, 29 Oct-2 Nov 2006, Cincinnati, OH.

Rodriguez-Saona, C., T. M. Poland, J. R. Miller, L. L. Stelinski, G. G. Grant, P. de Groot, L. Buchan and L. MacDonald. 2006. Behavioural and electrophysiological responses of the emerald ash borer, *Agrilus planipennis*, to induced volatiles of Manchurian ash, *Fraxinus mandshurica*. Chemoecology 16:75-86.

USDA-APHIS. 2009. Emerald ash borer program manual, *Agrilus planipennis* (Fairemaire) USDA-APHIS-PPQ-Emergency and Domestic Programs-Emergency Planning, Riverdale, Maryland.

Quantifying Abundance and Composition of Urban Forests for Economic Impact Modelling of Alien Invasive Species

Dan McKenney, Denys Yemshanov, John Pedlar, Kathy Campbell, Kevin Lawrence and Barry Lyons
Natural Resources Canada, Canadian Forest Service
Sault Ste. Marie, Ontario
Dan.McKenney@NRCan.gc.ca

Introduction

Historically, invasive species have caused significant economic impacts to North American forests despite large-scale mitigation efforts and slow-the-spread programs. Because resources for controlling new invasions are often limited, it is critical to estimate the potential economic impacts to help select the most efficient methods for mitigation and control, whether it is prevention, removal of host trees, biological control, or slow-the-spread measures. Economic analyses can help inform decisions about the best way to spend limited budgets as well as help justify research activities. In the case of emerald ash borer (EAB), a significant investment will be required to slow the expansion of isolated infestations and postpone the ultimate costs of treatment – tree removal and replacement.

Impact assessments and cost-benefit analyses of EAB infestations in Canada require georeferenced data on forest composition and abundance. Such data are generally available for natural forests, however little information exists for urban trees. To address this information gap, a protocol has been developed that estimates the composition of trees in an urban settings based on surveying a random sample of city streets. We hope that some of this data may be gathered in partnership with volunteer organizations such as the Federation of Ontario Naturalists. Here we summarize our initial efforts to develop the protocol and report preliminary results for several urban centres in Ontario.

Methods

We made use of the extensive tree survey data that exists for London, Ontario to guide our development of the urban tree survey (http://www.london.ca/d.aspx?s=/Trees Lawns and Gardens/treeinvnt.htm). This dataset allowed us to examine the number of 0.5-km segments of city streets that would need to be surveyed to obtain accurate estimates of tree species composition. The protocol developed from this exercise was tested in 5 Ontario communities (Sault Ste. Marie, Meaford, Owen Sound, London, and Sudbury). Further information was gathered using Google Earth for an additional 6 Ontario cities (Ottawa, Kitchener, Barrie, Guelph, Thunder Bay, and Chatham). The Google-based surveys did not provide information on tree species composition, but did help to elucidate general relationships between road length and the total number of front yard trees and the ratio of front-yard trees to back yard trees.

Results and Discussion

Survey Protocol

Based on the London tree dataset, reliable estimates of tree composition are obtained when approximately 10% of city streets have been surveyed in 0.5-km segments. Figure 1 shows how variation in the percent composition of sugar maple flat-lines by the time 10% of the total city street length has been covered. Based on these findings, and using a GIS database of the country's urban road network, we have generated random survey start points (at city street intersections) for all cities in Canada – enough start points have been generated to cover about 10% of the road length in any given city. Other aspects of the survey protocol include:

- At each start point, choose a direction to walk; to make the choice unbiased, select a direction in the following order – N, W, S, E – the first direction that looks suitable should be chosen;
- Survey only one side of the street;
- The preferred length of a survey route is 0.5 km

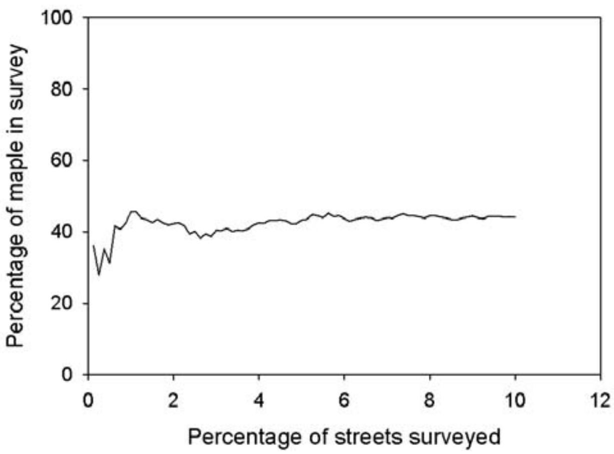

Fig. 1. Cumulative mean percentage of sugar maple as a function of the percentage of street length surveyed in London Ontario. Streets were surveyed in 0.5-km segments.

and can be measured using a pedometer, GPS unit, or trip odometer;

- In the case that a change in direction is required (*e.g.*, T-intersection) before the survey route is complete, choose the new direction based on the order outlined above (i.e., N, W, S, E);
- Identify only trees within about 10 m (30 feet) of the road;

Survey results for Sault Ste Marie (summarized at the genus level) are shown in Table 1. Note that EAB host species (i.e., ash, *Fraxinus* spp.) compose only about 2% of street trees, while host genera for Asian longhorned beetle (i.e., *Acer* spp., *Salix* spp., *Populus* spp., *Betula* spp., and *Ulmus* spp.) compose 53% of city trees. A web portal has been developed to facilitate public participation in the survey. The website provides a map with survey start points, survey protocols, datasheets, data entry facilities, and contact information. The site should be accessible to the public by the spring of 2010.

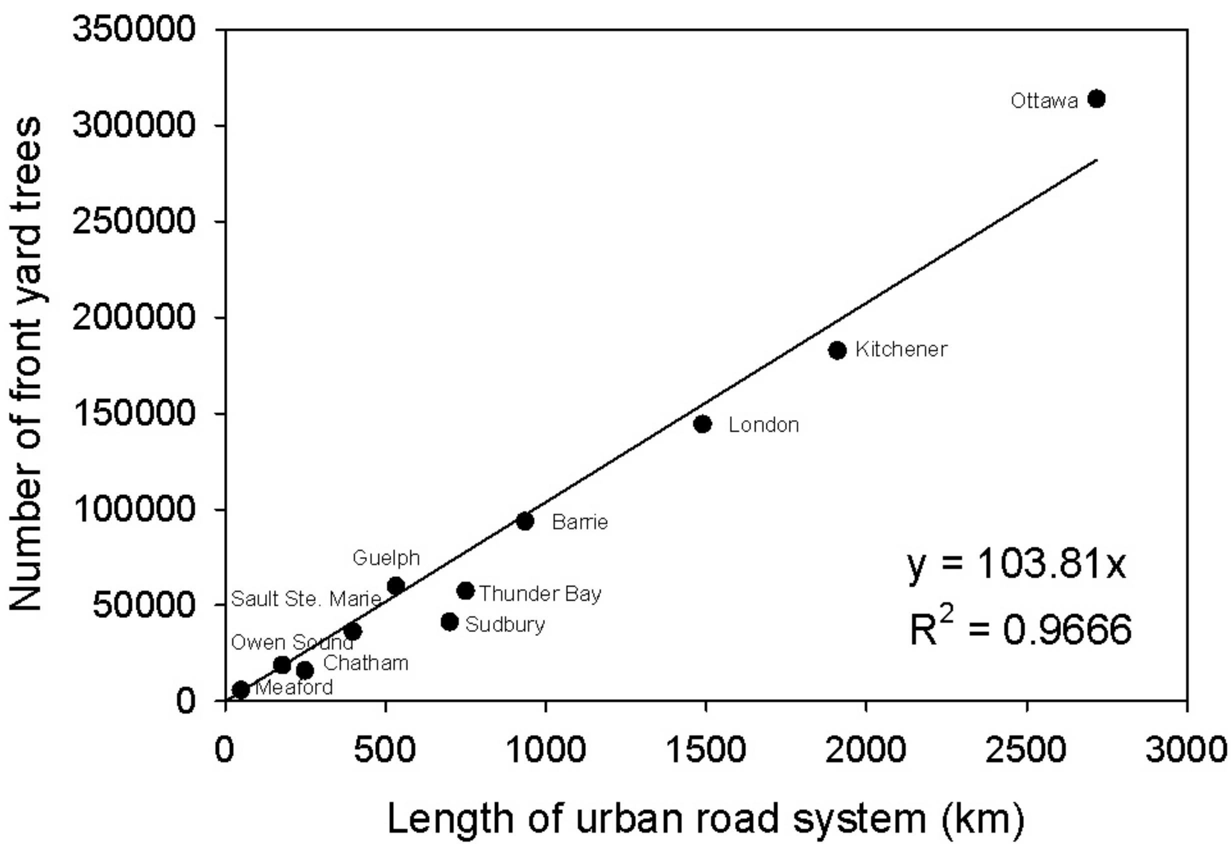

Fig. 2. Relationship between length of urban road network and total number of front yard trees (within 10 m of the road edge).

Table 1. Species composition of urban trees in Sault Ste Marie, Ontario.

Genus	Number Surveyed	Number/ km	Estimated Total Number of	% Composition
Fraxinus	85	4.3	8553	2.22
Malus	164	8.3	16502	4.29
Betula	191	9.7	19218	4.99
Fagus	2	0.1	201	0.05
Catalpa	1	0.1	101	0.03
Prunus	51	2.6	5132	1.34
Thuja	118	6.0	11873	3.09
Juniperus	6	0.3	604	0.16
Aesculus	11	0.6	1107	0.29
Ulmus	71	3.6	7145	1.86
Abies	45	2.3	4528	1.18
Ginko	0	0.0	0	0
Carya	0	0.0	0	0
Tsuga	0	0.0	0	0
Larix	5	0.3	503	0.13
Tilia	6	0.3	604	0.16
Tilia	44	2.2	4427	1.15
Robinia	23	1.2	2314	0.6
Gleditsia	0	0.0	0	0
Sorbus	57	2.9	5736	1.49
Acer	1001	50.7	100724	26.2
Morus	0	0.0	0	0
Quercus	88	4.5	8855	2.31
Pinus	259	13.1	26062	6.78
Populus	757	38.3	76172	19.82
Picea	822	41.6	82713	21.51
Liriodendron	0	0.0	0	0
Juglans	4	0.2	403	0.11
Salix	5	0.3	503	0.13
Other	4	0.2	402	0.1

Extrapolating Results to Other Cities

Surveys in other cities and Internet-based surveys have allowed us to develop a number of urban tree-related relationships that are useful for extrapolating results to other locations. We found a strong relationship between the total number of front yard trees in a city and the total length of the city road network (Fig. 2). The Internet-based surveys also allowed us to estimate the ratio of front yard to backyard trees; based on results from 6 cities the ratio was close to 1:1 (Table 2). Finally, from the survey data we collected from 5 Ontario cities, we were able to estimate the proportion of trees in each of three height classes (i.e., 1.5-5 m, 5-10 m, and > 10 m; Table 3).

