

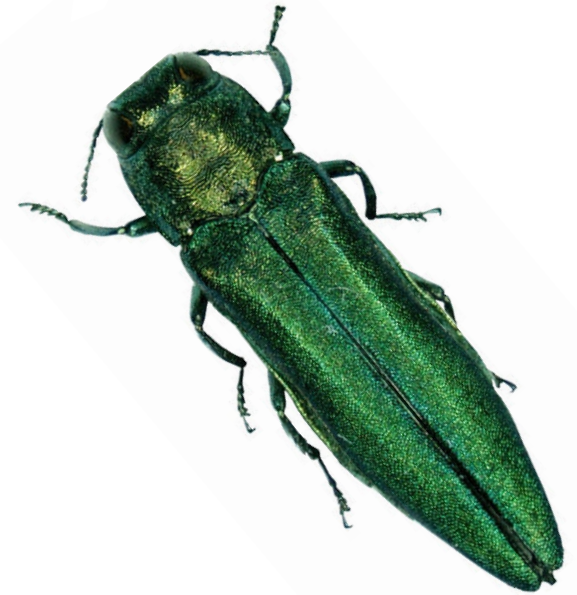


FACULTY OF FORESTRY
UNIVERSITY OF TORONTO

All that is **Green** is not **Gold**: The **Emerald Ash Borer** (EAB) Invasion of Toronto's Urban Forest, Canada

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Faculty of Forestry, University of Toronto, Canada



Session 1. Biosecurity: The Challenges

51st Arboricultural Association National Amenity Conference

Protect and Survive: 1st International Conference on Arboricultural Biosecurity

University of Exeter, Exeter, England

11 September 2017



Outline of Presentation

- Toronto's Urban Forest
 - The importance of trees in the modern city
- Biology of Emerald Ash Borer (EAB)
- The North American EAB Invasion – *An Ecological Tsunami*
- Toronto's experience with EAB
- Research and Development
- Lesson's Learned

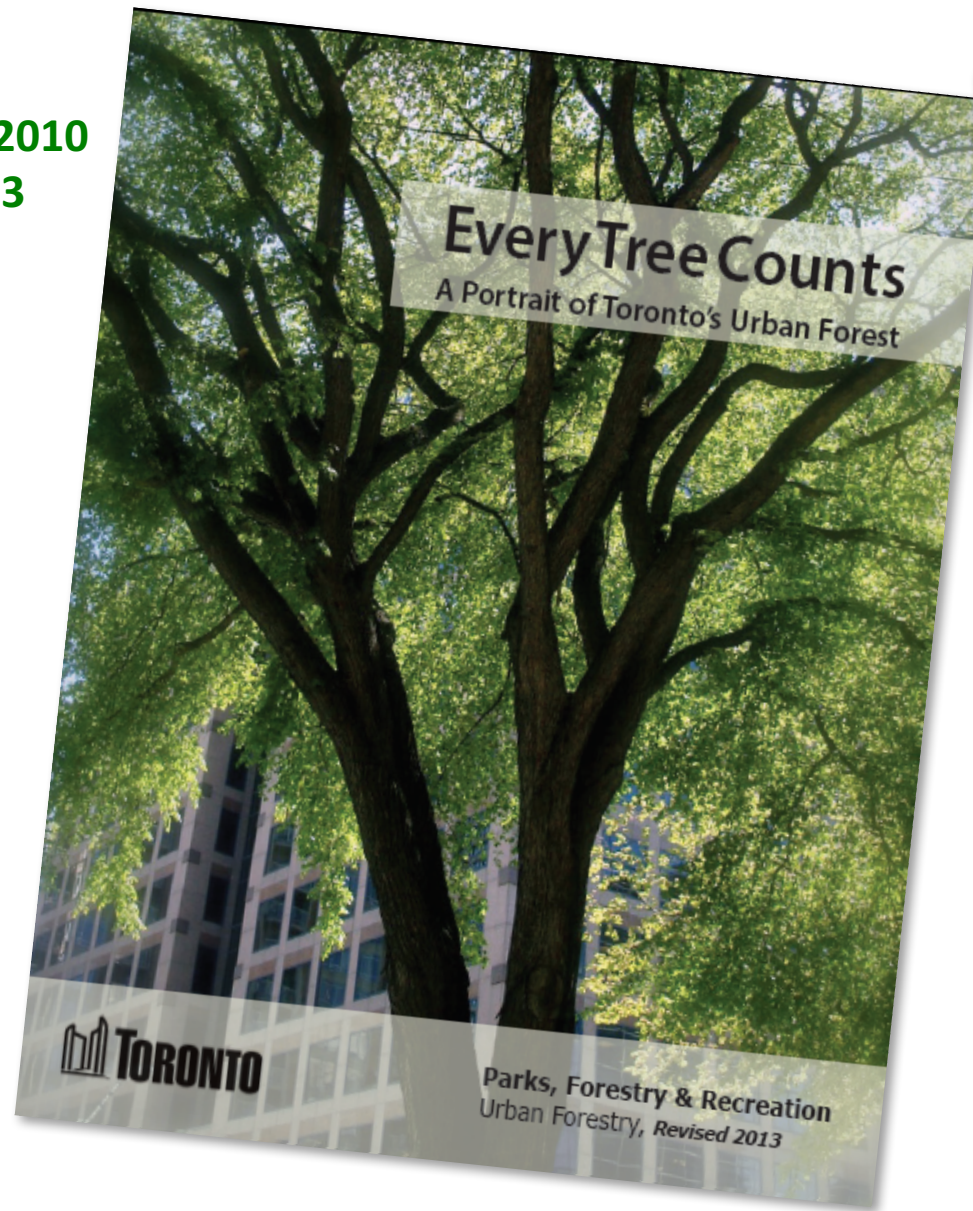


Toronto – a city within a park

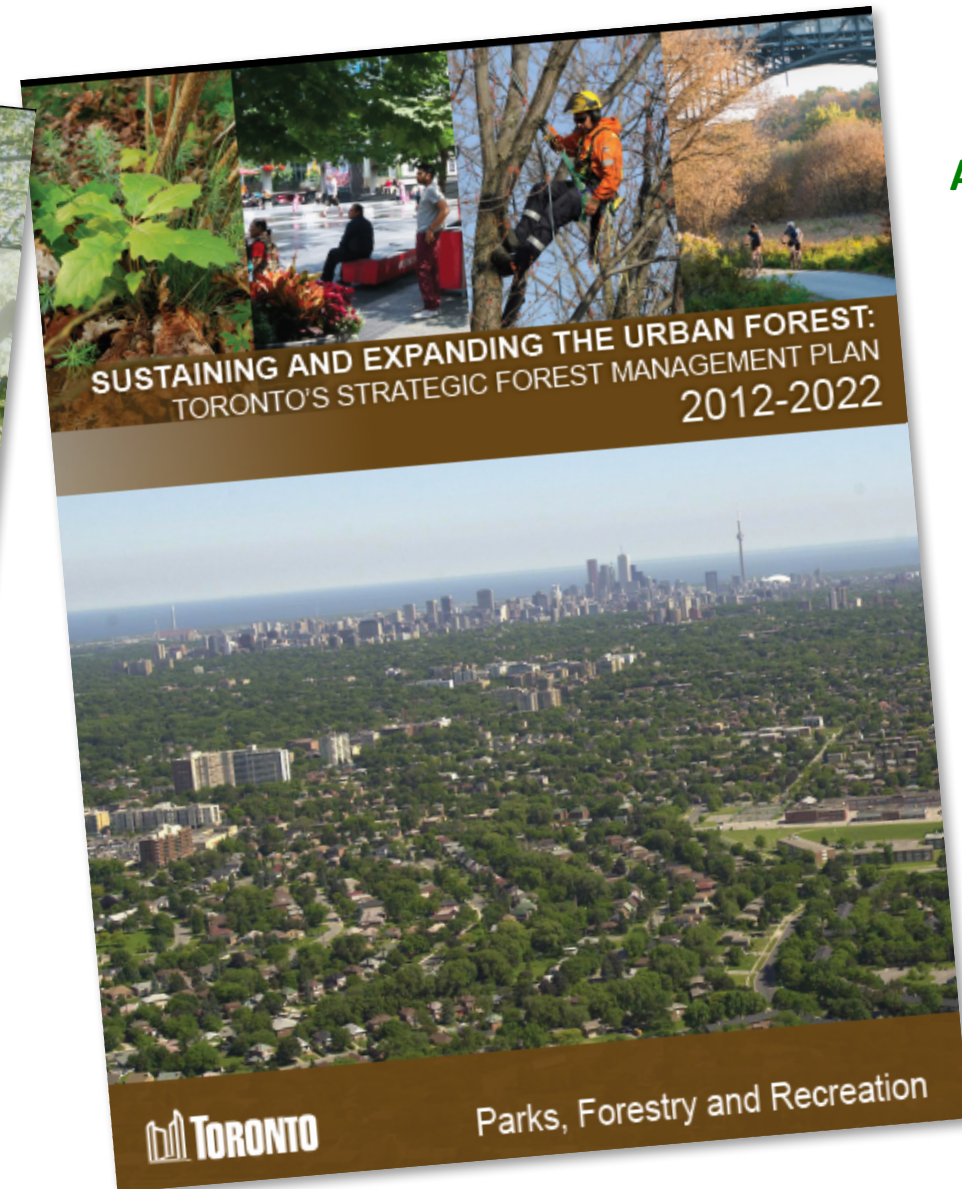


Resource Inventory and Strategic Management Planning

Completed 2010
Revised 2013

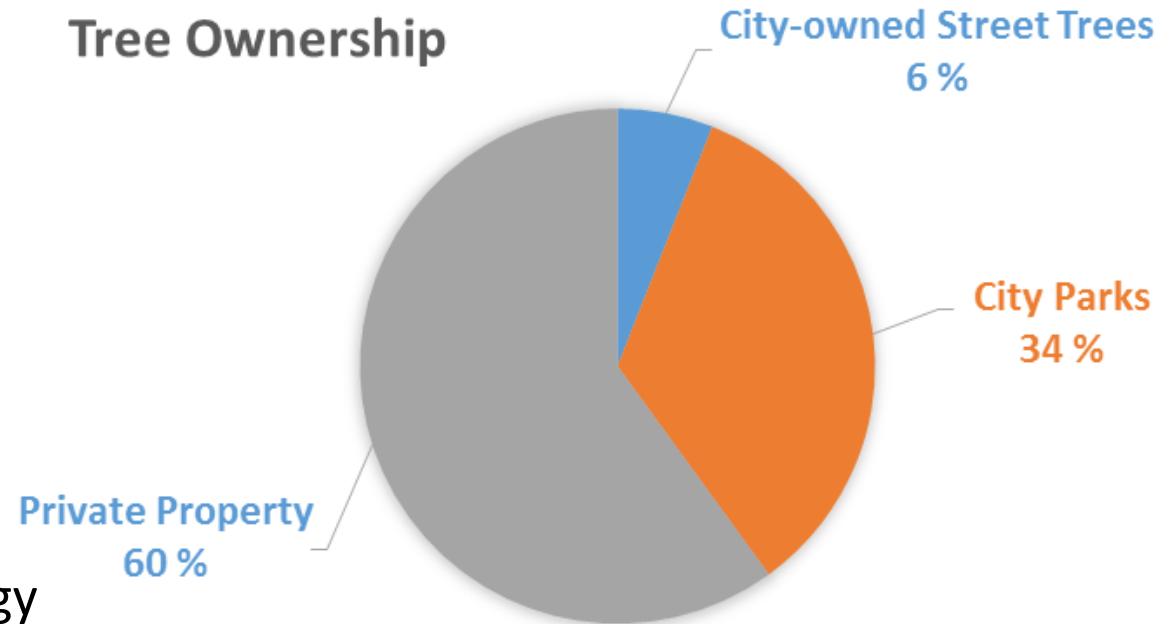


Approved 2013



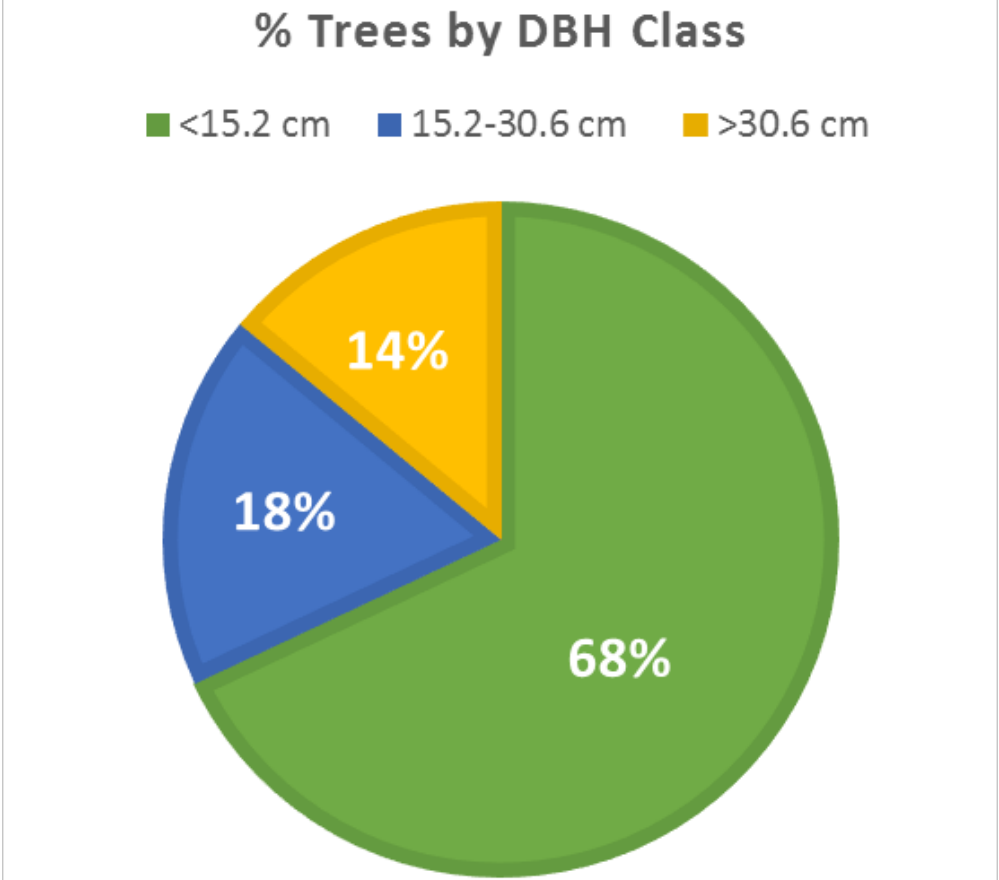
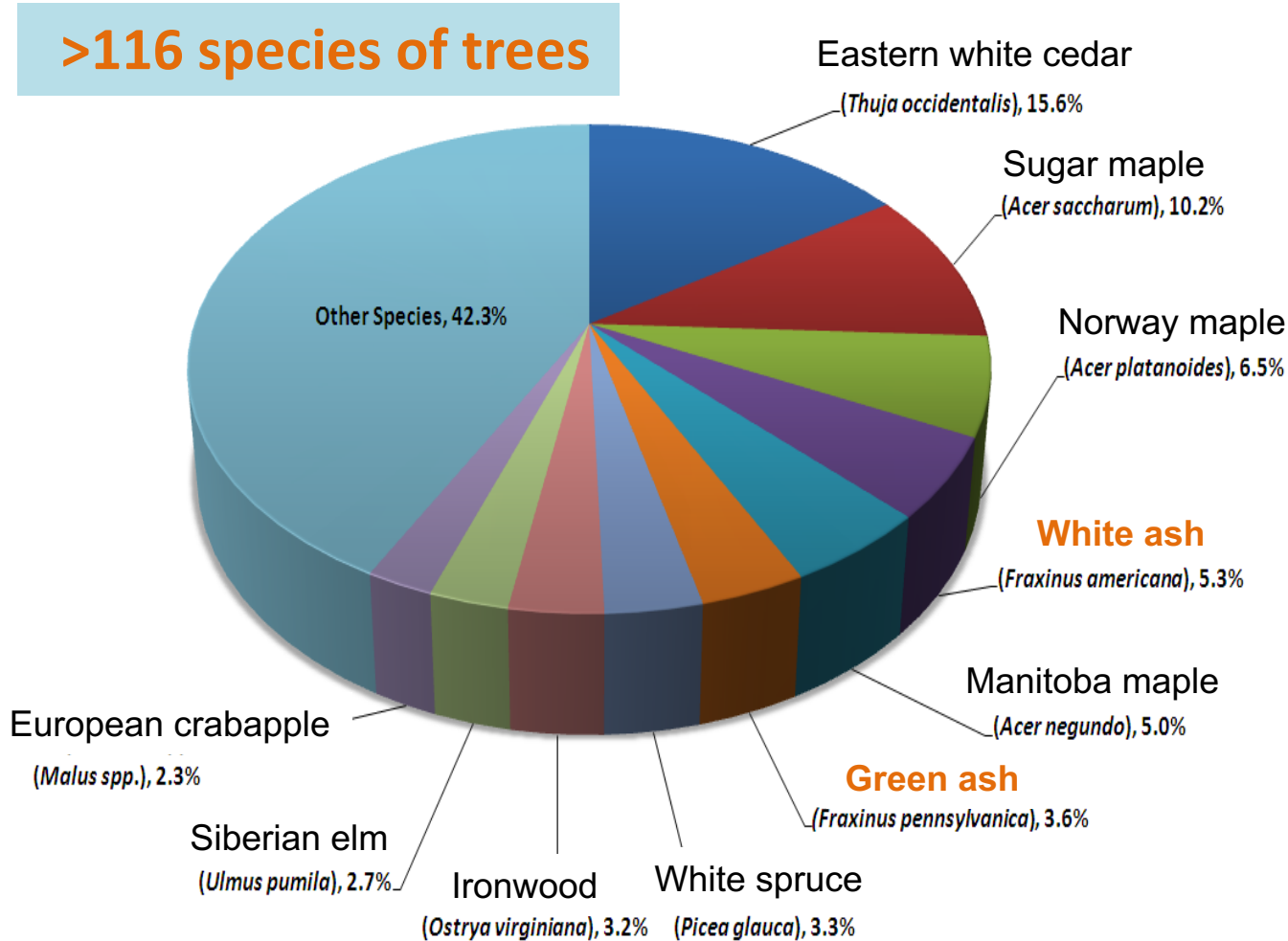
Toronto's Urban Forest by Numbers

- **10.2 million trees** in Toronto (4 per resident)
 - **4.1 million City-owned trees**
 - 600,000 trees along streets
 - 3.5 M trees in over 8,000 hectares of parks, ravines and natural areas
 - **6.1 million trees on private property**
- **Structural value \$7 Billion**
- **Provides \$28.2 Million in ecological services annually**
 - includes an estimate for: air pollution removal, energy savings, avoided carbon related to energy conserved and carbon sequestration
- **Carbon storage \$25 Million annually**



Current State of Toronto's Urban Forest

Species composition and size class distribution



Significant population of young trees

Natural Heritage System: Toronto's Ravines

Toronto's Natural Heritage System



View of downtown Toronto from Crothers Woods



11,000 ha of ravines, valleys and forests protected

17% of the City's total area

Recognised as a unique natural heritage feature for Toronto. A ravine strategy is being developed to identify objectives for these areas and set priorities to guide policies, investment and stewardship over the long term.



Strategic Forest Management Plan 2012-2022

VISION - A healthy and expanding urban forest, incorporating sound urban forestry practices and community partnership

Strategic Goals

1. Increase Canopy Cover
from 28% to 40%
2. Achieve Equitable Distribution
3. Increase Biodiversity
4. Increase Awareness
5. Promote Stewardship
6. Improve Monitoring

Major Challenges

- 1. Forest Health Threats**
2. Tree Maintenance Requirements and Expectations
3. Balancing Urbanization Impacts and Sustaining the Urban Forest
4. Climate Change Impacts
5. Recreational Pressures on the Urban Forest
6. Increasing Public Awareness of the Value/Sensitivity of the Urban Forest

Achieve equitable distribution of the urban forest

Increasing canopy where it is most needed

Aerial examples of different levels of canopy



0 %



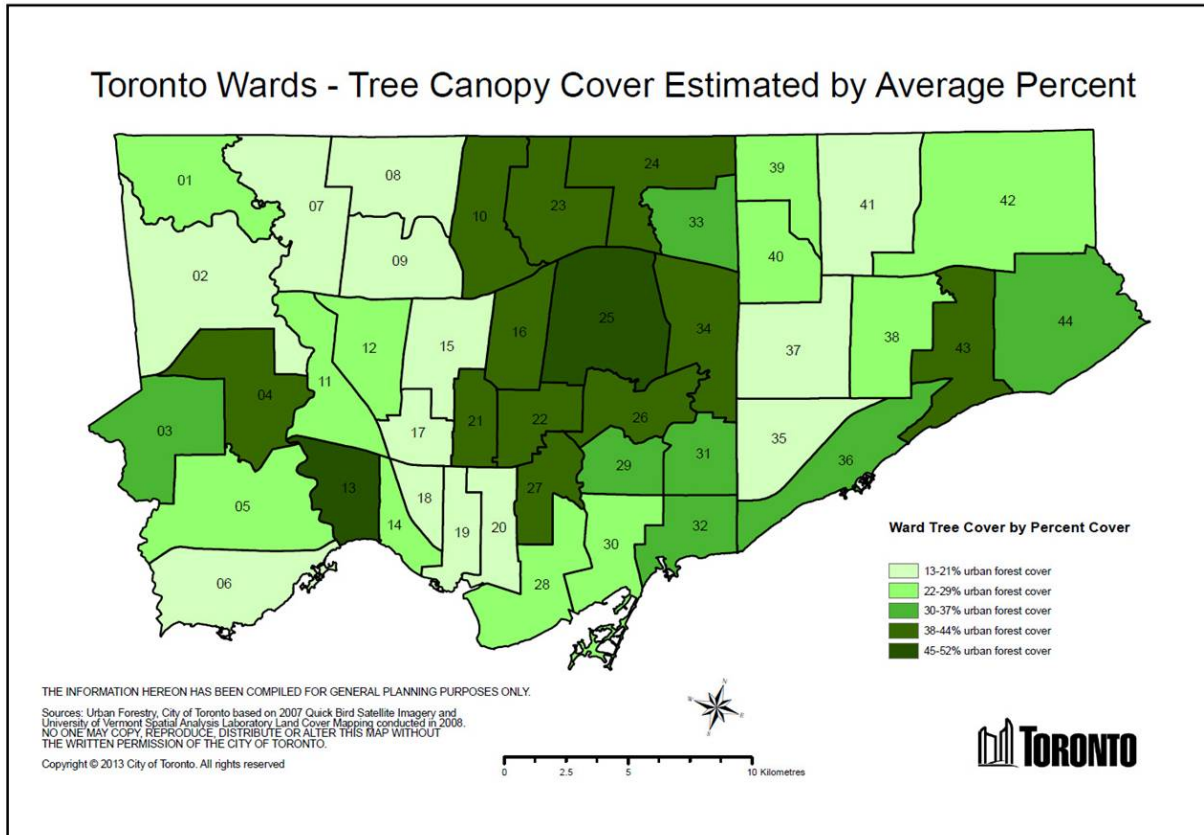
17 %



Target 40 %



- 40-50 year ambition
- Promoting Stewardship is key to success
- Engaging residents, neighbourhoods, community groups and landowners



Major Forest Health Threats

**Emerald Ash Borer
(EAB)**



**Asian Long-horned Beetle
(ALHB)**



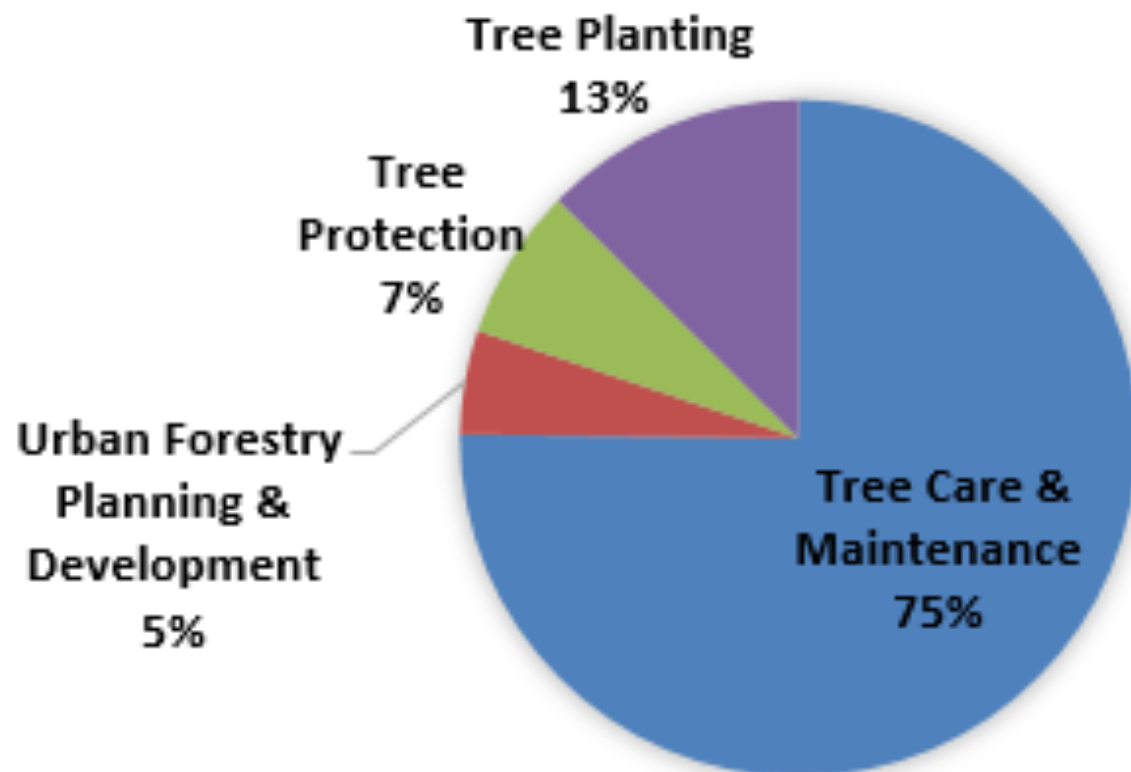
Gypsy Moth



**Dutch Elm Disease
(DED)**



Urban Forestry Budget for Toronto 2015



To manage and maintain a healthy and expanding urban forest, incorporating sound urban forestry practices and community partnership

Gross Expenditure Budget
\$70.0 million

Human Resources:
Urban Forestry has over 300 FTE's and manages over 300 contract staff

Urban Forestry Accomplishments

Planting

- 100,000 trees on average annually
- 82% survival rate
- **Planted >1.25 M trees on city lands since 2004**

Protection

- 6,700 trees protected annually
- 66% increase in service requests over 2008 and 9% increase over the previous 5 year average

Maintenance

- Over 400,000 maintenance activities annually
- Completed over 500,000 work orders annually



Emerald Ash Borer (EAB)

Agrilus planipennis

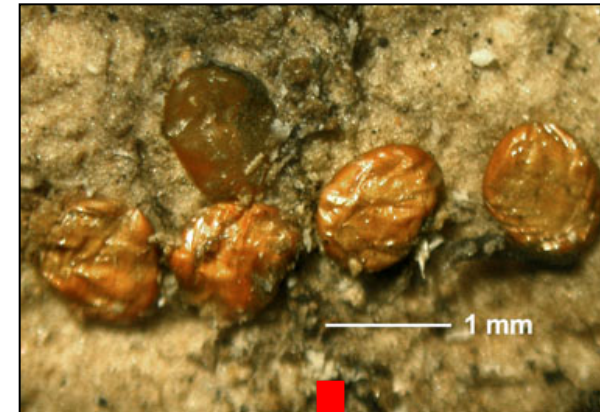
- Member of the beetle family Buprestidae
- Associated with ash trees (*Fraxinus* spp.)
- A native of eastern Asia, China, Japan, Taiwan, Korea, Mongolia and the Russian Far East.
- Considered a minor pest of ash trees in native range
- Accidentally introduced into north America, probably in the 1990s, most likely in imported wooden packing material