Application of Survey Results

The surveys and modelling work to date have provided some preliminary estimates of ash tree density and possible tree removal and replacement costs in Ontario's urban centres. These data are being integrated into more sophisticated models of population spread to provide more reliable estimates of impacts through both time and space. One important gap in this effort is estimates of park trees in urban centres. This presents another important challenge for quantifying the potential impacts of alien species.

Table 2. Ratio of front yard to backyard trees.

Urban Centre	Source	Total # Front yard Trees	Total # Backyard Trees	Ratio
Kitchener	Google Maps	182671	185804	0.98
Thunder Bay	Google Maps	57486	53179	1.08
Chatham	Google Maps	15989	21264	0.75
Ottawa Gatineau	Google Maps	313859	298641	1.05
Barrie	Google Maps	93777	98821	0.95
Guelph	Google Maps	59948	49506	1.21
Mean		**120622**	**117869**	**1.00**

Table 3. Proportion of urban trees in each of 3 different height classes for 5 Ontario cities.

Urban Centre	Proportion of Trees in Each Height Class		
	1.5-5 m	5-10m	>10m
Meaford	0.16	0.39	0.45
Owen Sound	0.26	0.37	0.37
London	0.31	0.17	0.52
Sudbury	0.31	0.49	0.20
Sault Ste Marie	0.13	0.54	0.34
Mean	0.23	0.39	0.37

Ecological Implications of Emerald Ash Borer Infestations and Management

Dave Kreutzweiser
Natural Resources Canada, Canadian Forest Service
Sault Ste. Marie, Ontario
Dave.Kreutzweiser@NRCan.gc.ca

The development and application of environmentally-responsible pest management methods and control products for the emerald ash borer (EAB) require science-based information on their ecological implications. This paper will cover two themes that relate to the management and control of EAB; 1) potential environmental effects of pest control products, and 2) ecological implications of EAB-killed trees. Both themes are being addressed by the Canadian Forest Service in partnership with the Ontario Ministry of Natural Resources and others. The first is considerably advanced, while the second is in the conceptual and planning stages. This work ensures that management and control strategies for EAB are developed and implemented in an environmentally-responsible fashion.

Environmental Effects of Pesticides for EAB

Our work to date on environmental effects of EAB control products has focused on the systemic insecticides, imidacloprid (*e.g.*, Confidor) and neem (azadirachtin, the active ingredient in TreeAzin). Systemic insecticides in general will pose less risk of environmental exposure and effects than broad-scale foliar insecticides because the stem or soil injections restrict the insecticide application to the tree being protected. Systemic applications by stem or soil injection to individual trees is not feasible for all forest pest management situations, but they may be well suited for control of invasive species within a restricted area before the species becomes widely distributed. They may also be well suited for protection of high value stands in urban and recreational settings or where infestations threaten environmentally-sensitive areas where broad-scale pesticide applications or tree-removal approaches are not acceptable.

The systemic insecticide, imidacloprid, is widely used for EAB control in the US, and was being considered for registration in Canada. Most of our research into the environmental fate and non-target effects of systemic insecticides was focused on imidacloprid in support of the pending registration. However, imidacloprid has been withdrawn from the registration process and is not available for EAB control in Canada. An alternative systemic insecticide based on the natural product, neem, has recently been granted an emergency registration for EAB in Canada and is available in the TreeAzin product through BioForest Technologies Inc. (see the paper by Joe Meating in this Proceedings). We have subsequently initiated further studies to determine the potential environmental impacts of neem as a systemic insecticide for EAB.

Our studies into the environmental fate and effects of imidacloprid (Kreutzweiser *et al.* 2007, Kreutzweiser *et al.* 2008a, Kreutzweiser *et al.* 2008b, Kreutzweiser *et al.* 2008c, Kreutzweiser *et al.* 2009) were targeted at potential impacts on decomposer organisms and processes in aquatic and terrestrial environments. The focus was on ecologically-sensitive areas, such as where ash trees occur in riparian (shoreline) forests, because of their role in providing ecological services and supporting biodiversity. We conducted experiments in laboratory microcosms (Fig. 1) to simulate natural environments. Imidacloprid was added directly to aquatic microcosms to mimic a soil application and subsequent leaching to nearby water bodies, and to terrestrial microcosms to measure the soil application impacts on soil organisms. We also determined the effects of foliar imidacloprid concentrations on decomposer organisms by adding leaves taken from imidacloprid-treated trees to aquatic and terrestrial microcosms. We measured effects on aquatic leafshredding insect survival and feeding rates; on litter-dwelling earthworm survival, feeding rates, growth rates and cocoon production; and on aquatic and terrestrial microbial decomposition activity. Our focus was on decomposer organisms because 1) the primary route of exposure to non-target invertebrates by systemic insecticides will be through the consumption and decomposition of leaves that fall from insecticide-treated trees, and 2) the decomposition of leaf litter is a critical ecosystem process that sustains forest floor nutrient cycling and supports biodiversity.

The main conclusions from this work are:

1. When a systemic insecticide is used for EAB control, it will pose much less risk of environmental harm when used as a trunk injection than when used as a soil injection.

2. Realistic concentrations of imidacloprid in leaves following trunk injections does not pose a risk of direct mortality to non-target decomposer invertebrates.

3. However, realistic concentrations of imidacloprid in leaves are likely to inhibit leaf litter decomposition processes.

4. Inhibition of leaf litter decomposition by imidacloprid is a result of sub-lethal, but toxic, effects on decomposer organisms and microbial communities

Fig. 1. Toxicity testing of systemic insecticides in laboratory microcosms

5. This could have negative implications for organic matter processing and nutrient cycling in ecologically-sensitive areas such as water-side forests, ravines, wetlands, conservation areas, etc., where the ash component is large and where the trees are treated with imidacloprid (currently not registered for EAB control in Canada, used extensively in the US)

The experiments with neem (TreeAzin) are underway. Early indications are that neem will not pose a significant risk of environmental impact, and would therefore be a preferred systemic insecticide for trees in ecologically-sensitive areas.

Ecological Implications of EAB-killed Trees

An ecological risk assessment will be required to inform pest management strategies for EAB. Information will be required that helps to determine where, when, and why pest management or control options should be invoked. While the protection of some values is obvious (*e.g.*, trees that improve property values, provide aesthetics, reduce noise, abate wind, etc.), other values may not be so obvious. This would include areas where ash contributes significantly to particular ecological services and critical habitat. In urban settings, treed areas that are less obvious but ecologically critical would include riparian forests such as stream and pond shorelines, forested ravines, and wetlands with significant ash components. This is particularly true when the shorelines have sufficient trees to create forest conditions (variety, diversity, shading, organic-rich soils, leaf-litter layers), not just water-side trees.

Ravine or riparian forests provide a number of critical ecological services (Fig.2) including 1) water runoff regulation and filtration, 2) shoreline stability to reduce erosion, 3) interception of nutrients and contaminants in runoff, 4) organic matter inputs to water bodies that support aquatic life, 5) unique water and shoreline habitats that are critical to sustain biodiversity, and 6) a linear continuity of forests that provides eco-corridors for a wide variety of animal life including insects, birds, amphibians and mammals. When ash is a significant component of these forests, the loss of ash from EAB could have negative implications for any or all of these ecological services.

We have recently initiated a large-scale, integrated field study to determine the environmental implications of ash mortality from EAB in ecologically-sensitive areas including ravine forests, woodlots, and wetlands. This will assess the extent to which ash is present in these kinds of forests across southwestern Ontario, the contributions by ash to various ecological services, and the impacts on those services by the loss of ash from EAB. The study includes measurements of effects on forest stand structure and recovery, understory vegetation responses, loss of sensitive forest species and the incursions by invasive plants, bird habitat features and impacts on bird communities, riparian (shoreline) forest structure and their influences on water bodies, amphibian habitats and populations, EAB dispersal rates, parasitoid and pathogen population development and spread rates, and optimal EAB detection and repellent technologies. This will identify susceptibilities, quantify threats, and inform the development of environmentally-sound management and mitigation strategies.

Fig. 2. A healthy riparian forest providing numerous ecological services

Management Implications and Guiding Principles

The best approach to EAB management is likely to be an integrated pest management (IPM) strategy such as the removal of highly-infested trees combined with a prophylactic treatment of nearby trees by systemic insecticide or other control options as they become available. The decision-making process for this should include ecological considerations. Urban forest managers should consider the ecological benefits of protecting ash trees in sensitive environments that might otherwise be overlooked because they are less obvious or less visible than park or boulevard trees. This could include treed ravines, conservation areas, wetlands, and shoreline forests of streams and ponds. The first step would be to identify and quantify these ecologically-sensitive areas, and to determine their ash component. If the ash component is significant, then important ecological services could be at risk and management or control options should be explored. Our current project will help to determine when the percent ash component of a forest stand becomes ecologically significant, but early indications are that forests with 30% or more ash could be at risk of significant ecological impacts from ash mortality.

It will not be possible to eradicate the EAB or to stop its spread across urban forests and trees. However, the intent of an IPM scheme for ecologically-sensitive areas would be to delay, reduce, and/or control EAB damage in those forests in order to sustain important ecological services and critical habitat in support of biodiversity and healthy ecosystems.

Literature Cited

Kreutzweiser D. P., D. G. Thompson and T. A. Scarr. 2009. Imidacloprid in leaves from systemically-treated trees may inhibit litter breakdown by non-target invertebrates. Ecotoxicology and Environmental Safety 72: 1053-1057.

Kreutzweiser D. P., K. P. Good, D. Chartrand, T. A. Scarr and D. G. Thompson. 2008a. Toxicity of a systemic insecticide, imidacloprid, to forest stream insects and microbial communities. Bulletin of Environmental Contamination and Toxicology 80: 211-214.

Kreutzweiser D. P., K. P. Good, D. T. Chartrand, T. A. Scarr and D.G. Thompson. 2008b. Are leaves that fall from imidacloprid-treated maple trees to control Asian longhorned beetles toxic to non-target decomposer organisms? Journal of Environmental Quality 37: 639-646.