Adult – 8-13 mm

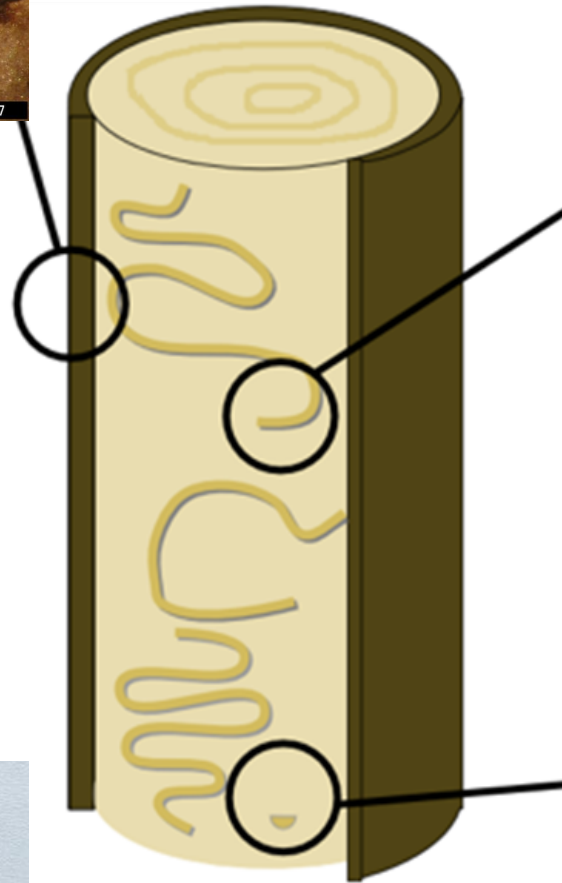


January	February	March	April	May	June 1-15	June 15-30	July	August	September	October	November	December
				Adult								
				Active Larva								
		Pupae										
Inactive Larva										Inactive Larva		

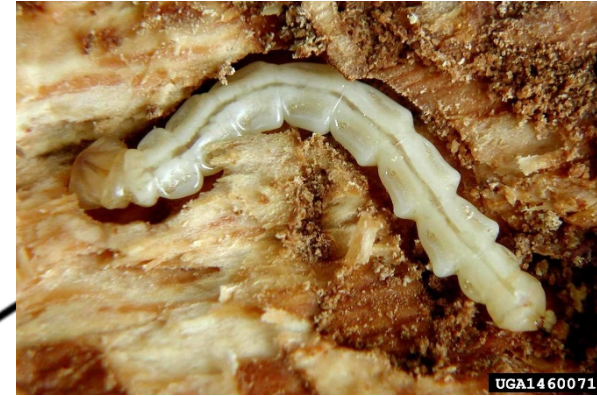


Life Cycle of emerald ash borer (EAB)

Spring-Summer



Spring



Summer



Autumn

In Canada, life cycle mostly spread over 2 years

Identification

- **Larval galleries.** Typical galleries meander, bending sharply and are packed with frass
- **D-shaped holes,** about 3 mm in diameter, produced by emerging adults
- Initial **thinning or yellowing** of the foliage (general or limited to certain branches)
- **Bark fissures,** 5-10cms in length, caused by the growth of callus tissue produced by the tree in response to larval feeding
- **Woodpecker activity.** Woodpeckers strip away small patches of bark, so that they can extract the borers
- **But EAB infestation difficult to detect until the symptoms are severe.**





Left:
Exit holes on bark



Right:
Bark stripping
by woodpeckers



Symptoms: crown dieback and chlorosis

Flagging: dieback
of single branch



Thinning and
chlorosis of crown

Crown dieback



Dead branches and
epicormic shoots

Symptoms of EAB infestation are similar to those caused by a variety of root and butt rots which can cause late flushing, thinning foliage and decline leading to eventual death.

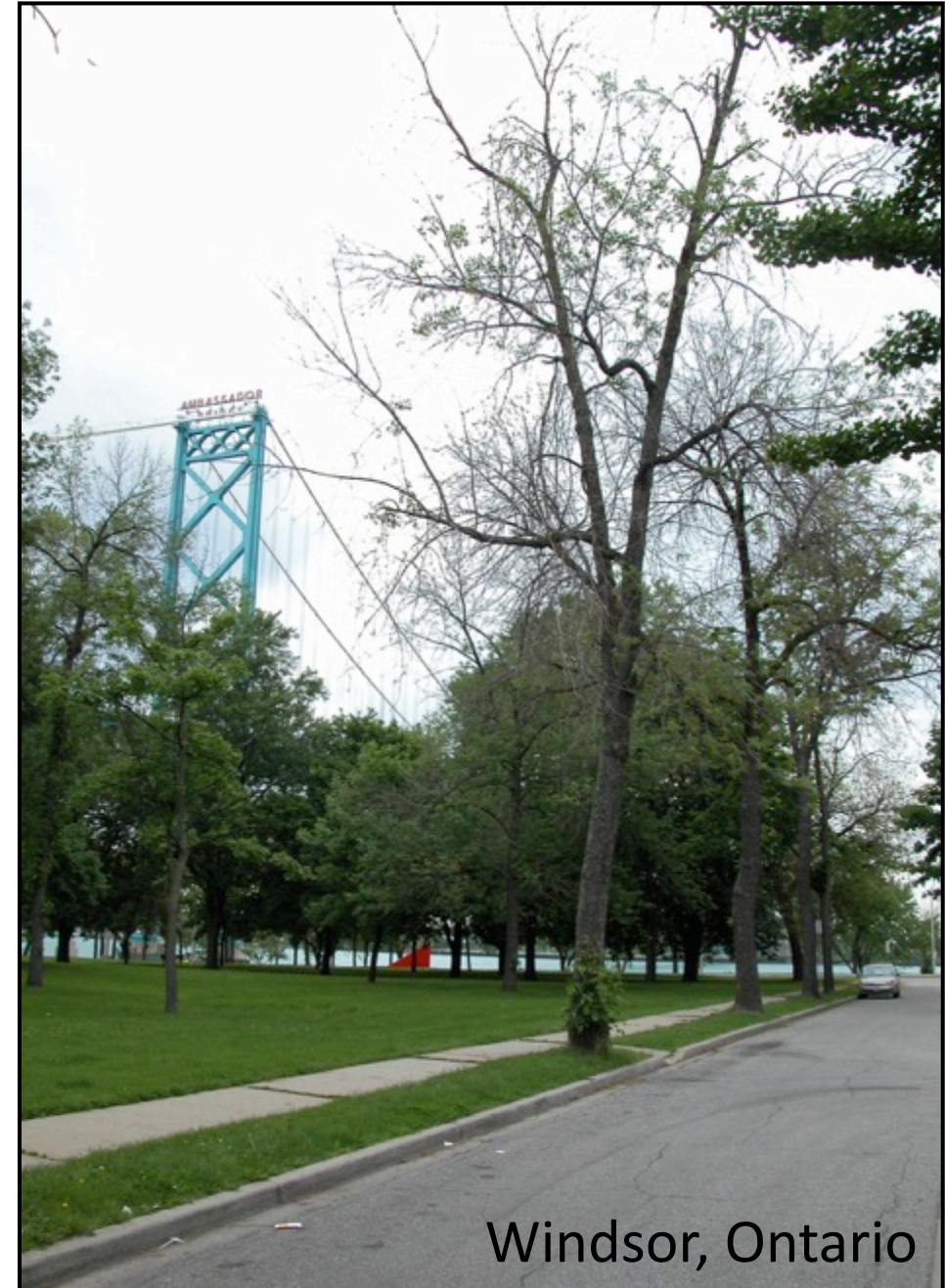
Severe infestation



Initial Detection in Canada



Discovered by provincial & federal
forest agencies in July 2002



Detroit, USA

CITY OF WINDSOR

"Take the Tunnel!" Your Gateway to Canada and the U.S.

See City Centre detail lower right

Ambassador Bridge

E.C. Row Expressway

TO TUNNEL

Legend:

- Art Gallery
- Convention
- Chrysler

Forest Health Monitoring & Biology

June 2003



August 2004



Invasive Species Strategy

1. Assessment and risk analysis

2. Prevention

3. Early detection

4. Rapid response and eradication

5. Research

6. Control & management (*slow the spread*)

7. Communications

8. Restoration

EAB Science Panel(s)



- Lead responsibility is federal (CFIA)
 - Province is resource owner (Ontario - MNRF) & has much at stake
 - Provided facilitation, tipping point, catalyst
-
- Funding research projects (CFS, Universities, Invasive Species Centre, Cities); approx. \$6.5 million invested
 - Critical Plant Pest Management Committee (regulatory)
 - Science & Survey Subcommittee, joint communications plan, public meetings

Partnership Activities



- Prov/Fed (CFS) monitoring & surveys complementing CFIA
- Fact sheets, management advice
- Survey guides
- Workshops, seminars, training (municipalities, First Nations)

Don't Move
Firewood!

Regulatory Strategies for EAB

2002-03 Strategy



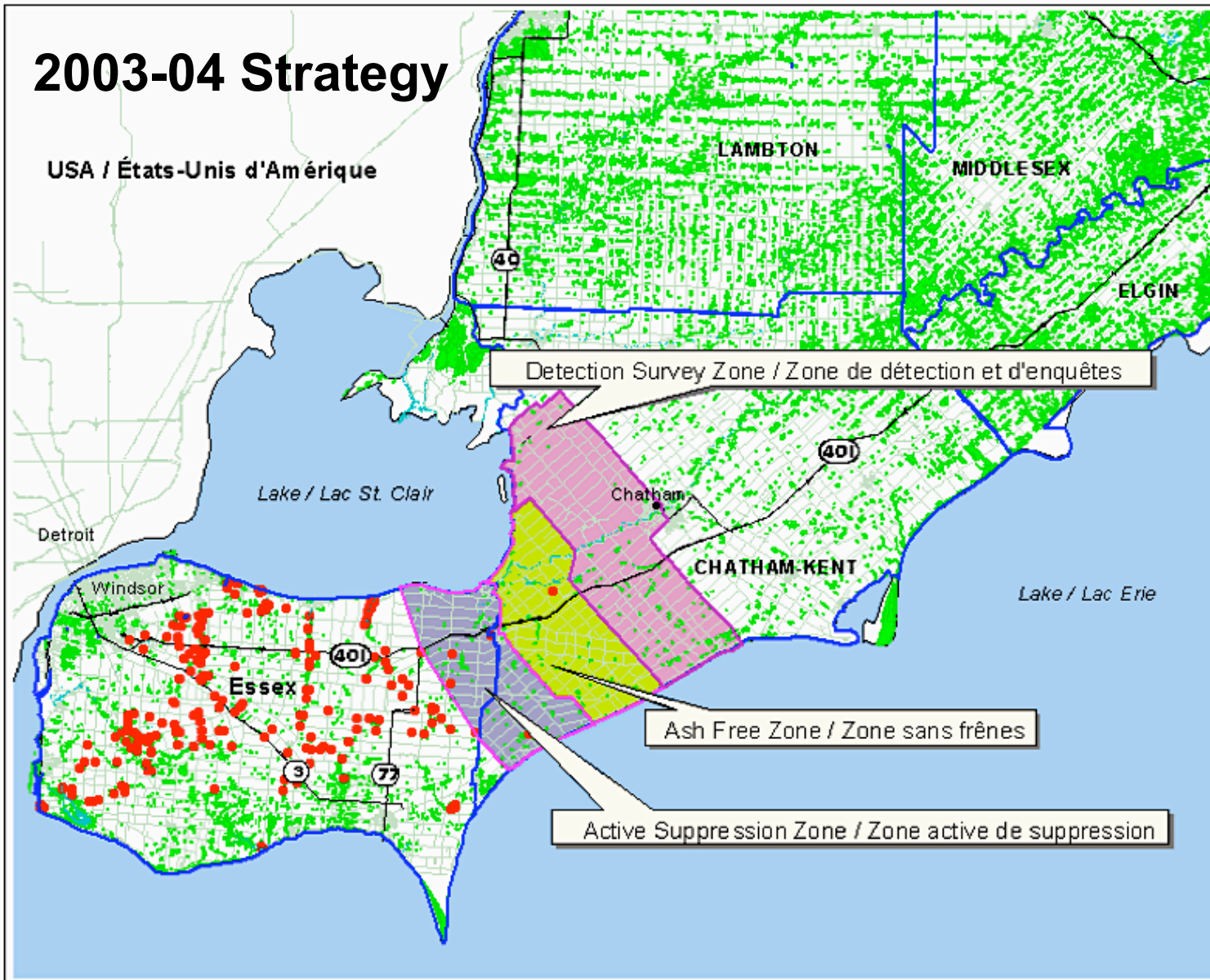


Agence canadienne
d'inspection des aliments

Canadian Food
Inspection Agency

2003-04 Strategy

USA / États-Unis d'Amérique



Positive Sites
Sites positifs

Highways
Autoroutes

Roads
Routes

Woodlots
Boisés

Municipal Boundaries
Limites municipales

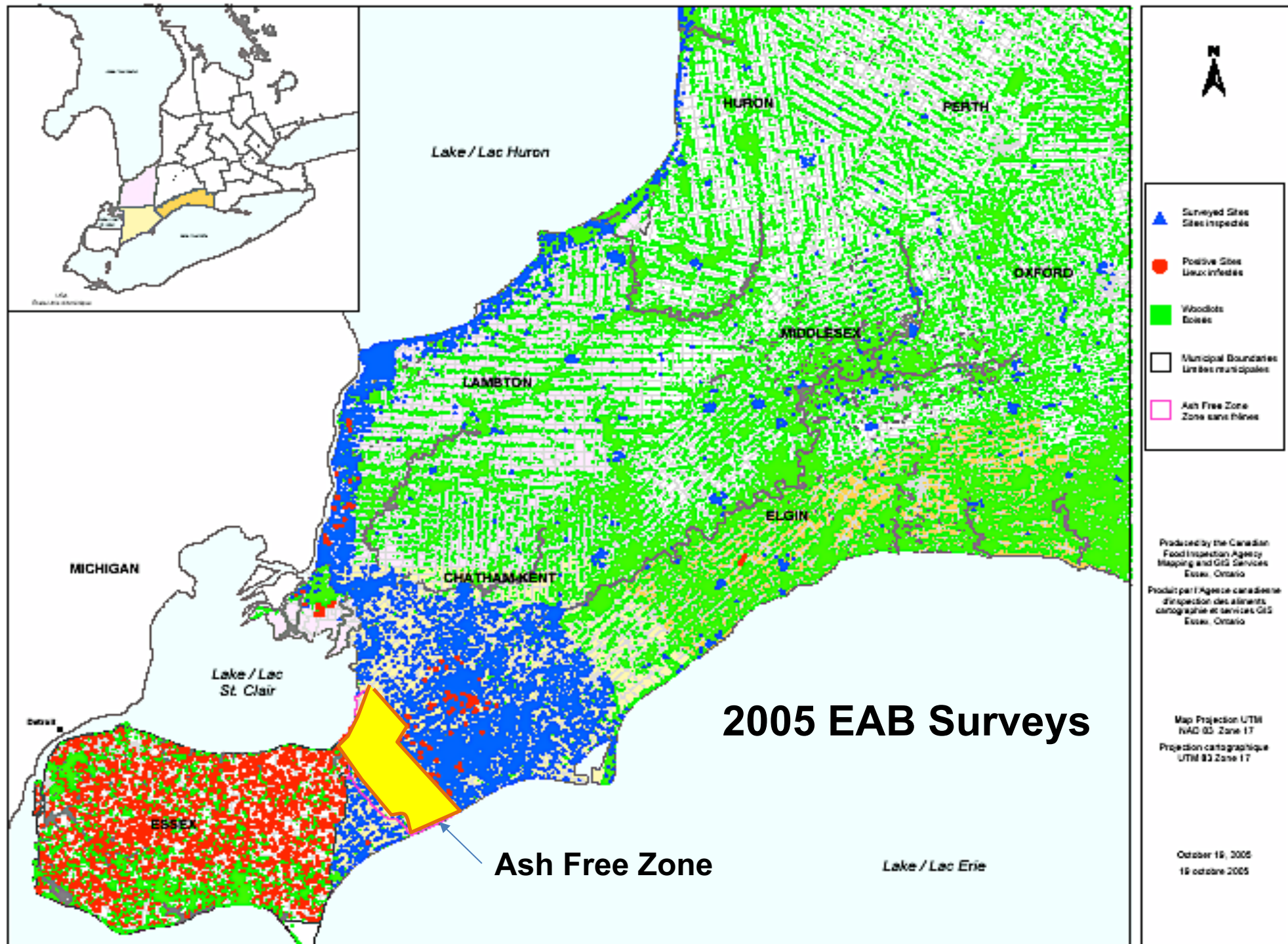
November 27, 2003
27 novembre 2003

Map Projection
UTM NAD 83 Zone 17
Projection cartographique
UTM 83 Zone 17

Km
0 10 20

Ash Free Zone / Zone « sans frênes »

Canada



Cooperative Emerald Ash Borer Project

EAB locations in Illinois, Indiana, Michigan, Maryland, Ohio, Pennsylvania and southwest Ontario, Canada

September 5, 2007

Ottawa & Montreal 2008

Probable origin of outliers in Michigan

4% sawmills
7% nursery stock
37% firewood
52% unknown

SSM

June 2008

Toronto
Dec 2007

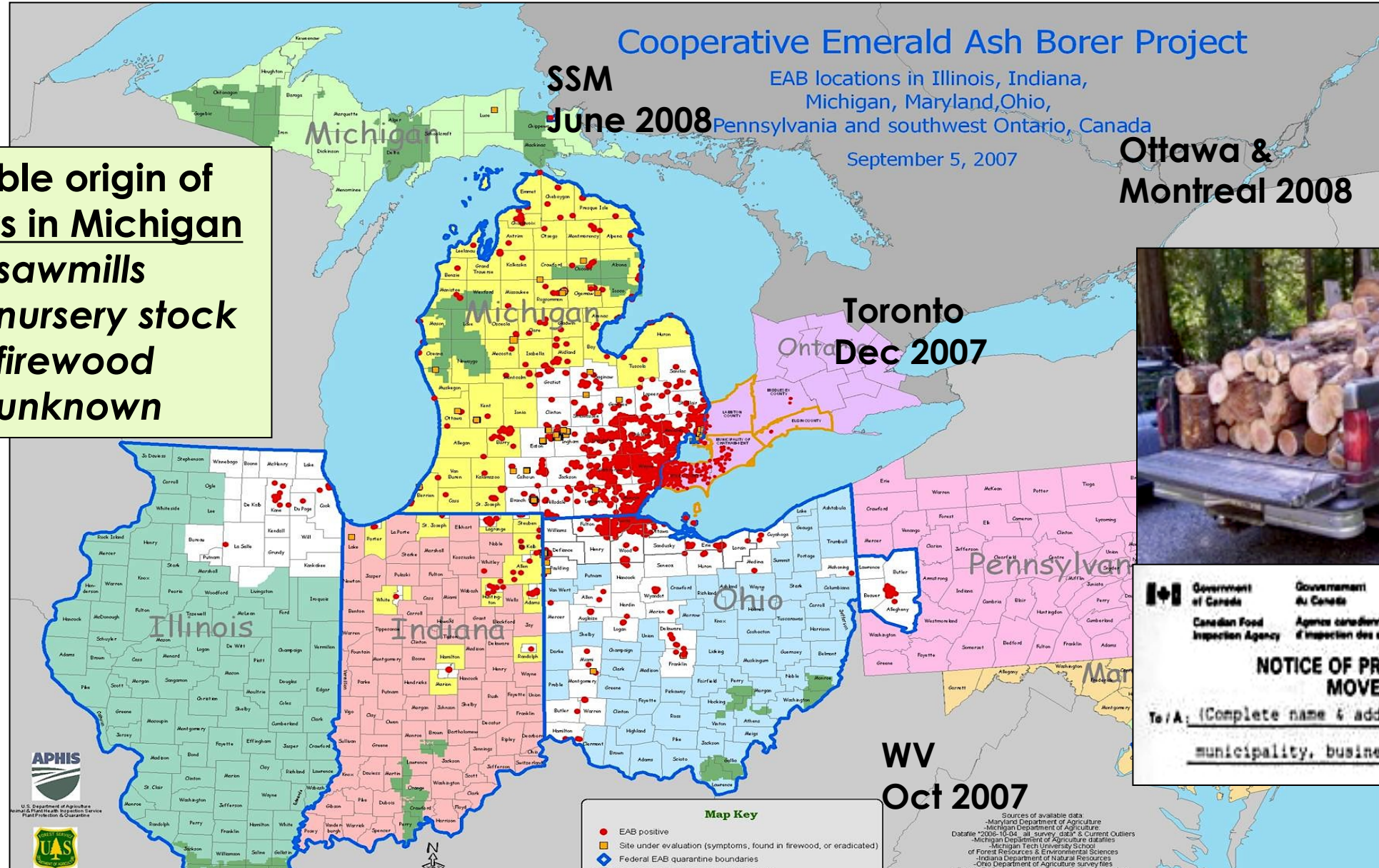
WV
Oct 2007



Government of Canada / Gouvernement du Canada
Canadian Food Inspection Agency / Agence canadienne d'inspection des aliments

NOTICE OF PROHIBITION OF MOVEMENT

To: A. (Complete name & address of the municipality, business or individual)



**Strategy by 2007-08: Containment & Limit Movement
= 'SLOW-THE-SPREAD'**

Emerald ash borer – the wave of invasion

200,000 ha of ash woodland in southern Ontario affected by 2014




Emerald ash borer
2004-2014

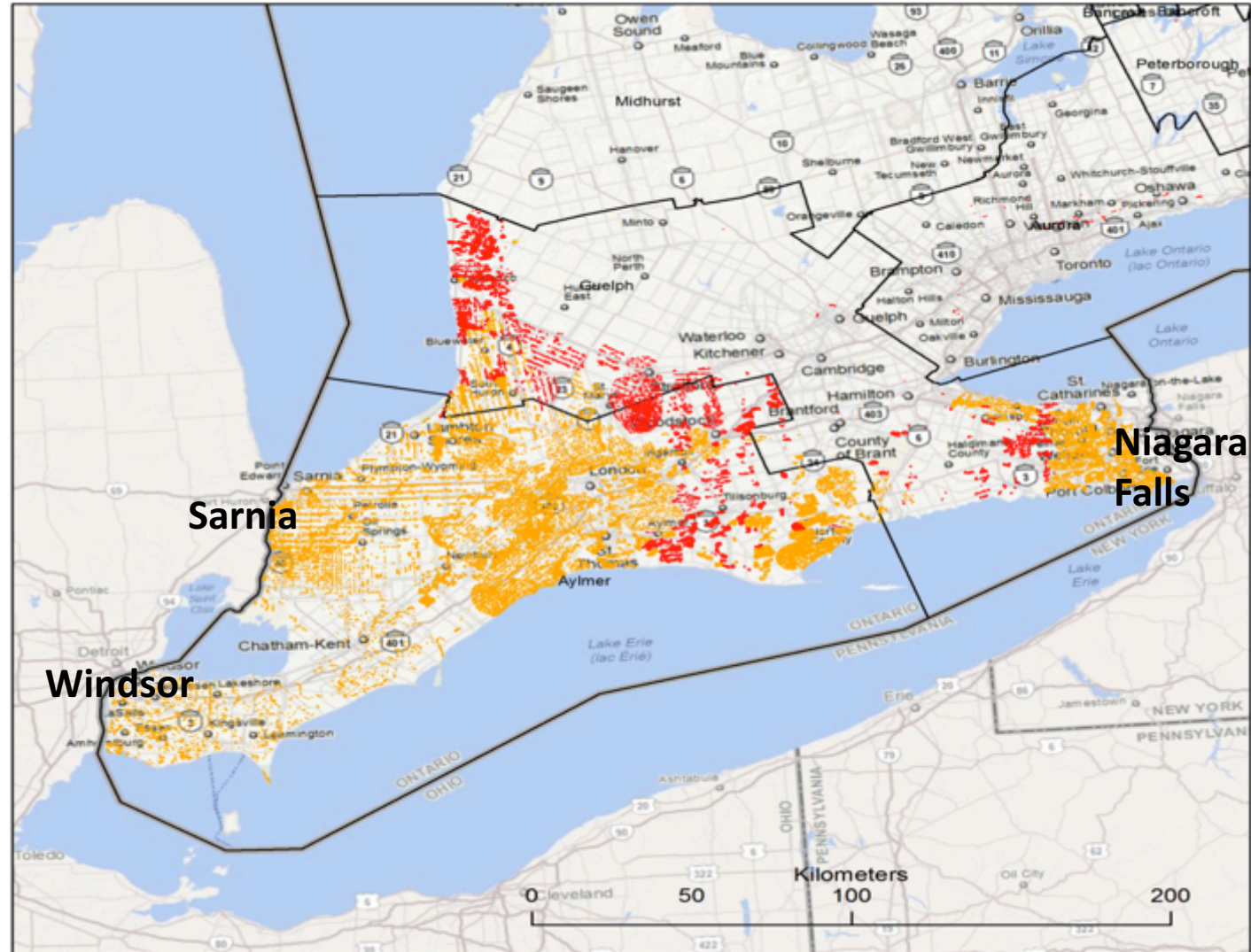
Southern Region

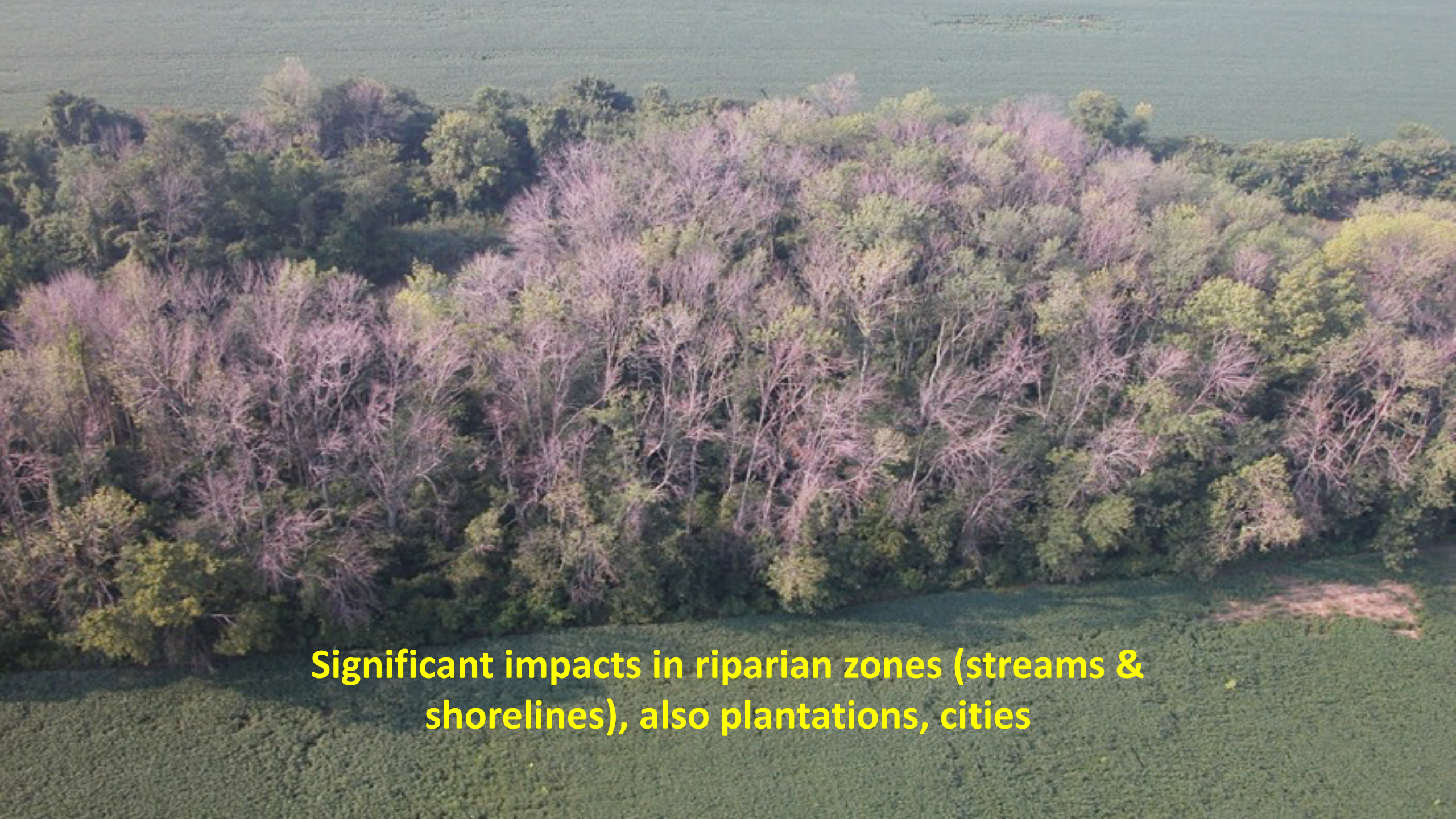
Map 1 of 3

Areas-within-which emerald ash borer caused moderate-to- severe decline to ash species.