Kreutzweiser D. P., K. P. Good, D. T. Chartrand, T. A. Scarr, S. B. Holmes and D. G. Thompson. 2008b. Effects on litter-dwelling earthworms and microbial decomposition of soil-applied imidacloprid for control of wood-boring insects. Pest Management Science 64: 112-118.

Kreutzweiser D. P., K. P. Good, D. Chartrand, T. A. Scarr and D. G. Thompson. 2007. Non-target effects on aquatic decomposer organisms of imidacloprid as a systemic insecticide to control emerald ash borer in riparian trees. Ecotoxicology and Environmental Safety 68: 315-325.

Communications and Public Outreach

Tony Fleischmann
Forestry Services - Hydro One Networks Inc.
tony.fleischmann@hydroone.com

As much as the logistical and operational aspects are important to a successful invasive insect control program, the communication and public involvement components are equally as essential to the planning, implementation and assessment of the project.

Communication strategies, public outreach initiatives and other lessons learned during the 2006 Gypsy Moth Control Program in Mississauga may help to plan for and address future invasive alien insect management programs in urban areas including control measures for the Emerald Ash Borer.

Important areas to consider when planning for any control initiatives include public outreach and education, political support and direction and regulatory compliance with all relevant agencies and authorities.

Public Outreach

Many residents living in residential woodland communities or adjacent to woodland parks and natural areas are generally very well informed about the environmental conditions and issues effecting these areas. Residents living in certain locations of Mississauga had been battling gypsy moth infestations for over twenty-five years. Through interaction between neighbourhood associations, municipal and commercial arborists and their own research, homeowners have been participating with integrated pest management programs involving tree banding, egg mass scraping and pheromone traps for many years. When gypsy moth numbers began to increase into breakout populations, area residents were well organized and prepared to address the problem through informative private rate payer websites, petitions to City Council and demonstrative activities including lawn signs and T-shirts raising awareness and support for action towards controlling the outbreak.

City staff developed a comprehensive communication strategy, in conjunction with the operational objectives, that was based on transparent transfer of information. Community representatives were invited to weekly update meetings and information brochures were developed and distributed to effected communities. Many community group and rate payer meetings were attended by City staff to provide information and answer questions regarding the control program and a Town Hall style meeting was also organized to address and respond to concerns. The City's website also offered an abundance of up-to-date information and details on the specific planning and operational processes and procedures.

Other essential tools and resources for public outreach and effective communication included a variety of street signs, posters and local publications while newspapers and radio stations allowed for the mass distribution of current details including spray schedules, cancellations and other relevant important information.

Political Support

In a highly urbanized municipal setting, political support and direction is essential to the success of any management program. A total to six corporate reports were presented to City Council in 2006 providing detailed information and updates on the program. Issues regarding scheduling, financial impacts, cost recovery, a Public Nuisance By-law, implementation expectations and follow up directives were addressed through this formalized political process.

Communication and interaction with local Ward Councilors on specific issues was also an important factor in the success of the program. Complaint resolution and written responses to queries where often addressed through the Mayor's or Councilor offices.

Regulations and Compliance

The aerial gypsy moth control program in Mississauga involved an extremely high degree of authoritative and regulatory compliance including two Ministerial exemptions from Transport Canada and the Ministry of the Environment. Extensive communication, planning and cooperation with all of the technical stakeholders resulted in all approvals and exemptions being duly achieved. Full compliance with all relevant acts, regulations and legal requirements were maintained throughout the aerial spray program including a Pesticide Compliance Audit performed by the Ministry of the Environment.

Technical Stakeholders involved in these directives and compliance issues included:

- Transport Canada: Ministerial exemption to fly the helicopter over residential areas under 1,000 feet
- Peel Regional Police: coordination of road closures during spray operations
- Ministry of Transportation and the Ontario Provincial Police: 400 series highway traffic control issues
- GO and Mississauga Transit: commuter scheduling during spay operations
- Greater Toronto Airport Authority (RCMP): air traffic control issues
- Fire and Emergency Medical Services: emergency plans and resources within the treatment areas during flight operations

Other critical organizations involved in the communication and operational components of the program included BioForest Technologies, Zimmer Air Service, Region of Peel Public Health, Mississauga's Forestry, Communications and Transportation & Works Departments, Valent BioSciences and the Ministry of Natural Resources.

Success Measures and Follow Up Initiatives

Virtually every component of the gypsy moth control program consisted of some degree of measurement from egg mass density and delineation surveys to deposit testing and drift modeling. These statistics and measurements assisted in documenting the scientific justification for the spray program as well as compliance and the successful achievement of the overall objectives of the program. Follow up egg mass density and defoliation survey details were presented to City Council and other communication outlets in order to share and celebrate the results of the control program. Residents were also encouraged to continue with their own integrated pest management programs to help sustain gypsy moth populations at acceptable levels within their communities.

A $10,000 Green Streets Canada grant was received from the Tree Canada Foundation to offset some of the communication and public outreach costs and to help showcase and distribute Mississauga's Gypsy Moth Control Program to other interested stakeholders.

Mississauga also had the opportunity to include specific gypsy moth control questions on a local Environics survey in the winter of 2006. Results of the survey were very encouraging as over 80% of respondents who were aware of the program agreed that the management and communication aspects of the control measures were well handled.

Short History of Municipal EAB Management at the Town of Oakville 2008 to 2010

John McNeil, R.P.F.
Manager of Forestry, Town of Oakville
Oakville, Ontario
jmcneil@oakville.ca

Following the confirmation of EAB in the Iroquois Ridge South Community in July 2008 we began treating approximately 250 ash street and park trees with TreeAzin. Today, the only ash trees which are alive and healthy in this neighbourhood are those which we treated. This would seem to confirm our early speculation that the EAB population had been building undetected for several years in this neighbourhood. Treatment results indicate a 97.5% efficacy rate. But where else was EAB in Oakville? With no urban forestry support program in place in Canada and Ontario for lower tier municipalities we were on our own to find out. However, my understanding is that the current CFIA detection methodology misses 3 out of 4 infested ash trees. How were we going to reliably map EAB? Should we treat more trees? Should we follow the CFIA protocol for ALHB at the City of Toronto in 2003 and begin sanitizing the host and replacing the canopy? Where are the 177,300 public and private ash trees located? Fraxinus represents 9.3% of Oakville's urban forest, according to our 2005 Urban Forest Effects Model Project with the U.S. Forest Service. As the town's urban forester I had a sinking feeling in the pit of my stomach that the future for EAB was going to be like that described to me by some of my colleagues in southwestern Ontario: chaos.

The town retained BioForest Technologies. This firm declared their conflict of interest as the only supplier of TreeAzin in Canada. In my opinion, retaining BioForest has been a smart strategic move; with so few qualified firms specializing in forest pest management to choose from I have seen several poor selections – resulting in poor EAB management plans. In my opinion, this widespread variability in the quality of EAB management strategies at the lower level of government is the result of a combination of the lack of leadership at the upper level and lack of a formal urban forestry infrastructure in Canada. BioForest developed an EAB Emergency Response Plan that town Council approved in the fall of 2008. It outlined the following key areas for the town to build in order to fight this long-term battle: (1) Inventory; (2) Strategic Management Plan; (3) budget. All three components need to complement each other. It also stressed that this insect should be managed on an ecosystem level. This explains our current initiatives to try and obtain coordinated support from senior levels of government as well as hosting a regional level EAB Task Force.

Implementation of this Plan began in 2009. Town Council approved (1) $250,000 for a Town tree inventory- phase 1; a priority was placed on adding the 13,800 ash street and Park trees into a Tree Layer on the Corporate GIS linked to Forestry's CityWorks asset management system and (2) $50,000 for Phase 2 of TreeAzin treatments: 9 "Ash Reserves" were established – 1 in each Oakville community and (3) $100,000 to begin under planting part of the ash canopy.

Throughout 2009, I braced for the public outcry - as Forestry staff began to notice changes in the ash canopy over parts of Oakville- that never came.

In early 2010, BioForest staff introduced us to a CFS researcher who needed a location to further test an EAB early warning system; we jumped at the chance to partner with CFS. By spring, Oakville was the first municipality in Canada to complete a community-wide EAB distribution map using a combination of our staff arborists and assistance from Maple Hill Tree Services, Arborcorp Tree Experts and Peter Williams Forestry and Environmental Services [please refer to this link to view a copy of the map: http://www.oakville.ca/Media_Files/forestry/2010AshTreeDeteectedMap.pdf]. While I was relieved to learn we had only 1 epicentre, I was surprised by the widespread distribution of the previously undetectable low level distribution of EAB population. Our hard work was beginning to show promise: the combination of this project, our Inventory Project, our 2005 UFORE Project and the pest management decision support system of BioForest made me feel, for the first time, confident about the future with EAB. In my opinion, those municipal urban forest managers who are either not using the most effective method or no systematic method to map EAB in their community need to stop wasting time and adopt the Ryall method. I believe that serving the public interest requires these kinds of efforts.

All of the Ryall method plots were located on public property. Understanding the biology of the pest motivated us to follow up on BioForest's recommendation to inventory private ash trees (representing 57% of Oakville's ash trees and 80% of Oakville's treatable ash canopy) using hyperspectral imaging technology (HSI); this is based on the success of the City of Milwaukee's successful HSI Project in 2009. In July of this year a plane collected data from Oakville with a specialized spectrometer calibrated with local ash tree spectral signatures: the objectives of this project include mapping all of the 177,300 ash trees, an updated canopy cover analysis to our 2005 UFORE Project and most promising for EAB management across the continent - an attempt to identify a spectral pattern for EAB infestation. The U.S. Forest Service is partnering with the town in this project being carried out by AMEC Earth and Environmental Ltd [please refer to this link to view more information about this Project: http://www.oakville.ca/nr-10aug10_1.htm]. In addition to this project, we have almost completed inventorying all town street and Park trees and expect to begin Phase - 3 Woodlot inventory. Our EAB partnerships have generated research efforts including a green Trapping Project [please see these links for more information on this Project: http://www.oakville.ca/nr-10may17.htm and http://www.oakville.ca/Media_Files/forestry/EAB2010trapmap.pdf], a TreeAzin Threshold Project, an ALHB Project, an Ash Tree Growth Algorithm Project and an EAB biology project. The largest component of the 2010 EAB WorkPlan approved by Council [please refer to these links to view full staff report: http://www.oakville.ca/Media_Files/forestry/2010EABWorkplan.pdf and http://www.oakville.ca/nr-10july15.htm] was our Ash Tree Treatment Program- consisting of 1,600 selected-street and Park trees treated with the 5 ml dose of TreeAzin by our contractor, Davey Tree Expert Company. Emphasis was placed on treating large stature trees and trees located in the area of "moderate" level infestation. This reflected our 2010 treatment objectives: priority canopy protection and insect suppression [please refer to this link to see a map of the 2010 Ash Tree Treatment Program: http://www.oakville.ca/Media_Files/forestry/2010EABTreatmentProgram.pdf]. Door hangers advised residents that this was the beginning of a 15 year treatment effort. A Communications Plan is being finalized with public open houses planned for next year.