 Area of Moderate-to-Severe Decline – 2014

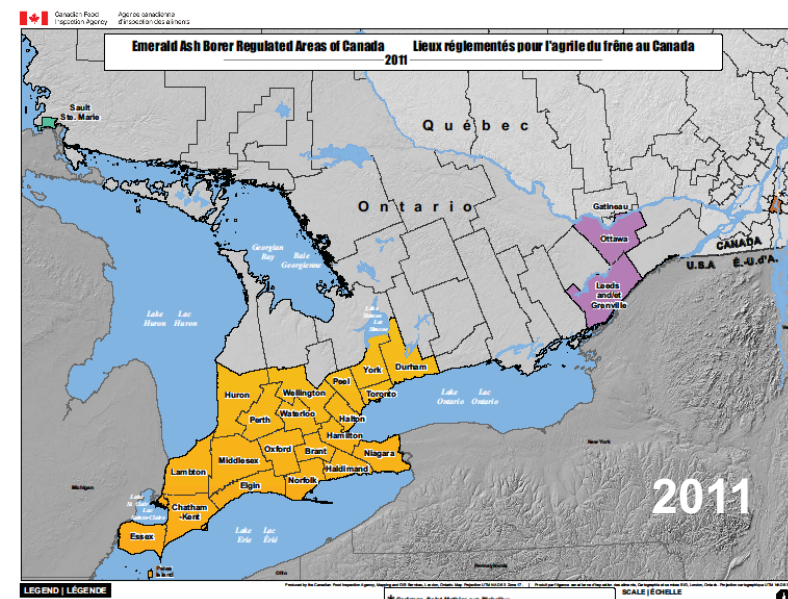
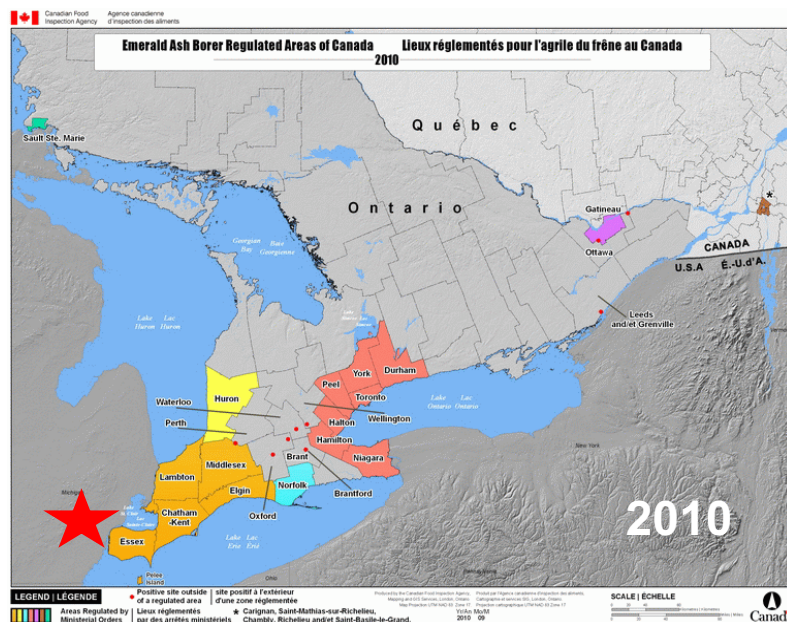
 2004 – 2013 Area of Moderate-to- Severe Decline and Mortality
*no 2008 data



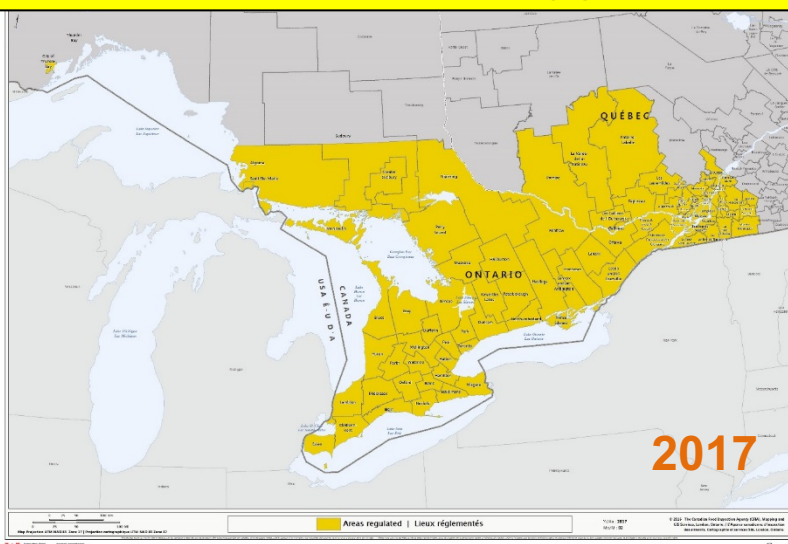
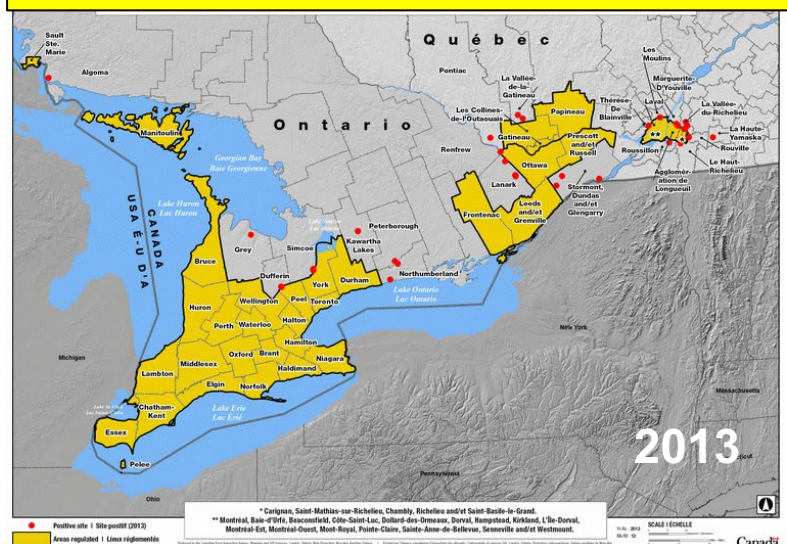


Significant impacts in riparian zones (streams & shorelines), also plantations, cities

CFIA Regulated Areas 2010-2017



Infested ash material can be moved within the controlled zone(s)





United States
Department of
Agriculture

Cooperative Emerald Ash Borer Project

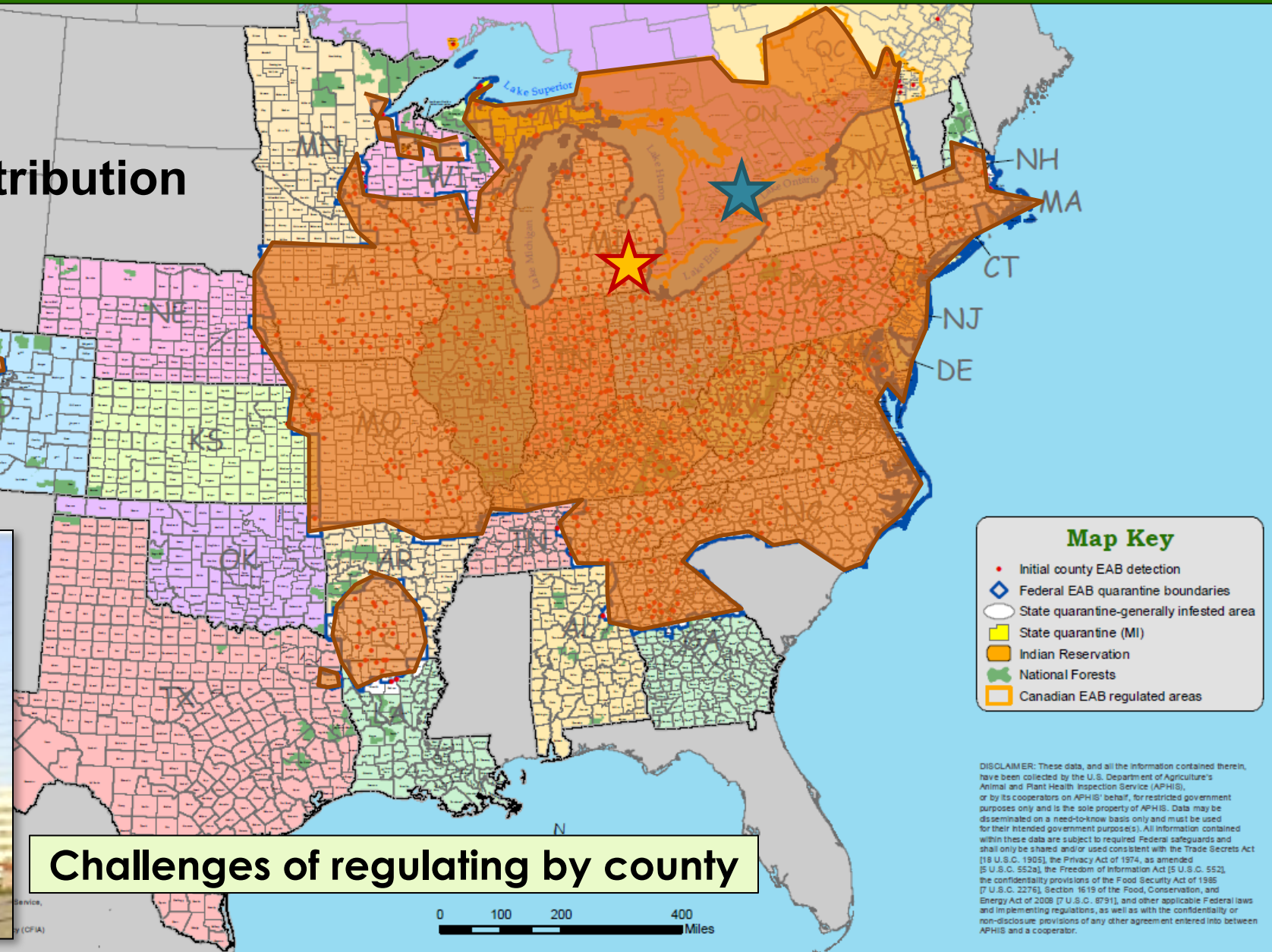
Initial county EAB detections in North America