These efforts will tie into an EAB Strategic Management Plan expected to be approved by Council this fall/winter. The Plan is expected to contain performance measures based on canopy cover since Oakville's new Official Plan contains a Corporate objective to increase urban forest canopy from 29.1% to 40%. In this way we can track our success in managing EAB.

TreeAzin™ Systemic Insecticide and the EcoJect® System: New Tools for Insect Management

Joe Meating
BioForest Technologies, Inc.
Sault Ste. Marie, Ontario
jmeating@bioforest.ca

TreeAzin™ Systemic Insecticide

In 2001, BioForest Technologies Inc. began a collaborative effort with the Canadian Forest Service to develop a new insecticide for use in urban and environmentally sensitive areas. TreeAzin™ Systemic Insecticide is a neem-based bioinsecticide that is effective against a wide range of damaging insect pests, but has very low mammalian and avian toxicity. TreeAzin is a 5% formulation that is rapidly taken up and translocated in both coniferous and deciduous tree species. The active ingredient, azadirachtin, is commercially available in North America and is registered in more than 40 countries.

Azadirachtin has multiple modes of action. In immature insects it acts as a growth regulator, disrupting or prolonging development. In mature insects azadirachtin can act as an insect repellent or reduce female fecundity.

In 2002, BioForest began field trials to assess the efficacy of TreeAzin against several damaging tree pests and over the next few years, efficacy trials were conducted in Canada and the U.S. against a variety of pests including:

emerald ash borer*	birch leafminer*
gypsy moth*	pine false webworm*
spruce budworm*	introduced pine sawfly*
jack pine budworm*	mountain pine beetle?
forest tent caterpillar*	brown spruce long-horned beetle?
cedar leafminer*	Asian longhorned beetle (bioassays)?

* TreeAzin provided significant efficacy.
? TreeAzin efficacy likely but not confirmed

The TreeAzin efficacy trials were conducted on a variety of tree species including conifers and deciduous species:

red pine	lodgepole pine
jack pine	red and bur oak
white pine	trembling aspen
white spruce	ash
balsam fir	maples
cedar	white birch

More recently, trials have been or will be conducted for pests such as:

- bronze birch borer
- Japanese beetle
- hemlock wooly adelgid
- red elm weevil
- two-lined chestnut borer

The discovery of emerald ash borer (EAB) in Michigan and Ontario in 2002 resulted in considerable effort to develop treatment options. BioForest and the CFS conducted several laboratory and field trials to test the efficacy of TreeAzin against this serious pest. Results indicated that:

1. TreeAzin is rapidly taken up and effectively translocated in ash trees following trunk injections.

2. Toxicologically significant concentrations are likely to occur in injected trees throughout the larval and adult feeding period.

3. TreeAzin is highly effective at inhibiting larval development and preventing adult emergence at very low doses.

4. TreeAzin does not cause direct mortality of feeding adults (as expected).

5. TreeAzin causes reduced fertility and fecundity of adult females feeding on leaves.

In 2004, BioForest entered into a Product Licence Agreement with Natural Resources Canada that gave BioForest the sole right to use, manufacture, market, sell, and distribute TreeAzin™ Systemic Insecticide on a worldwide basis.

During the period 2004-2008, BioForest continued studies in preparation for submission to federal regulatory agencies in Canada, Pest Management Regulatory Agency (PMRA), and the United States, Environmental Protection Agency (EPA). These studies included:

- Toxicological studies (6-pack)
- Formulation stability studies
- Chemical characterization studies
- Residue analysis
- Environmental fate studies

In February 2008, BioForest was granted an Emergency Registration (ER) for TreeAzin™ Systemic Insecticide by PMRA for use against the emerald ash borer in the province of Ontario. In July 2008, the ER was extended to include the province of Quebec.

In October 2008, The United States EPA registered TreeAzin™ Systemic Insecticide for use against a variety of insect pests. In December 2008, The Organic Materials Review Institute (OMRI) added TreeAzin to its list of approved pesticides for use in organic crop protection.

In 2009, PMRA issued another ER for TreeAzin against the EAB and BioForest submitted TreeAzin to PMRA for full registration.

EcoJect®System

Concurrent to the development of TreeAzin™ Systemic Insecticide, BioForest began development of a safe, simple and efficient tree injection tool. This effort followed an assessment of commercially available injection devices. The resulting EcoJect® System has proven to be effective for injecting TreeAzin and other formulations into a variety of tree species.

Components of the EcoJect® System, such as the canisters and nozzles, are re-usable and will provide the applicator with hundreds of injections. The portable field pump provides the applicator with on-site loading capability and multiple trees can be set up for treatment at one time thus improving efficiency. Typical injection times using the EcoJect®, System and TreeAzin vary but most trees will be treated in the 5 minute to 20 minute range.

Emerald Ash Borer Decision Support System

BioForest has considerable experience with decision support systems in forest pest management. In 2009, BioForest began to develop a new tool to assist the EAB management decision making process. The EAB Decision Support System (EABDSS) integrates tree inventory data and EAB outbreak dynamics to dramatically improve development and targeting of management actions as well as detailed cost estimates for annual and multi-year budgeting.

Biological Control of Emerald Ash Borer

D. Barry Lyons
Natural Resources Canada, Canadian Forest Service,
Sault Ste. Marie, Ontario
Barry.Lyons@NRCan.gc.ca

Introduction

Biological control is the tactic of using living organisms to regulate pest populations. There are two potential strategies for biological control of invasive forest pests like emerald ash borer (EAB), *Agrilus planipennis* Fairmaire. The classical biological control strategy for invasive species involves searching for natural enemies (parasitoids, predators and pathogens) in populations of the pest in the geographic region of its origin. For EAB, this would involve explorations for potential biocontrol agents in China, Korea, Taiwan, Japan and the Russian Far East. In the augmentative/inundative strategy, natural enemies of organisms related to the pest in the region where the alien species has invaded are sought. For EAB, this involves examining the natural enemy complex of native Buprestidae, especially species of *Agrilus*. This strategy may also involve examining North American populations of EAB and looking for natural enemies that have already made the host switch to this invasive species. These natural enemies are then mass reared and introduced into EAB populations.

Surveys reported by Liu *et al.* (2003) in southeastern Michigan indicated that parasitism by native parasitoids in EAB populations amounted to less than 1%. Similarly, they reported that fungal pathogens only resulted in ca. 3% mortality in these same EAB populations. The most prevalent fungus collected was *Beauvaria bassiana* (Balsamo) Vuillemin.

Other North American organisms have made the successful transition to preying on EAB populations. A few predatory beetles (i.e., *Enoclerus* sp. (Cleridae), *Catogenus rufus* (F.) (Passandridae) and *Tenebriodes* sp. (Trogossitae)) have been collected feeding on EAB life stages under the bark of host trees (Liu *et al.* 2003). According to Cappaert *et al.* (2005), woodpecker predation is probably the most important source of mortality in EAB populations in Michigan and has accounted for 9 to 95% mortality. Lindell *et al.* (2008) have observed hairy, downy and red-bellied woodpeckers preying on EAB and recommended the maintenance of conditions (*e.g.*, nest sites) that attract woodpeckers. The predatory wasp, *Cerceris fumipennis* Say (Hymenoptera: Crabronidae), has been shown to collect EAB adults to provision its nest. Although the impact of the wasp on EAB populations is not significant, this species may prove to be a useful biosurveillence tool for detecting low density EAB populations (Careless *et al.* 2009).

Classical Biological Control with Exotic Parasitoids

Staff of the Forest Service (FS) and the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (USDA), and their collaborators have undertaken explorations in China for potential biological control agents for EAB since 2003 (Liu *et al.* 2003). Three species of hymenopterous parasitoids of EAB, two larval parasitoids and one egg parasitoid, were discovered in China. The first parasitoid discovered was an unknown species of *Spathius* (Hymenoptera: Braconidae) that was named *agrili* and described by Yang *et al.* (2005). It is a gregarious ectoparasite (i.e., multiple parasitoid larvae feed and develop outside the host) that lays 1 to 35 eggs on a single EAB host larva. This idiobiont (i.e., arrests the development of the host larva) has up to four generations a year and observed parasitism rates have ranged from 30 to 90% (Yang *et al.* 2005). The second larval parasitoid was also a new species and was named *Tetrastichus planipennisi* Yang (Hymenoptera: Eulophidae) (Yang *et al.* 2006). They described this parasitoid as a gregarious endoparasite (i.e., multiple parasitoid larvae feed and develop inside the host) that has caused 32 to 65 % parasitism of EAB populations in northeastern China. It is a koinobiont (i.e., does not inhibit development of host larvae) that may have 56-92 individuals developing per host larva and overwinters as a mature larva (Yang *et al.* 2006). The solitary egg parasitoid was a new species and was described by Zhang *et al.* (2005) as *Oobius agrili* Zang and Huang (Hymenoptera: Encyrtidae). Laboratory rearing techniques were developed for all three parasitoid species (Bauer *et al.* 2008). Laboratory tests were undertaken to determine if these parasitoids would attack non-target hosts in North America. The results suggested that *S. agrili* and *O. agrili* might only occasionally attack other *Agrilus* species (Bauer *et al.* 2008).

Fig. 1. *Phasgonophora sulcata* female reared from ash log infested by emerald ash borer.

Prior to the release of the three parasitoids into the wild, an environmental assessment was conducted (USDA-APHIS 2007). This was followed by the publication of the report in the Federal Register and a 60-day comment period, after which permits for release were approved. The three parasitoids were first released at sites in Michigan in 2007 (Bauer *et al.* 2008). Two of the parasitoids, *S. agrili* and *O. agrili*, were recovered at the release site in the spring of 2008 (Bauer *et al.* 2008) and in 2009 *T. planipennisi* was recovered at release sites (USDA-FS 2009). Additional releases of one or more of these species have been made in Ohio, Indiana, Maryland and Illinois in 2008 and 2009 (USDA-FS 2009).

In 2008, USDA-APHIS completed the construction of a biological control production facility in Brighton, Michigan for mass rearing the three species of Chinese parasitoids (Bauer *et al.* 2008). The facility came on production in the spring of 2009. The USDA-APHIS five-year plan for biological control of EAB is available online (USDA-APHIS 2008).

Augmentative or Inoculative Biological Control with Native Parasitoids

Surveys were undertaken to determine the parasitoid fauna associated with three native species of *Agrilus*. Log bolts were collected from white birch, *Betula papyrifera* Marsh., infested with bronze birch borer, *Agrilus anxius* Gory, in Sudbury, Thunder Bay and North Bay Districts, Ontario. Bolts were also collected from red oak, *Quercus rubra* L. infested with *Agrilus bilineatus* (Weber) in Midland District, Ontario and from balsam poplar, *Populus balsamifera* L. infested with bronze poplar borer, *Agrilus liragus* Barter & Brown in Thunder Bay District, Ontario.

EAB adults are routinely reared from green ash, *Fraxinus pennsylvanica* Marsh., log bolts infested with EAB in the Quarantine Facility at the Great Lakes Forestry Centre to produce insects for other experimental purposes. All parasitoids that emerged from these log bolts were collected and identified (Table 1).

Parasitoids were identified by taxonomists at the Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada. Parasitoids in the genus *Atanycolus* (Hymenoptera: Braconidae) were sent to Paul Marsh (United States National Museum, retired) for identification. Four species of *Atanycolus* were collected from *Agrilus* infested logs (Table 1). Three of these were reared from ash. One of these species, *A. cappaerti* Marsh and Strazanac, is a newly described species reared from EAB (Marsh *et al.* 2009). The four parasitoid species, highlighted in Table 1, may have potential for biological control of EAB.

Serendipitously, a collection of green ash log bolts

Table 1. Species of hymenopterous parasitoids reared from bolts from four tree species infested with four species of *Agrilus*, the relative abundance of each species and its potential as an *Agrilus* parasitoid. Potential biological control agents for emerald ash borer are highlighted in yellow.

Species	**Host Tree** *Fraxinus*	*Betula*	*Populus*	*Quercus*	***Agrilus* host**
Braconidae					
Aliolus stictopleurus Martin	U				no
Atanycolus hicoriae Shenefelt	VC	VC			yes
*Atanycolus disputabilis (*Cresson)		C			unknown
Atanycolus longicauda Shenefelt	C				unknown
Atanycolus cappaerti Marsh & Strazanac	C	C			
Bassus sp.	U				unknown
Chelonus sp.				U	unknown
Coeloides rossicus betulae Mason		U			maybe
Doryctes rufipes (Provancher)			C		yes
Leluthia astigma (Ashmead)	U			U	yes
Macrocentrus marginator (Nees)	U				no
Spathius simillimus Ashmead				C	yes
Ichneumonidae					
Dolichomitus irratator (Fabricius)	U				maybe
Dolichomitus messor (Gravenhorst)		U	U		maybe
*Rhyssella nitida (*Cresson)		U			no
Xorides humeralis (Say)	U				maybe
Pteromalidae					
Holcaeus sp.		U			unknown
Platygerrhus algonquina (Girault)		U			unknown
Chalcididae					
Phasgonophora sulcata Westwood	VC		U		yes
Eupelmidae					
Metapelma spectabile Westwood	U				yes
Balcha indica (Mani & Kaul)	C				yes
Eulophidae					
Baryscapus sp.		U			unknown
Aulacidae					
Pristaulacus sp.		C			no

U = uncommon, C = Common, VC = very common from a site in southwestern Ontario in the later stages of an EAB outbreak produced unprecedented numbers of two species of parasitoids (Lyons 2008). Of the 215 insects reared from these bolts 146, 54, 9, and 6 were *A. planipennis*, *Phasgonophora sulcata* Westwood (Hymenoptera: Chalcididae) (Fig. 1), *Balcha indica* (Mani & Kaul) (Hymenoptera: Eupelmidae) and other parasitoids, respectively, suggesting a parasitism rate of 32.1%. At a nearby location 11 parasitoids (8 *P. sulcata* and 3 others) emerging from bolts were greatly outnumbered by 648 emerging EAB adults, suggesting a parasitism rate of only about 1.2%. Apparently parasitism rates vary spatially and probably temporally as well.

In 2007, we placed sticky-band traps in the woodlot in Essex Co. from which the high number of *P. sulcata* had been obtained. At approximately bi-weekly intervals throughout the summer we examined the traps and removed EAB and *P. sulcata* adults. Six hundred EAB adults and 407 adults of *P. sulcata* were collected from the traps suggesting a parasitism rate of 40.7%. The flight periods of the two species are shown in Fig. 2. The flight period of the parasitoids seems to be synchronized with the egg laying period of EAB and supports the observation by Haack *et al.* (1981) that the parasitoid lays eggs near the host's eggs.

As part of ongoing investigations into the biology of the parasitoids, ash log bolts were collected from Sarnia, Ontario, an area known to have high parasitoid populations. Bolts were collected in October 2008, April 2009 and May 2009. The logs were reared at 24°C and the times to emergence of EAB, *P. sulcata* and *Atanycolus* sp. were determined. The adults parasitoids were placed in rearing cups at 21°C with access to water and honey and examined daily until they died. The mean times to emergence for the threes species are shown in Fig. 3. *Atanycolus* sp. emerged well in advance of EAB, while *P. sulcata* emerged well after EAB. These results for *P. sulcata* support the observed late flight period of the parasitoid relative to the host observed in the field. Observed emergence of adults of *Atanycolus* sp. would be out of synchrony with the majority of the larval stages of EAB. Cappaert and McCullough (2009) observed a bivoltine (two generations a year) life cycle for *Atanycolus* sp. The insects observed here would represent the first generation that would only have two-year life cycle EAB larvae to attack. Males and females of *Atanycolus* were extremey long lived with males and females living for an average of more than 100 days (Fig. 4). Mean survival rates for *P. sulcata* male and female adults were considerably shorter (Fig. 4).

Balcha indica is itself an alien species, which is

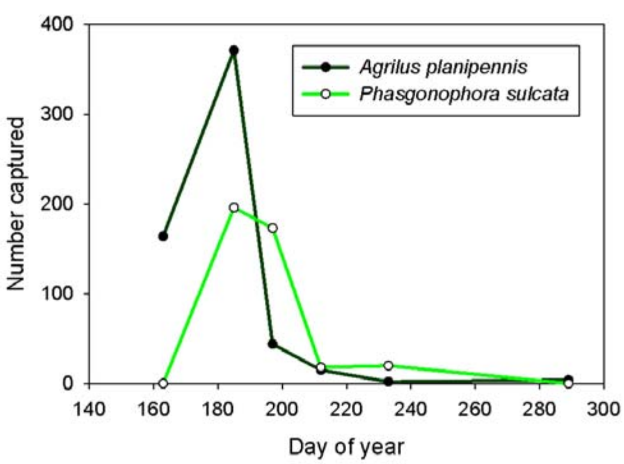

Fig. 2. The flight period of *Phasgonophora sulcata* relative to its host emerald ash borer.

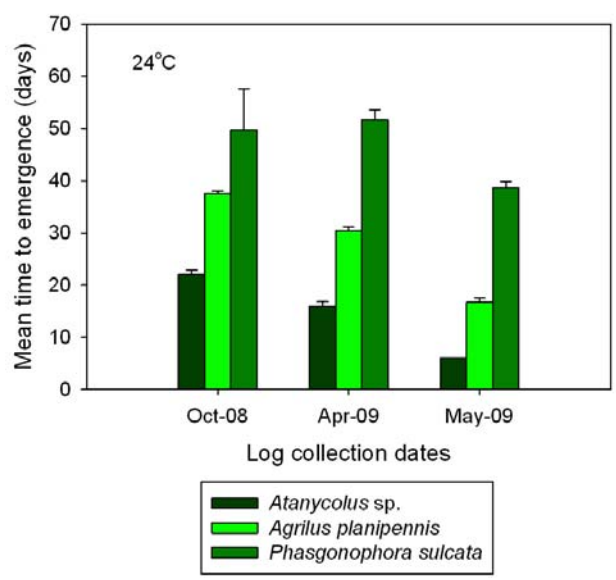

Fig. 3. Mean (+SE) emergence times for the two parasitoids, *Phasgonophora sulcata* and *Atanycolus* sp. relative to the host emerald ash borer at a constant temperature of 24°C.

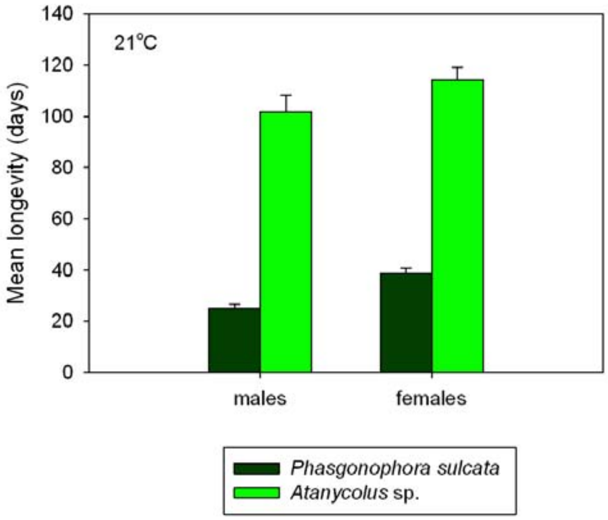

Fig. 4. Mean (+SE) longevity of male and female *Phasgonophora sulcata* and *Atanycolus* sp. at a constant temperature of 21°C.

native to southeastern Asia and probably arrived in North America on some host other than EAB because its discovery in Virginia in 1994 pre-dates the estimated arrival of EAB in that area (Gibson 2005). In North America only females of *B. indica* are known, although males are known to occur in Asia (Gibson 2005). The abundant species *P. sulcata* is a native parasitoid of other *Agrilus* species (Haack *et al.* 1981). Cappaert and McCullough (2009) have begun investigations into the biology and biocontrol potential of *A cappaerti* discovered in EAB populations in Michigan. Any of these parasitoid species may be suitable biocontrol agents against EAB, but all will require further study.

Augmentative or Inoculative Biological Control with Native Pathogens

Investigations into the potential biological control of EAB using native entomopathogens is being undertaken by G. Kyei-Poku and colleagues at the Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre in Sault Ste. Marie, Ontario. Collections of mycosed EAB prepupal and adult cadavers, and EAB frass containing fungi were made from Sarnia, Windsor and London, Ontario in well established EAB populations. Fungal pathogens from four genera were isolated from these cadavers and are currently in culture. *Beauveria* sp. was the predominant 'natural' pathogen from mycosed EAB and gallery frass. *Lecanicillium* sp., *Metarhizium* sp. and *Paecilomyces* sp. were present but at very low levels. Preliminary bioassays to assess the virulence of the various fungal isolates are underway.