August 1, 2017

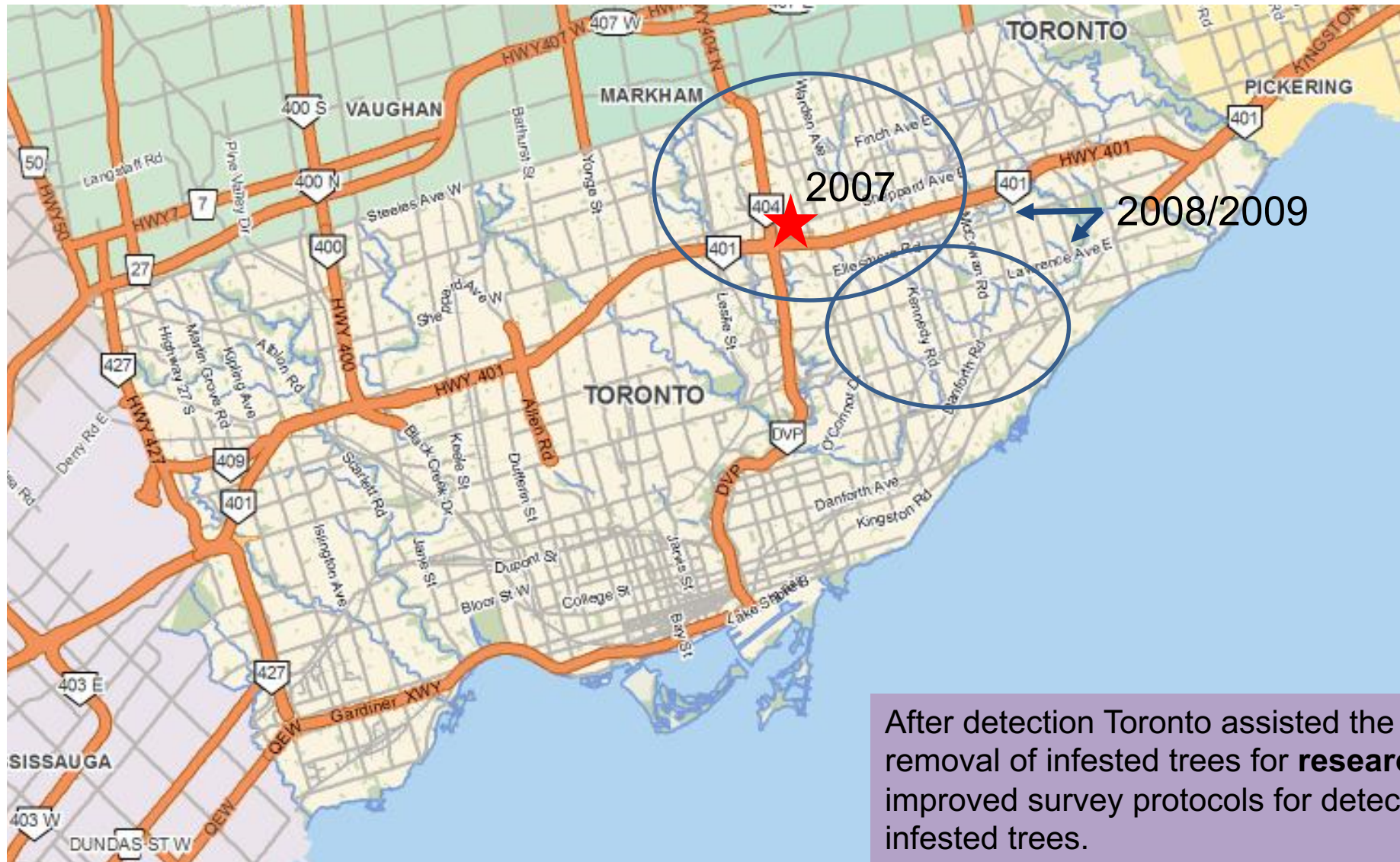
2017 Distribution



Challenges of regulating by county

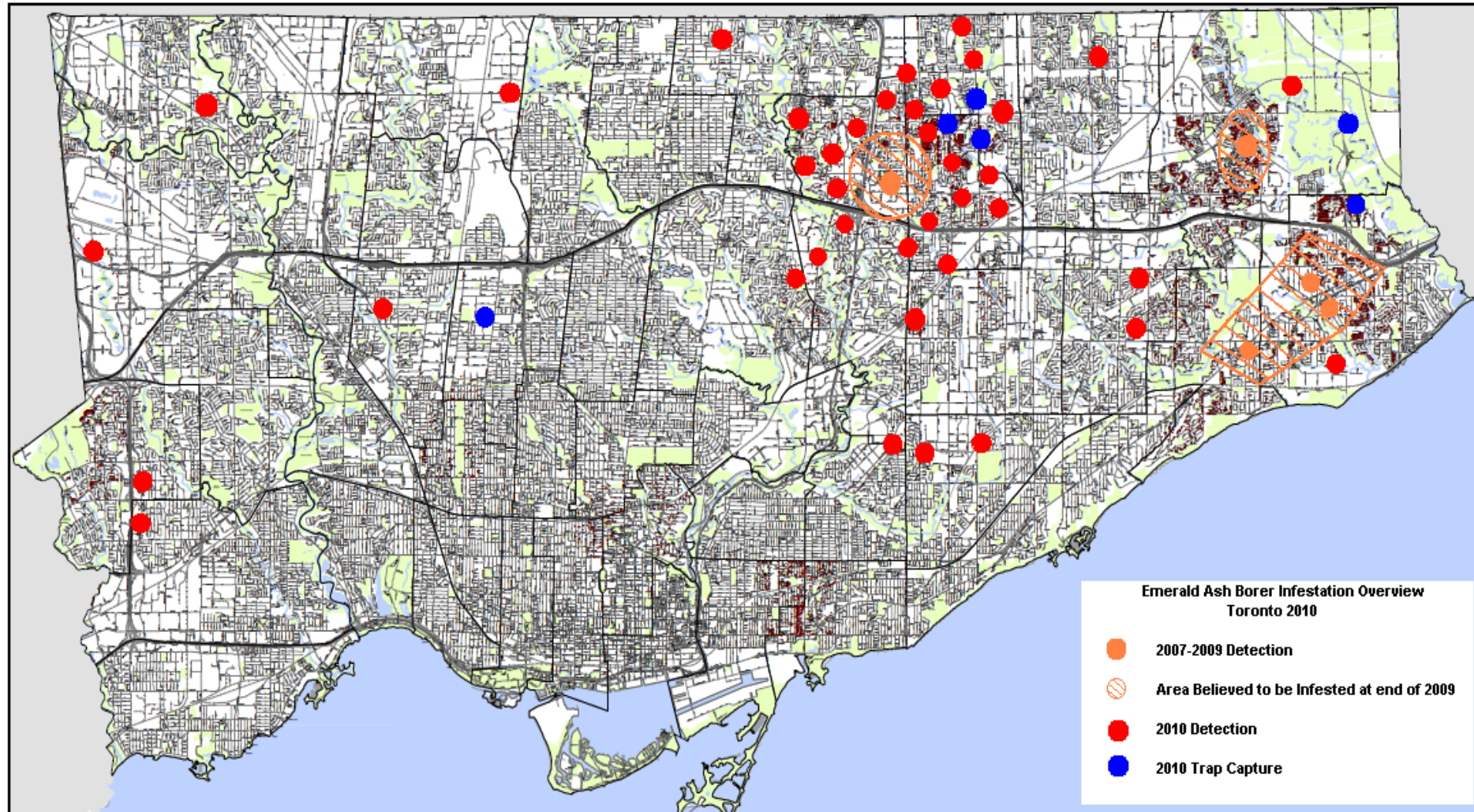


Original point of EAB detection in Toronto (2007) ★



Results of Systematic Survey 2010

Supported by Canadian Forest Service



By 2012 the entire city was considered to be infested

Toronto's 5-Point Management Plan for EAB

Adopted March 2011

1. Monitoring and surveying the ash resource
2. Removal of dead and dying ash trees
3. Insecticide treatment of selected ash trees
4. Tree replacement and proactive planting
5. Communication and public outreach

Important considerations ...

- Mitigate public risk
- Minimise impact on natural heritage
- Co-operate with both public and private sectors in research and development



Ash Mortality

2010-2019

Year	Number of trees injected	Number of Tree Removals*
2010		34
2011	203	1928
2012	4025	3959

“tree mortality in as little as 2 years and stand mortality in as little as 5 years”

Recognition by City Council of the scale of the problem led to increased funding from 2012 to 2019



Impact of Tree Removal

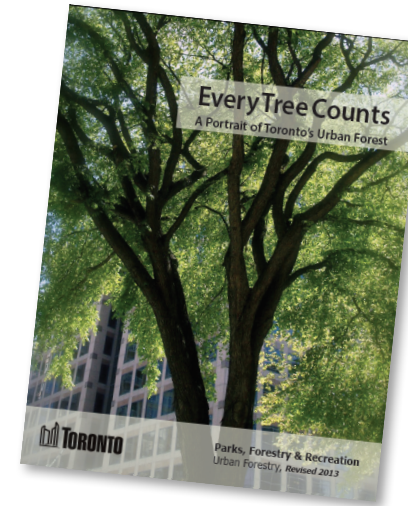
The estimated EAB programme cost is \$74.5 million



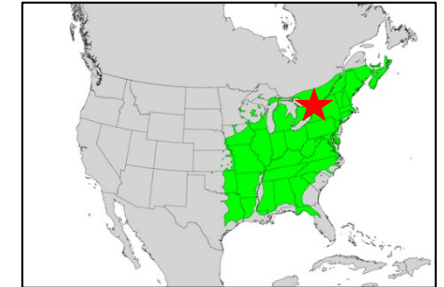
Ash (*Fraxinus* spp.) in Toronto

Ash (*Fraxinus* spp.):

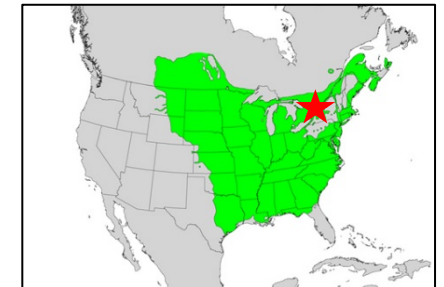
- 5 native species in southern Ontario (16 in North America):
 - White ash (*Fraxinus americana*)
 - Green ash (*Fraxinus pennsylvanica*)
 - Black ash (*Fraxinus nigra*)
 - Blue ash (*Fraxinus quadrangulata*) (rare)
 - Pumpkin ash (*Fraxinus profunda*) (rare)
- Exotics:
 - European ash (*Fraxinus excelsior*)
 - Manchurian ash (*Fraxinus mandshurica*) + hybrids
- **All are susceptible to attack by EAB**
- **860,000 ash trees within the city (8.4 % of tree population)**
- **Impact on urban forest canopy – 2.3 %**
- **Estimated structural value = \$570 Million**



Species Range Maps



White ash



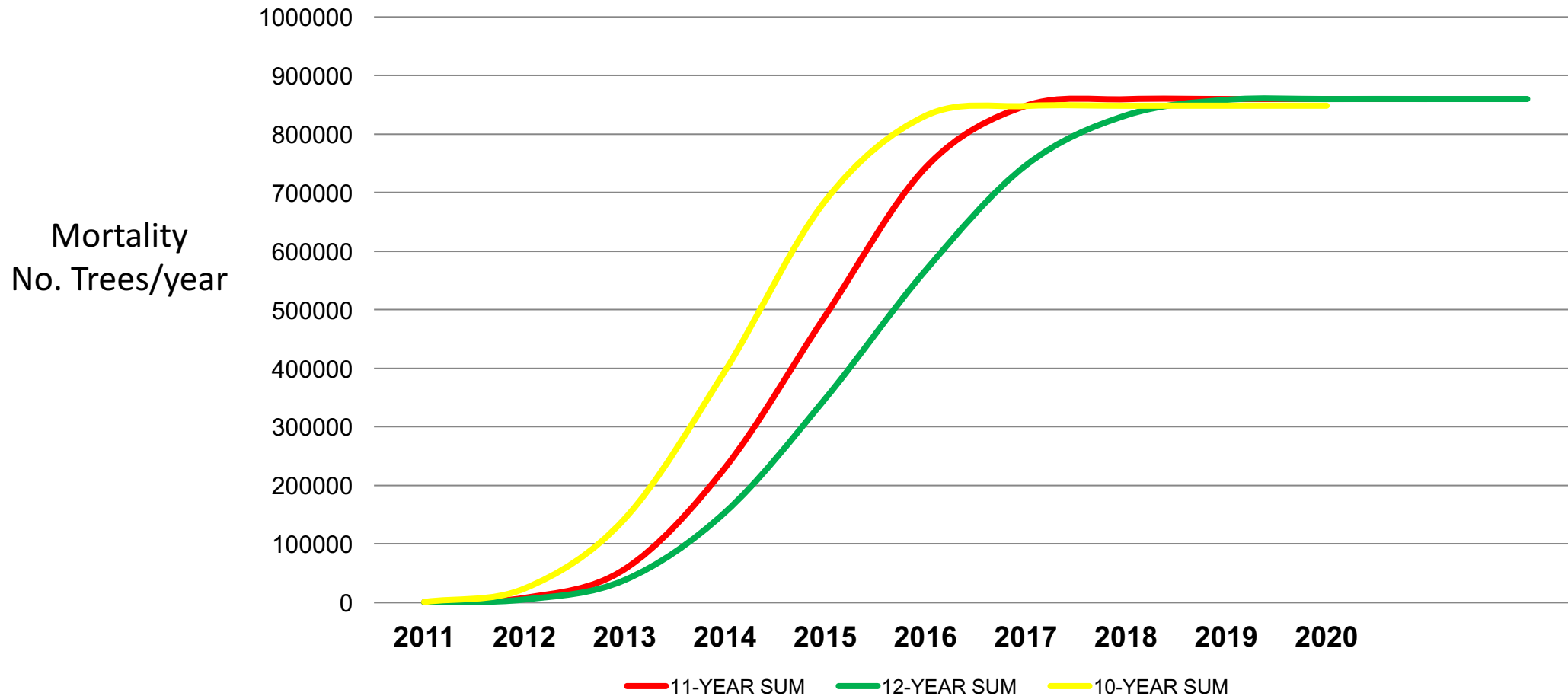
Green ash



Black ash

Cumulative Ash Mortality (Predicted)