A small percentage of the EAB samples were also infected with nematodes. A newly discovered nematode kills and multiplies on EAB. Molecular characterization indicated that the recovered nematode is a *Rhabditis* (*Oscheius*) species.

Searches for entomopathogens associated with or infecting native *Agrilus*, congeners of EAB were also undertaken. A microsporidian, *Cystosporogenes* sp., was isolated from the bronze birch borer, *A. anxius*, and cross infectivity tests with EAB are being conducted. Microsporidia are pathogens that do not typically kill their host but usually reduce the host's reproductive potential.

Liu and Bauer (2006) have demonstrated the susceptibility of EAB to commercial strains of the fungi *Beaveria bassiana* and *Metarhizium anisopliae.*

Acknowledgements

I would like to thank G. Jones, A. Kent, N. O'Brien, M. Rains, A. Sauve and S. Woodcock for assistance in the laboratory and field. Thanks to A. Keizer and H. Evans for collecting infested logs in the field. Thanks are also extended to A. Bennett, G. Gibson H. Goulet and J. Huber (Agriculture and Agri-Food Canada, ECORC) for identifying the parasitoids. *Atanycolus* spp. were graciously identified by P. Marsh (United States national Museum, retired). George Kyei-Poku provided the information on his research on entomopathogens.

Literature Cited

Bauer, L. S., H. Liu, D. Miller and J. Gould. 2008. Developing a classical biological control program for *Agrilus planipennis* (Coleoptera: Buprestidae), an invasive ash pest in North America. Newsletter of the Michigan

Entomological Society 53: 38-39.

Cappaert, D., D. G. McCullough, T. M. Poland, and N. W. Siegert. 2005. Emerald ash borer in North America: a research and regulatory challenge. American Entomologist 51: 152-165.

Cappaert, D. and D. G. McCullough. 2009. Occurrence and seasonal abundance of *Atanycolus cappaerti* (Hymenoptera: Braconidae) a native parasitoid of emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae). The Great Lakes Entomologist 42: 16-29.

Careless, P. D., S. A. Marshall, B. D. Gill, E. Appleton, R. Favrin and T. Kimoto. 2009. *Cerceris fumipennis* – a biosurveillance tool for emerald ash borer. Canadian Food Inspection Agency. Ottawa, Ontario. pp. 16.

Gibson, G. A. P. 2005. The world species of *Balcha* Walker (Hymenoptera: Chalcidoidea: Eupelmidae), parasitoids of wood-boring beetles. Zootaxa 1033: 1-62.

Haack, R. A., D. M. Benjamin and B. A. Schuh. 1981. Observations on the biology of *Phasgonophora sulcata* (Hymenoptera: Chalcididae), a larval parasitoid of the two-lined chestnut borer, *Agrilus bilineatus* (Coleoptera: Buprestidae) in Wisconsin. The Great Lakes Entomologist 14: 113-116.

Lindell, C. A., D. G. McCullough, D. Cappaert, N. M. Apostolou and M. B. Roth. 2008. Factors influencing woodpecker predation on emerald ash borer. American Midland Naturalist 159: 434-444.

Liu, H. and L. S. Bauer. 2006. Susceptibility of *Agrilus planipennis* (Coleoptera: Buprestidae) to *Beauveria bassiana* and *Metarhizium anisopliae*. Journal of Economic Entomology 99: 1096-1103.

Liu, H., L. S. Bauer, R. Gao, T. Zhao, T. R. Petrice and R. A. Haack. 2003. Exploratory survey for the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), and its natural enemies in China. The Great Lakes Entomologist 36: 191-204.

Lyons, D. B. 2008. Emerald ash borer: It's here to stay, let's learn to manage it. Forest Health & Biodiversity News 12: 4-5, 7.

Marsh, P. M., J. S. Strazanac, and S. Y. Laurusonis. 2009. Description of a new species of *Atanycolus* (Hymenoptera: Braconidae) from Michigan reared from the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae: Agrilinae). The Great Lakes Entomologist 42: 8-15.

Yang, Z.-Q., J. S. Strazanac, P. M. Marsh, C. Van Achterberg and W.-Y. Choi. 2005. First recorded parasitoid from China of *Agrilus planipennis*: a new species of *Spathius* (Hymenoptera: Braconidae: Doryctinae). Annals of Entomological Society of America 98: 636-642.

Yang, Z.-Q., J. S. Stranzanac, Y.-X. Yao and X.-Y. Wang. 2006. A new species of emerald ash borer parasitoid from China belonging to the genus *Tetrastichus* Haliday (Hymenoptera: Eulophidae). Proceedings of the Entomological Society of Washington 108: 550-558.

Zhang, Y.-Z., D.-W. Huang, T.-H. Zhao, H.-P. Liu and L.S. Bauer. 2005. Two new species of egg parasitoids (Hymenoptera: Encyrtidae) of wood-boring beetle pests in China. Phytoparasitica 33: 253-260.

USDA-APHIS. 2007. Proposed Release of three parasitoids for the biological control of the emerald ash borer (*Agrilus planipennis*) in the continental United States. Environmental Assessment, April 2, 2007. United States Department of Agriculture, Animal and Plant Inspection Service. Available at: http://www.aphis.usda.gov/plant_health/ea/downloads/eab-ea4-07.pdf (accessed 9 December 2009).

USDA-APHIS. 2008. Emerald ash borer biological control program 5-year plan. Available at: http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/eab-biocontrol-5yr-plan.pdf (accessed 21 December 2009).

USDA-FS. 2009. Biological Control of the emerald ash borer. Available at: http://nrs.fs.fed.us/disturbance/invasive_species/eab/control_management/biological_control/ (accessed 10 February 2010).

Past Experience: the Dutch Elm Disease Story
Did the Sky Fall?

Laszlo Magasi
Retired, Natural Resources Canada, Canadian Forest Service
Fredericton, New Brunswick
magasi@nb.sympatico.ca

Fredericton's elm population did not succumb to the ravages of Dutch elm disease because Fredericton's City Council heeded the advice from scientists at the Forest Biology Laboratory and started to prepare for the arrival of this fast approaching, devastating, wide-spread danger to the city's magnificent but aging elm monoculture.

Well in advance of the discovery of the disease in Fredericton in 1961, the city's trees were "cleaned up" through a vigorous campaign of pruning healthy trees and the removal of approximately 500 decadent trees, thus denying the disease-carrying elm bark beetles of breeding habitat. Beetle-proofing – and the practice of quickly and consistently removing all infected trees – forms the basis of Fredericton's almost 60-year-old sanitation program, the most important aspect of the city's Dutch elm disease management program.

Fredericton, the capital city of New Brunswick, was established in 1783, became a city in 1848 and amalgamated several surrounding villages in 1973. Major elm plantings in 1818 by the military, 1883-1887 by civic officials and in the 1940s created an eventually vulnerable monoculture.

Dutch elm disease is caused by a fungus; it is carried and spread by the elm bark beetle and it kills trees. It devastated elms in cities, villages and the countryside in much of the American mid-west since 1930, spread into Quebec, then into New Brunswick at Woodstock in 1957 from where it spread along the St. John River, reached Fredericton in 1961, continued to spread, it intensified and killed close to 95% of the trees in 8 years.

Beetle-proofed Fredericton was ready, with (1) a Fredericton Tree Commission of eight volunteer members; (2) a Division of Parks and Trees of now close to two dozen employees, including a professional City Forester; (3) a by-law allowing the city to enter private property to inspect and remove trees; (4) a supportive city council; (5) a resolve to create a multi-species, uneven-aged urban forest and (5) a dedication to sanitation.

Control measures against Dutch elm disease include: (1) surveys; (2) chemicals; (3) trap trees; (4) tree injection; (5) tree implants; and most important (5) sanitation.

Sanitation methods include: (1) preventive pruning; (2) preventive tree removal; (3) clear cutting; (4) prompt removal of infected trees; (5) burning or burying infected tree material; (6) stump removal; and (7) tree replacement.

Fredericton's Dutch elm disease (DED) story is divided into several periods, each with its own problems and successes:

Preparation 1952 – 1960 – No DED; preventive pruning, cutting; establishment of Tree Commission in 1952.

Invasion 1961 – 1969 – DED under 0.01%; 15 trees lost; establishment of Parks and Trees Division in 1967.

Build-up 1970 – 1975 – DED 0.1 – 1.0%; 225 trees lost; losses to DED: Fredericton 4.2%, outside 72%; most of tree work (77%) in amalgamated areas.

High pressure and peak 1976 – 1980 – DED 1.7 – 7.8%; 883 trees lost; losses to DED Fredericton 19.7% outside 95+%; a green island in a sea of destruction; very high beetle influx, chemical control used to lower populations; clear-cutting in amalgamated areas; fighting the beetles, the disease – and the doubters/critics of the program.

Downturn 1981 – 1985 – DED 5.3 – 1.7%; 457 trees lost; loss to DED 28.8% in 25 years; consistent lowering of infection rates.

Under control 1986 – 1990 – DED 1.0% or less; 124 trees lost; first 1% loss in 12 years; no higher than 31 trees lost in a single year.

Since 1990 – still losing a few trees to DED but numerous old trees also succumbed to many years (since 1983) of repeated severe defoliation by the elm leaf beetle.

While Fredericton' loss to Dutch elm disease was 30% in 30 years, the loss in outside areas and in "do nothing" communities was 95% in just 8 years. This means that the program did make a difference and that **70 % of Fredericton's elm trees were saved**.

Beside saving old trees, tree planting – with a wide variety of species – has also been an on-going program in Fredericton, to replace trees removed, to plant in newly established areas and to convert the city's aging monoculture to a healthy, urban forest.

It cost Frederictonians about a penny/day/citizen to save some 5000 old elm trees and to convert the old monoculture to a vibrant urban forest, while it cost the "do nothing" communities most of their elm trees, plus the cost of removing the dangerous, hazardous dead trees for no benefit at all. (The "penny/day/citizen" comment is based on an approximately quarter of a million dollars/year Parks and Trees Division budget and a population of 55 000 people.)

Fredericton succeeded in its efforts to fight Dutch elm disease because (to quote D. Murray, City Forester) "we **anticipated** the arrival of Dutch elm disease and **prepared** for it by denying the bark beetle of suitable breeding habitat. We managed the disease by being **consistent and sticking with the program** even when things looked pretty grim. We gained more than 30 years which allowed us to convert our even-aged monoculture to a healthy, uneven-aged, multi-species urban forest."

The sky did not fall in Fredericton.

Managing Emerald Ash Borer: What Have We Learned?

Taylor Scarr
Ontario Ministry of Natural Resources
Sault Ste. Marie, Ontario
Taylor.Scarr@ontario.ca

This insect was only discovered in 2002 in the Detroit area of Michigan and the Windsor area of Ontario. The insect has spread rapidly in the United States and in eastern Canada, with an infestation as far east as Carignan, Quebec. The insect is spreading two ways: on its own through beetle flights, and by people moving infested material. These two pathways make the borer a pest of woodlots and forested areas, as well as of urban forests.

At the time of its discovery, the insect didn't even have a common name. Since then we have learned much about its biology and ecology. We have learned about its ability to kill all sizes and species of ash (*Fraxinus* spp.) except blue ash (*Fraxinus quadrangulata* Michx.). We have developed and improved survey and detection methodologies, and devised tools for protecting trees.

In an overall context, the Canadian Food Inspection Agency (CFIA) is the lead organization for these types of invasive species. Even so, we all have much at stake because of the impacts this insect is having on the rural and urban forests.

The CFIA has led the official survey for emerald ash borer. CFIA also imposes regulatory controls to slow the spread of the beetle to new areas. Meanwhile, the Canadian Forest Service has put considerable resources and effort into research on biology, ecology, impacts, survey and detection, tree protection, and long term biological control. Much of the research has also involved or been done in partnership with universities such as Guelph, Toronto, and Trent.

It is in the urban forest where many of the new finds are initially discovered. As the insect has spread, the urban foresters, municipal arborists, consultants, and tree care specialists have become the first line of detection and defence. As evidence of the effectiveness of education and awareness programs, many of the recent finds have been made not by federal or provincial field staff, but by those working in the urban forest who have been made aware of this insect and know how to spot infestations.

So what do you do when an infestation has been identified in your area? Whether you are managing a woodlot, conservation area, county forest, or an urban forest, the overriding message we heard during the workshop is that you need to have a plan. You need to have a forest management plan with clear objectives against which you can compare the impacts of emerald ash borer. Knowing whether the beetle will negatively affect those objectives will help guide you in determining what you should do or not do. It will also help you prepare for the beetle's arrival if it has not yet made it to your area.

If the objectives for which you are managing the trees or the forest are not affected by the loss of ash trees, then no real management response is needed. For example, emerald ash borer may be of limited impact if you are managing a sugar bush that has some ash trees intermixed. If dead trees pose a problem because they become safety hazards, then you have a dead or dying tree problem, more than an invasive species problem.

No matter what your plan though, you can only gauge the importance of the arrival of emerald ash borer if you have an inventory. What tree species do you have, how many trees are there, what size are they, where are they, and how important are they to you?

The lessons from Dutch elm disease are an example of how to respond strategically to the arrival of a devastating invasive species. The Fredericton, New

Brunswick experience showed that the sky does not necessarily fall when a tree-killing pest arrives. By preparing in advance for its arrival, and tactically employing techniques to slow its spread and extend its impacts out over time, you can protect the values of the urban forest. This allows you to amortize the cost of managing the pest over several years, making the program more affordable. The Dutch elm disease experience also showed that the greater cost will be incurred from doing nothing, and that these costs are incurred over a very short time period.

To implement the management plan and enable you to respond to emerald ash borer, you need to have the appropriate policies and procedures in place to deal with an invasive species. For example, if you need by-laws to empower you to conduct surveys or pest control programs on private land, get those in place before the invasive species arrives.

The economic analysis shows how important this insect is to the urban forest. The cost of tree removal and replacement can be enormous. Cost benefit analysis is needed to support your request for resources and to verify the need to mount a management response. While doing nothing may cost the most in terms of tree loss and removal, you still need a solid analysis to guide the allocation of your scarce resources. You need good data and informative analysis to develop good policy and to argue for those scarce resources.

Make sure you are aware of what others are doing on emerald ash borer. The Canadian Forest Service (CFS) and Ontario Ministry of Natural Resources (OMNR) and universities have several research programs on the go that are answering many of the pressing questions about emerald ash borer. Through collaboration with U.S. counterparts, these people can give you insight into the progress being made south of the border.

In developing your emerald ash borer plan, consult with the CFIA. To be effective, your program needs to mesh with theirs. Not only will you want to know what the current CFIA regulations are, you may need to influence those regulations so that they complement your local efforts.

Communications are key to the success of any program to combat emerald ash borer. No matter what your legal or moral authority might be, if you don't have the support of the public, the property owners, or your political masters, you will not have the social licence to proceed. The urban gypsy moth control program conducted in 2006 in Mississauga is an excellent example of how effective communications can cultivate public and political support. This can turn a potentially controversial program into one for which support is so strong that other property owners want to join the program.

Critical to the success of any communications plan are transparency and integrity. In particular, it is important to acknowledge where your uncertainties are. You still need to make management decisions in the face of uncertainty. By acknowledging those uncertainties you let your critics know you have heard their concerns and taken them into consideration.

Your communications plan needs clear objectives, key messaging, a clear timeline, effective tools and tactics, and feedback or evaluation to determine what is working and what needs improvement or changing. To earn the social trust, you need both public outreach and public involvement. You also need to be able to respond to information enquiries and to have an issue resolution process in place. Throughout it all, you need to protect your integrity through honesty and by making sure you do not step outside your particular area of expertise.

The CFIA, OMNR, and many municipalities have undertaken several communications efforts. Awareness has been raised through workshops, trade shows, professional meetings, websites, toll-free numbers, media notices, training sessions, and a myriad of promotional material such as pins, magnets, posters, buttons, business cards, and tattoos. Take advantage of these.

The CFS with support from OMNR and CFIA has produced a field guide to emerald ash borer for use by technical and professional staff. This guide is of particular use in detecting initial infestations. Similarly, the CFS has led the production of a manual on how to conduct formal surveys. Both of these publications are excellent resources for urban forest managers and their staff and contractors.

Research remains an imperative. Whatever actions we take need to be based on the best available science. And we need to continue to improve on this science. Significant progress has been made in detecting emerald ash borer. The CFIA has used visual surveys from the ground to look for signs or symptoms of infestation. Some very promising results from the CFS work shows that sticky traps baited with lures from green leaf volatiles may provide an effective tool for detecting the presence of the borer in a particular area.

The CFS has also developed the branch sampling and bark stripping technique to determine whether a particular tree is infested. This will increase the accuracy of surveys to make them far more effective than visual surveys alone.

These tools can be used in systematic surveys. They can be coupled with aerial reconnaissance to identify high risk or symptomatic trees for subsequent ground surveys to increase the efficiency and effectiveness of detection programs.

An understanding of the biology of emerald ash borer is the foundation of developing your response to the insect. The little bit we did know about this new arrival was from work that had been done in China prior to the Cultural Revolution. This limited background and some preliminary inspections of some cut trees provided the basis for the first fact sheet that guided our early surveys and management approach. We have learned a great deal in the last few years. We know its preference for different ash species, its ability to kill ash trees within a few years, its mating habits, egg laying habits, fecundity, dispersal patterns, and its phenology in Ontario. We are able to better predict the influence of weather and climate, and have been able to show that a significant portion of the beetle population takes two years to complete its life cycle in Ontario. Hopefully this will help slow the spread of the insect into northern areas.

Progress is also being made in developing management tools. The CFS with support from OMNR and in partnership with a private company, BioForest Technologies Inc., has developed TreeAzin as an insecticide that can be injected into ash trees to control emerald ash borer. This product has at least two uses. It can be used as a prophylactic to protect individual trees such as ornamentals and specimen trees. It can also be used as part of integrated pest management program to eradicate a satellite infestation of the borer.

In the event a true outlier or satellite infestation is found, the branch sampling technique can be employed to determine which trees are infested and how large the infestation is. Infested trees can then be removed and chipped or burned to kill the beetles. Nearby trees can then be treated with TreeAzin to eliminate light or non-detectable infestations.

Use of TreeAzin can help spread your tree losses over time, and amortize the costs of tree removal and replacement. It can also buy time for advances in research and technology, such as improved detection tools or development of biocontrol agents.

Finally, any management program needs a rehabilitation or restoration component. This will ensure you have a viable forest after the arrival of a destructive invasive species. It will also mitigate the effects of your management actions themselves, which will no doubt have some impacts. You will only earn your social licence for your program if you demonstrate from the beginning a commitment to ameliorate what you do or mitigate what the beetle might do.

The future of the beetle in Ontario gets clearer every day. We can expect emerald ash borer to continue to spread through the range of ash. Despite regulations and outreach programs, some people will move the beetle to new areas. Even though this may slow down as more people become aware of the risk, the beetle will continue to spread on its own. If you have yet to see the emerald ash borer infestation, then visit it now before it visits you.

Eventually we can expect an equilibrium to become established where low numbers of ash trees exist on the landscape. Any increases in ash abundance will be met with subsequent increases in beetle abundance. In the meantime, this insect has proven that it will kill large numbers of ash trees as it invades a new area. We need to continue to pursue advances in detection and survey methods. We need to refine tree protection using insecticides, and can expect to see the development of other products to add to the tool box for controlling emerald ash borer. Early detection followed by regulation of infested areas will be the first step in slowing the spread of the borer. We will learn from the control programs that integrate detection, identification of infested trees, removal of infested trees, and treatment of potentially infested trees. We need to share the results or our work, both our successes and our failures.

Effective control programs will help spread the tree losses and economic costs over time. They will also buy time for further advances in research. They could be applied to ecologically-important areas where ecosystem services such as protection of source water or support of biodiversity can be maintained. An integrated pest management plan for ecologically sensitive areas could delay, reduce and potentially control the damage by the borer in order to sustain these important ecological services and healthy ecosystems over time. Eventually, we will need to adjust to living with emerald ash borer on the landscape. Biocontrol by native or introduced parasitoids, diseases or predators is needed to mitigate the long term impacts of the emerald ash borer on the ash resource and the urban, rural and Crown forests of Ontario.

Much has been learned about emerald ash borer in only a few years since its discovery. Many of the lessons we have learned can be applied to other invasive species problems. Not the least of these lessons is the importance of having systems in place beforehand for the detection, identification, rapid response, management, research, communications and site rehabilitation for invasive species. Emerald ash borer has also taught us the importance of urban and rural forests in addressing invasive species. For example, when OMNR and CFS staff first found emerald ash borer in Windsor in 2002, the insect had already been present for a few years. We now know the importance of including urban and rural forests in invasive species detection programs.