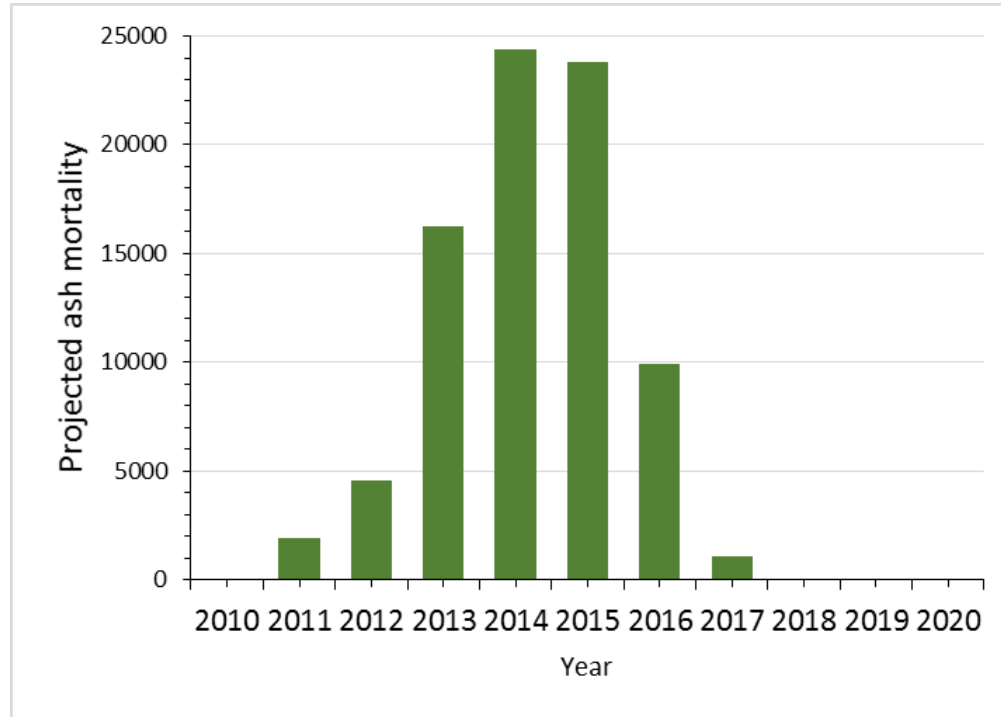
Total Population = 860,000 trees



Calculations in part based on experience in Windsor and Detroit

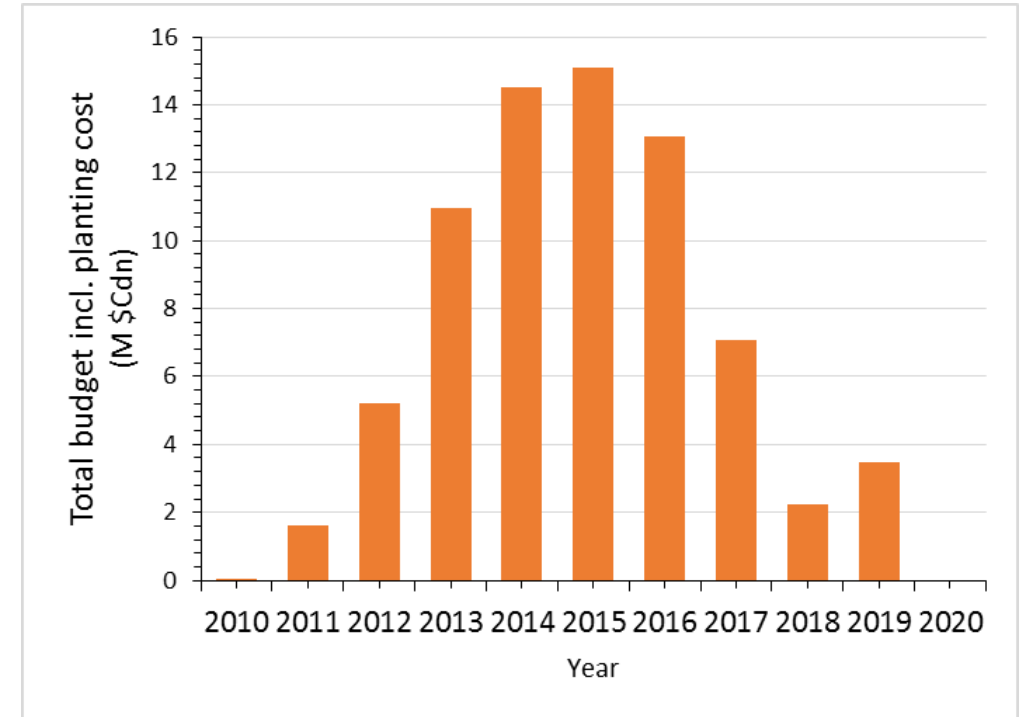
Projected Ash Tree Mortality (Street and Park Trees) 2010-2019

Ash Mortality



- Peak year for Mortality = 2014 (24.4 K trees)
- Total number managed ash = 82 K tree (city-owned)
- Trees protected = 16 K, down to 11 K trees
- Peak year for operations = 2015 (\$15.1 M)
- Total Approved Budget = \$74.5 M

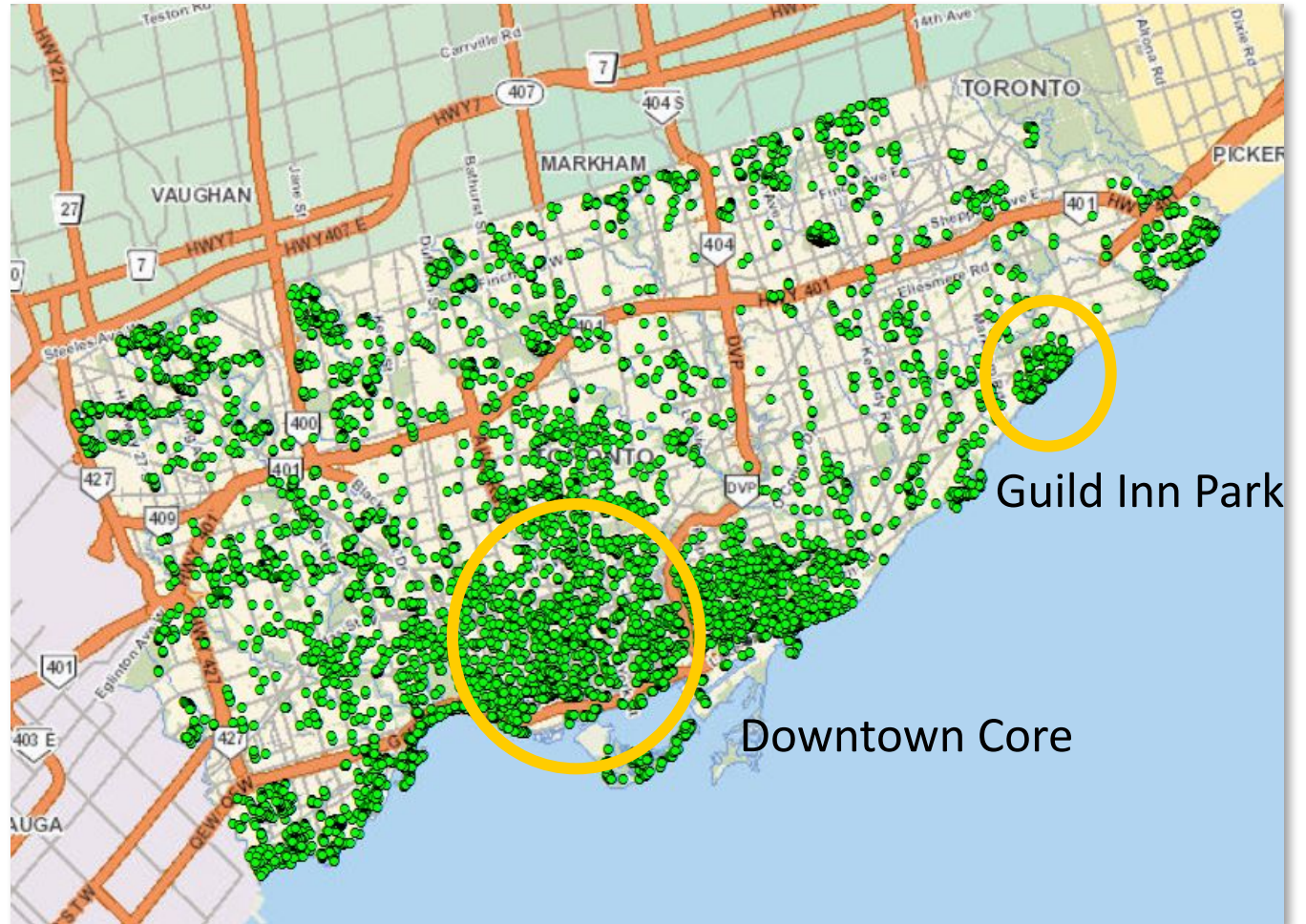
Total Budget (incl. Planting)



- Average tree removal cost = \$752
- Average tree injection cost = \$185
- Average tree planting cost = \$250
- Wood disposal = \$334,000

TreeAzin™ Insecticide Injection Programme

- Original plan for 16,000 trees
- Currently approximately 11,000
- Inject 2 out of 3 years
- Pre- and Post-inspection by city foresters
- Injections completed by contractors
- Map shows locations of trees in the protection programme 2016





Street trees protected with TreeAzin


Enhancing Resilience

Guidelines for selection of alternative species

SPECIES	SELECTION CRITERIA							PREFERRED SITE CONDITIONS	
	Native*	Indigenous**	Site Adaptability	Transplantability	Seed/Propagule Availability	Ease of Propagation	Pests***	Soils	Soil Moisture
Silver Maple (<i>Acer saccharinum</i>)	yes	yes	wide	excellent	readily; local seed	high	several, none serious	all	prefers moist to wet will tolerate a wide range of moisture conditions
Hackberry (<i>Celtis occidentalis</i>)	yes	marginally	very wide	excellent	intermittent; local seed	high	several, none serious	all (prefers limestone based)	prefers moist, well-drained will tolerate a wide range of moisture conditions
Eastern Cottonwood (<i>Populus deltoides ssp deltoides</i>)	yes	marginally	moderately wide	fair to good	readily; local hewed cuttings	high	several, some debilitating	all	prefers moist to wet
Freeman Maple (<i>Acer saccharinum x rubrum</i>)	yes	probable	moderately wide	good	good; local seed	good	several none serious	all	prefers moist to moderately wet will tolerate a wide range of moisture conditions
Black Cherry (<i>Prunus serotina</i>)	yes	yes	somewhat restricted	good	intermittent; local seed	high	several, some debilitating	prefers sandy loam & loams	prefers moist, well-drained poor growth on very dry or very wet
Paper Birch (<i>Betula papyrifera</i>)	yes	yes	somewhat restricted	good	intermittent; local seed	moderate	several, some debilitating	prefers sandy loam	prefers moist, well-drained
Big-Toothed Aspen (<i>Populus grandidentata</i>)	yes	yes	somewhat restricted	good	sporadic; local seed	moderate	several, some debilitating	all (prefers sandy loam)	prefers moist to moderately wet
Trembling Aspen (<i>Populus tremuloides</i>)	yes	yes	wide	good	sporadic; local seed	moderate	several, some debilitating	all	prefers moist, well-drained will grow on dry sites
American Sycamore (<i>Plantanus occidentalis</i>)	yes	marginally	wide	excellent	uncertain; local seed & cuttings	good	several, none serious	all (prefers sandy loam & loams)	prefers moist to wet
Bur Oak (<i>Quercus macrocarpa</i>)	yes	yes	wide	fair	intermittent; local seed	high	several, none serious	all	prefers moist, well-drained will grow on shallow soil & drought prone sites
For use as a minor component									
Elm, White & Slippery (<i>Ulmus americana & rubra</i>)	yes	yes	wide	good	intermittent; local seed	moderate	several, some lethal	all	prefers moist to wet

* growing naturally within southern Ontario; ** local adaptation to environmental conditions with TRCA watersheds;
*** both biotic (i.e. insects, diseases, mammals) and abiotic (i.e. weather), debilitating = stressful/of concern but not generally lethal

April 2012

 **Conservation**
for The Living City



List includes: silver maple, Freeman maple, black cherry, bur oak, American sycamore, etc

Ash woodland management: Guild Inn Park

>30 % ash, mostly mature trees in area with extensive network of path and high public use

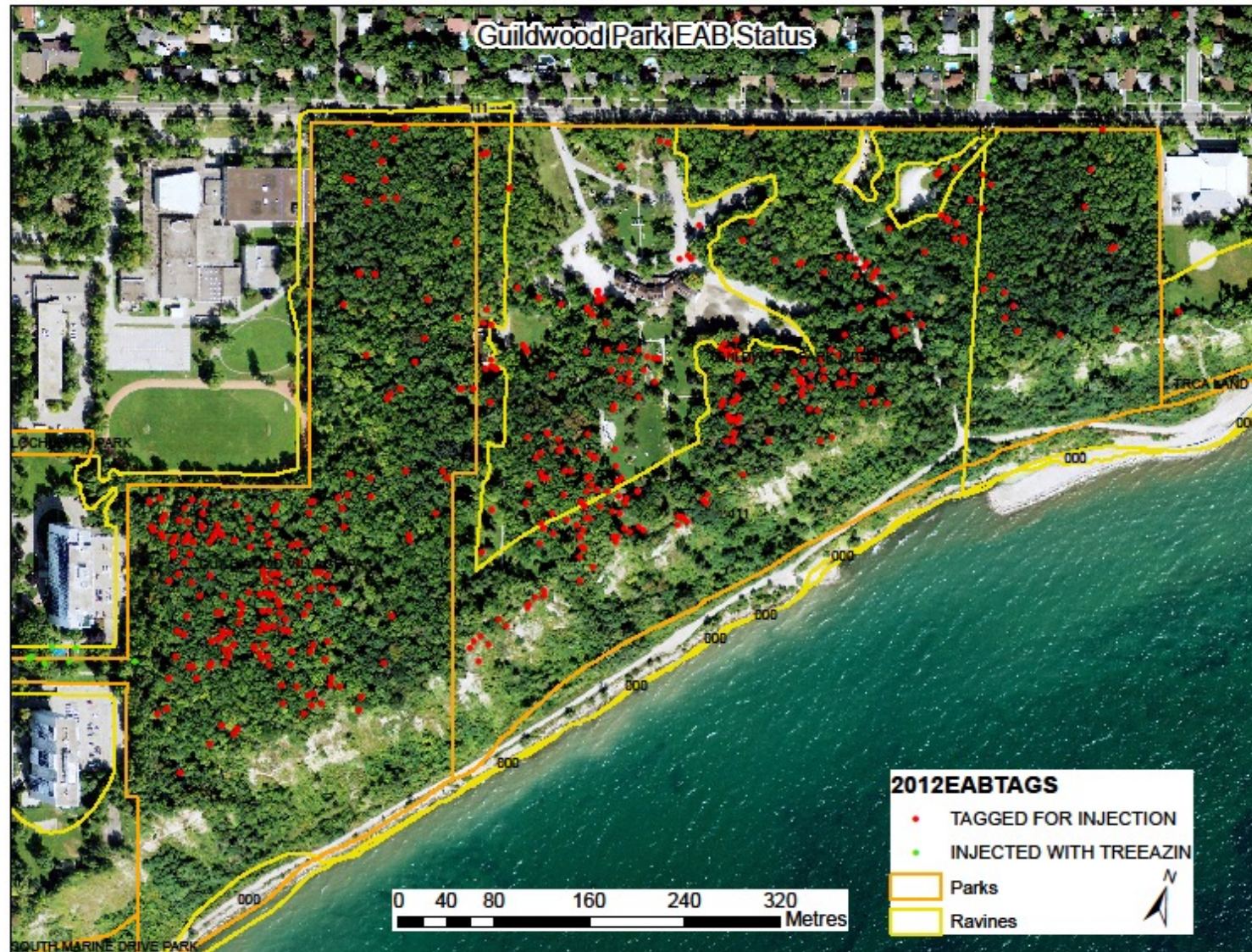


Popular location for family outings, photography, weddings



Designated Environmentally Significant Area (ESA)

Guild Inn Park – Tree Injection Programme





Guild Inn Park (harvested 2014-2015)

- Several hundred trees treated
- 2000 trees marked for removal (mitigate risk)



Harvesting Operations



- Winter operations to minimise site disturbance and public safety concerns

Communications Issues:

Getting messages across, dealing with complaints



Complaints about “healthy” trees being removed



Complaints about debris and brush left on site

Communications

- **Essential element of EAB management:**

- Media interviews
- Community meetings
- **“What you need to know about EAB Management”** booklet
- Transit shelter poster
- Neighbourhood tree replacement/education (LEAF)



The Emerald Ash Borer will destroy an estimated 860,000 ash trees in Toronto by 2017.