Much remains to be done in research and control of the emerald ash borer. Even so, we now have several tools and strategies available to mount a strategic response plan to reduce the impacts of the beetle, to foster public and political support, and to ensure a viable and healthy forest.

List of Attendees

Richard Michael Baic
Arborist
519-724-2357
mitchellbaic@hotmail.com

Greg Bales
Stewardship Coordinator
Halton - Peel Woodlands and Wildlife Stewardship
905-713-7410
greg.bales@ontario.ca

Adam Baker
Baker Forestry Services
905-877-9390
bakerforestryservices@huges.net

Dan Baker
Baker Forestry Services
905-877-9390

Allison Barr
Program Officer
Canadian Food Inspection Agency
905-937-3196
Allison.Barr@inspection.gc.ca

Nick Betts
Conservation Specialist
Grand River Conservation Authority
519-621-2763 x2305

Ian Buchanan
Manager, Natural Heritage and Forestry Services
Roads Branch, Transportation Services Department
York
905-895-1200 x5204
Ian.Buchanan@york.ca

Lindsay Burtenshaw
Terrestrial Ecologist
Royal Botanical Gardens
905-527-1158 x257
lburtenshaw@rbg.ca

Rich Canfor
Forest Technician
Municipal Law Enforcement
Hamilton
905-549-2424 x5552
Richard.Canfor@hamilton.ca

Eric Cleland
Forest Health Technical Specialist
Ontario Ministry of Natural Resources
519-773-4741
Eric.Cleland@ontario.ca

Mark Covert
Burlington
covertm@burlington.ca

Richard David
613-551-0954
richard.david@akwesasne.ca

Amanda Dooney
Forest Health Technician
Community Services Department
Norfolk County 519-426-5999 x2245
Amanda.Dooney@norfolkcounty.ca

Ken Elliott
Ontario Ministry of Natural Resources
519-873-4626
ken.elliott@ontario.ca

Tony Fleischmann
Hydro One
519-591-8550
tony.fleischmann@hydroone.com

Sean Fox
Arboretum
University of Guelph
519-830-2744
sfox@uoguelph.ca

Bill Gaines
Forestry Coordinator
Conservation Halton
905-336-1158 x261
bgaines@hrca.on.ca

Brian Geerts
Urban Forestry Technician
Parks & Recreation Department
City of Brantford
519-756-1500 x5511
bgeerts@brantford.ca

Carla Gillies
Gillies Tree Care
416-809-8733
gilliestreecare@mac.com

Ken Goldsmith
Forest Technician
Bruce County
519-5342092
kgoldsmith@brucecounty.on.ca

Anne Hayes
BioForest Technologies Inc.

John Hennessy
Parks Operations, Community Services
City of Brampton
905-702-0602
vinegar.taster@hotmail.com

Tom Hildebrand
Forester
Restoration Services
Toronto and Region Conservation Authority
416-661-6600 x5379
THildebrand@trca.on.ca

Greg Hill
Maple Hill Tree Service
416-997-2053
greg@maplehilltree.com

Julie Holmes
Canadian Food Inspection Agency
905-570-7355
julie.holmes@inspection.gc.ca

Tony Hopkin
Director, Integrated Pest Management
Great Lakes Forestry Centre
Canadian Forest Service
705-541-5568
ahopkin@nrcan.gc.ca

Ed Hunwicks
Parks Operations, Community Services
City of Brampton
416-806-0268
edward.hunwicks@brampton.ca

Richard Jean
Town of Oakville
905-845-6601 x3354

Andy Kenney
University of Toronto
416-978-0474
a.kenney@utoronto.ca

Julia Kollek
Environment Hamilton
Hamilton Stewardship Council
905-627-5410
jkollek@gmail.com

Bohdan Kowalyk
Aurora District Forester
Ontario Ministry of Natural Resources
905-713-7714
bohdan.kowalyk@ontario.ca

Dave Kreutzweiser
Canadian Forest Service
Natural Resources Canada
705-541-5648
Dave.Kreutzweiser@NRCan.gc.ca

Donna Lacey
Forest Management Technician
Saugeen Conservation
519-364-1255 x31
D.Lacey@SVCA.ON.CA

Rick Lipsitt
City Forester
City of Burlington
905-333-6145
LipsittR@burlington.ca

Barry Lyons
Canadian Forest Service
Natural Resources Canada
705-541-5617
Barry.Lyons@NRCan.gc.ca

Randy Machan
Forestry Supervisor
Grand River Conservation Authority
519-621-2761
rmachan@grandriver.ca

Les Magasi
Canadian Forest Service (retired)
Natural Resources Canada
506-454-3680
magasi@nb.sympatico.ca

Quin Malott
Parks & Forestry Manager
Stratford
519-271-0250 x276
crobinson@city.stratford.on.ca

Ken Marchant
consultant
519-824-3412
marchjack@rogers.com

Tawnia Martel
Assistant Ecologist
Hamilton Conservation Authority
905-525-2181 x229
tmartel@conservationhamilton.ca

Jason Martin
Parks Operations, Community Services
City of Brampton
905-874-2907
tree.j@hotmail.com

Susan McGowan
Forest Health Technical Specialist
Ontario Ministry of Natural Resources
613-258-4072
Susan.McGowan@ontario.ca

Dan McKenney
Canadian Forest Service
Natural Resources Canada
705-541-5569
Dan.McKenney@NRCan.gc.ca

Mike McNamara
Manager of Forestry & Horticulture
City of Hamilton
905-546-2424 x3919
Mike.McNamara@hamilton.ca

John McNeil
Manager of Forestry & Cemetery Services
Parks & Open Space Department
Town of Oakville
905-845-6601 x3395
JMCNEIL@oakville.ca

Joe Meating
President & Director Forest Surveys and Protection
BioForest Technologies Inc.
705-942-5824
jmeating@bioforest.ca

Becky Moule
Plant Health Care Technician
Arbortech Professional Tree Care
519-245-1019
arbortech@bellnet.ca

Lorraine Norminton
Stewardship Coordinator
Hamilton-Wentworth
519-826-3569
lorraine.norminton@ontario.ca

Paul O'Hara
Blue Oak Native Landscapes
905-540-9963
blueoak@sympatico.ca

Steve Orford
BioForest Technologies Inc.

Mary Orr
Canadian Food Inspection Agency
416-661-8158
mary.orr@inspection.gc.ca

Gard Otis
Professor
School of Environmental Sciences
University of Guelph
519-824-4120 x52478
gotis@uoguelph.ca

Meghan Quinn
Urban Forestry Branch
City of Toronto 416-891-0547
mquinn2@torontoca

Ryan Redvers
Redvers Tree Service
289-231-8733
redverstree@rogers.com

Kevin Reese
District Forester
Midhurst District
Ontario Ministry of Natural Re-

sources
705-725-7553
kevin.reese@ontario.ca

Ron Reinholt
Regional Forester
Legislative and Planning Services Department
Regional Municipality of Halton
916-825-6000 x7279
Ron.Reinholt@halton.ca

Jozef Ric
Urban Forestry Branch
City of Toronto
416-392-1436
jric@toronto.ca

Jennifer Roberts
Conservation Halton
905-336-1158 x251
jroberts@hrca.on.ca

Nadine Ropp
Maple Hill Tree Service
416-997-2053

Bill Rose
Forest Health and Silviculture Specialist
Southern Region
Ontario Ministry of Natural Resources
705-755-3202
bill.rose@ontario.ca

Dan Rowlinson
Ontario Ministry of Natural Resources
705-945-5737
dan.rowlinson@ontario.ca

Krista Ryall
Canadian Forest Service
Natural Resources Canada
705-541-5549
Krista.Ryall@NRCan.gc.ca

Tami Sadonoja
Forest Health Technician
City of Hamilton
905-546-2424 x5386
Kathy.Albers@hamilton.ca

Brian Sapezinskas
Arborist
Zap's Tree Care
519-773-5811
zaptreeservice@amtelcom.net

Alex Satel
asatel@ufis.ca

Taylor Scarr
Ontario Ministry of Natural Resources
taylor.scarr@ontario.ca

Steve Scheers
Superintendent, Resource Management
Community Services Department
Norfolk County

Terry Schwan
District Forester
Guelph District
Ontario Ministry of Natural Resources
519-826-4933
terry.schwan@ontario.ca

Allison Scovil
Science Intern
Royal Botanical Gardens
905-527-1158 x238
ascovil@rbg.ca

Loretta Shields
Canadian Food Inspection Agency

Wade Speirs
City of Brampton
wade.speirs@brampton.ca

John Stewart
Forestry Operations Coordinator
Grand River Conservation Authority
519-240-5792
jstewart@grandriver.ca

Shelley Stewart
University of Guelph
shelley@uoguelph.ca

Mike Thibeault
Urban Forest Innovations Inc.
905-274-1022
mikeufi@rogers.com

Brianna Thornborrow
BioForest Technologies Inc.
905-208-6601 x2900
BThornborrow@oakville.ca

Richard Ubbens
Urban Forestry Branch
City of Toronto

Philip van Wassenaer
Urban Forest Innovations Inc.
905-274-1022
pwassenaer1022@rogers.com

Jon VanderBoom
Complete Tree Service
800-263-8312
arborist3@completetreeservice.com

Kristjan Vitols
Supervisor, Tree Nursery & Natural Resource Management
Urban Forestry Branch
City of Toronto
416-392-0432
kvitols@toronto.ca

Wayne Wakel
Professor
Horticulture Department
Niagara College
905-641-2252 x4478
wwakal@niagaracollege.ca

Nigel Ward
Royal Botanical Gardens
905-870-7447
nward@rbg.ca

Lindsay Watchorn
Acting Watershed Forester
Grand River Conservation Authority
519-621-2763 x2245
lwatchorn@grandriver.ca

Dave Wilby
D.F. Wilby Tree Surgeons
905-339-2420
info@wilbytrees.ca

Mike Williams
Associate Stewardship Coordinator
Dufferin South Simcoe Land Stewardship Network
705-721-4444 x247
m_williams@ducks.ca

Peter Williams
Williams & Associates, Forestry Consulting Ltd.
519-856-1286
forstar@execulink.com

Richard Wilson
Forest Program Pathologist
Forest Health & Silviculture Section
Ontario Ministry of Natural Re-

sources
705-541-5106
richard.wilson@ontario.ca

Ron Wu-Winter
Restoration Services
Toronto and Region Conserva-
tion Authority
416-661-6600
rwu-winter@trca.on.ca