DISCOVER WAYS TO SAVE YOUR ASH TREE.

For more info on the Emerald Ash Borer visit toronto.ca/eab



 **Toronto**

Call **3-1-1**



Public bus with EAB information, 2015

Private Landowner Issues



[+ Expand All](#) [- Collapse All](#)

+ Why were ash trees being removed from natural areas?

+ How are the tree removal operations being timed to reduce site impacts?

+ What measures are being taken to protect wildlife habitat during tree removal operations?

+ Can the public use sites while ash removals are on-going?

+ What is going to happen with the ash wood removed from the sites?

+ Will the removal and movement of wood risk further spread of EAB?

Research Priorities (2002- present)

1. Understanding EAB biology
2. Detection - *monitoring EAB spread*
3. Impacts - *ecological and economic*
4. Control and management -
insecticide, parasitoids, pathogens



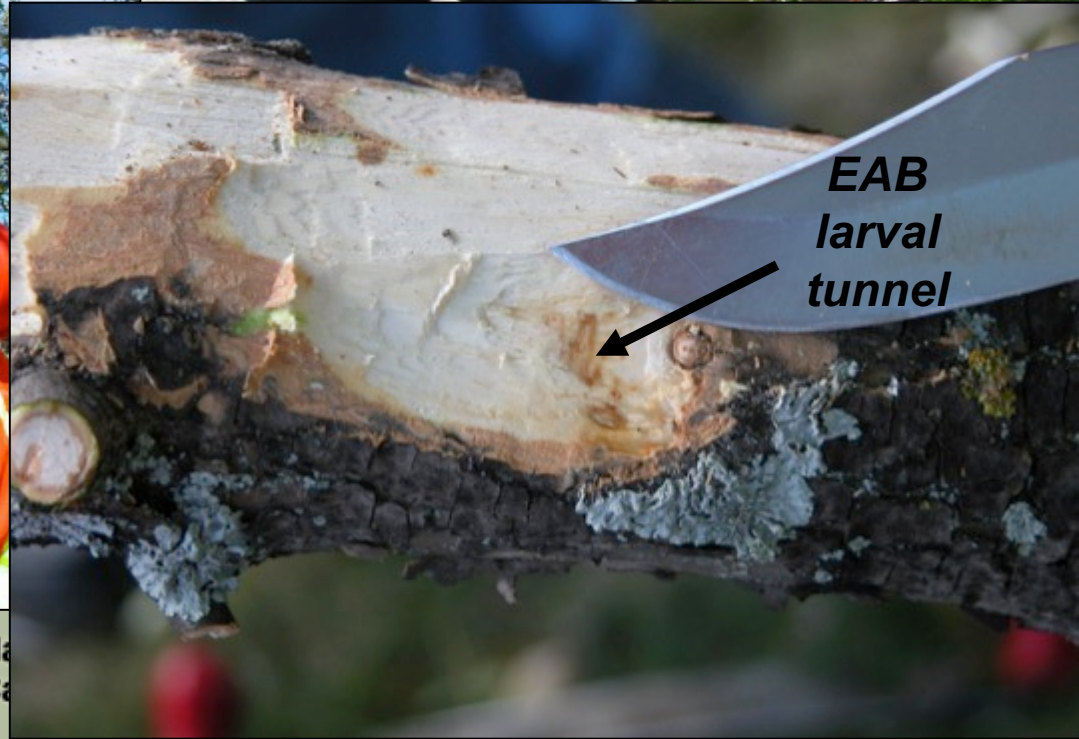
Branch sampling for EAB



*Pat Hodge,
MNRF*



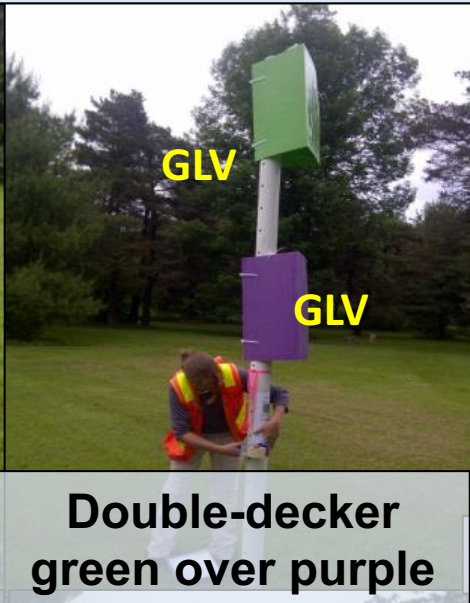
*Dr. Krista
Ryall, CFS*



Na
Ca

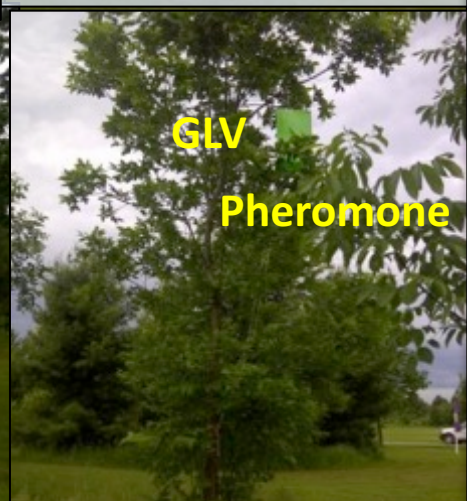
Best Trap for Detecting EAB?

Lures: Green leaf volatile (GLV), Lactone pheromone



Funded by Forest Industry (FPL Ltd, Provinces - ON, SK, MB, USDA-APHIS

2 Sites in ON, MI, OH, PA



Year II: 2015

Trapping for EAB



EAB Control (insecticide)

Province of Ontario regulates insecticide use:

- TreeAzin insecticide developed by BioForest Technologies and Canadian Forest Service
- Environmental fate testing
- City trial demonstration 2007 (London, Ontario)
- Emergency registration 2007-11
- Full registration 2012



Classical Biological Control for EAB

Released in Canada



***Tetrastichus planipennisi* Yang**
(Hymenoptera: Eulophidae)

- *gregarious endoparasitoid*
- *multiple generations per year*
- *parasitism rates in China 50%*
- *sex ratio 4:1 (female:male)*
- *adults emerge late May – probably require hosts with 2-year life cycle*

Approved in Canada



***Oobius agrili* Zhang & Huang**
(Hymenoptera: Encyrtidae)

- *reproduces parthenogenically*
- *solitary egg parasitoid*
- *female:male = 15:1*



Approved but not suitable



***Spathius agrili* Yang**
(Hymenoptera: Braconidae)

- *gregarious idiobiont ectoparasitoid*
- *3-4 generations per year*
- *parasitism in field 30-90%*
- *1-35 eggs/host*
- *sex ratio 3:1 (female:male)*
- *adults emerge late in season*



***Tetrastichus planipennisi* – Adult parasitoid release**

Searching for Native Parasitoids



**Canadian
Forest Service,

Forestry,
University of
Toronto**



EAB Ecological Impacts – Monitoring



Pre-EAB

Changes in understory plant & community composition

Changes in riparian zones, water quality, & soil



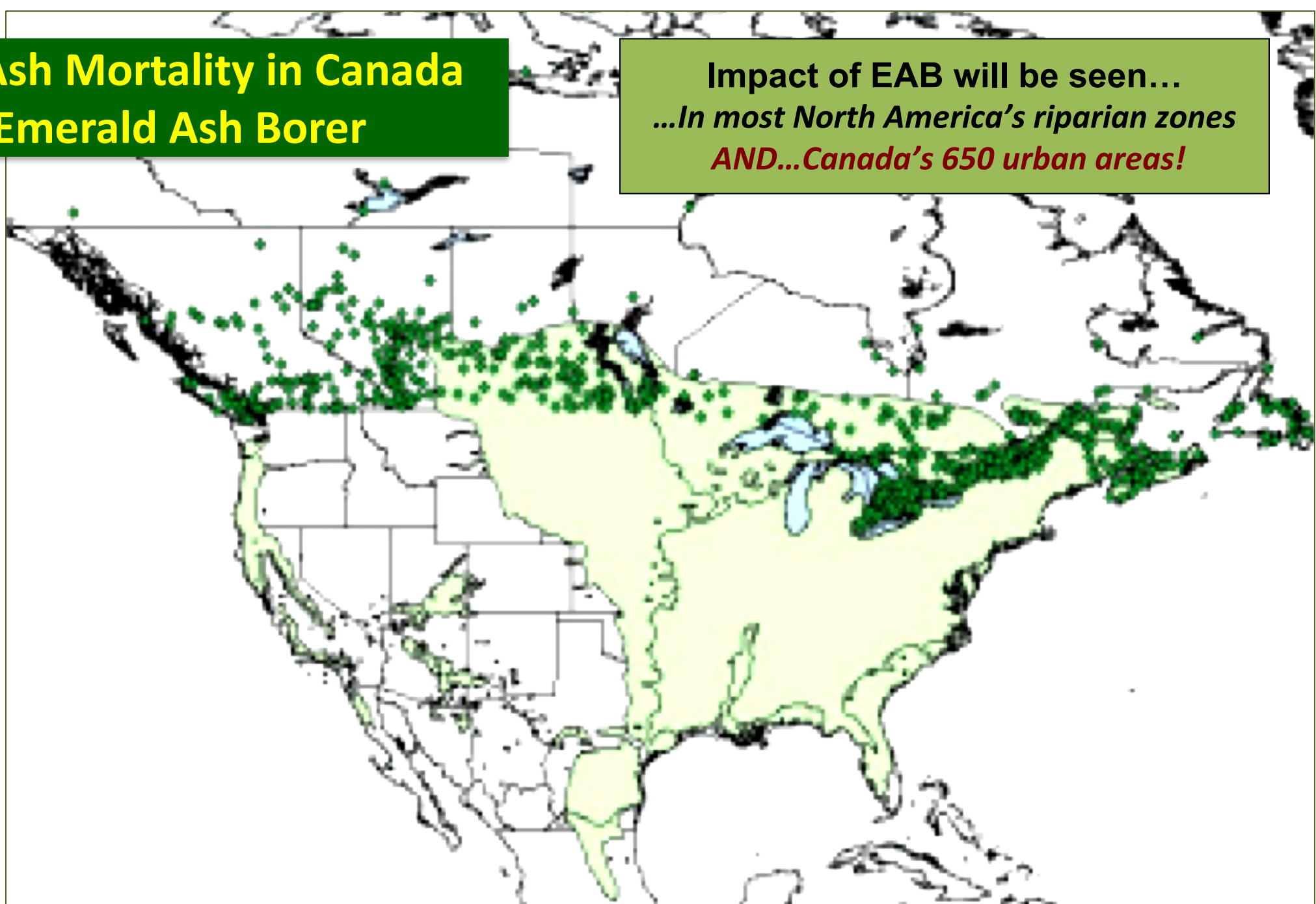
Post-EAB

EAB Known Unknowns

1. **Future forest: how much ash?**
2. **Impacts in contiguous forest & over long-term?**
3. **Role of native parasitoids?**
4. **Effectiveness of introduced parasitoids?**
5. **Tree protection needs after invasion wave passes & populations decline** (*after the green tsunami!*)?

Potential Ash Mortality in Canada from Emerald Ash Borer

Impact of EAB will be seen...
...In most North America's riparian zones
AND...Canada's 650 urban areas!



Faculty of Forestry, University of Toronto

Urban Forestry and Settled Landscapes Programme



- **Research on urban forestry** at Toronto from 1965
 - Founding chair Prof. Eric Jorgensen, first to develop the concept of Urban Forestry
- **Master of Forest Conservation** (Professional Degree)
- **Interdisciplinary approach** - collaboration with landscape architecture, urban planning, etc
- **Research across scales** – gene to landscape
- **Professional Development and Outreach**
 - International Advanced Practitioner Workshop 2015
- **Strategic research collaboration on EAB**
 - Defra-funded PhD with Faculty of Forestry, Forest Research and Canadian Forest Service
 - 2017-2021



IN RELIQUUM TEMPUS ARBORES HODIE
Trees today and for the rest of time

EAB Lessons Learned – Management

- **EAB is difficult to detect until the symptoms are severe**
 - Early detection methods need to be refined if there is any chance of containment/eradication
- **EAB – rapid initial spread overwhelms natural and management control measures**
 - Movement of firewood, nursery stock and other ash products a major issue
- **Inventory and Monitoring is essential and needs to be supported, refined**
- **Public engagement in forest health issues is ongoing** – education, communication, political support; recognition of the many values and benefits of the urban forest
- **Professional education and training**
 - Forest health education requires greater profile in arboriculture and urban forestry courses and CPD

EAB Lessons Learned – Research

1. **Visual detection techniques unreliable** (arrives undetected & spreads before you know it!)
2. **Significant research advances:**
 - **Biology:**
 - life cycle, mortality
 - **Prediction:**
 - Branch sampling
 - Trapping (green prism trap, green leaf volatile, pheromone, *'trapping out males'*)
 - **Control:**
 - Insecticides (TreeAzin, Imidachloporid)
 - Parasitoids (exotic & native)

EAB Lessons Learned

- **Planning and Coordination**

- Effective management has only been possible with strong support from across government and public-private partnerships; securing adequate funding for tree/forest health requires leadership and engagement at the political level

- **The Urban Forest is on the front line!**

- Invasive pests and diseases will continue to be imported through cities and urban areas
- Sharing knowledge and building networks – Toronto has learned from others and wants to share its experience for the benefit of other communities
- Arboriculturists will play an increasingly important role in safeguarding the health and ecological resilience in urban treescapes

- **EAB is our “most unwanted” pest**

- **We will need to work hard to keep it out!**



Key Stakeholders

- Canadian Food Inspection Agency (CFIA)
- Canadian Forest Service (CFS)
- Faculty of Forestry, University of Toronto
- Forestry Branch, City of Toronto
- Invasive Species Centre, Canada (ISC)
- BioForest Technologies
- Ontario Ministry of Natural Resources & Forestry (OMNRF)

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FACULTY OF FORESTRY
UNIVERSITY OF TORONTO

All that is **Green** is not **Gold**: The **Emerald Ash Borer** (EAB) Invasion of Toronto's Urban Forest, Canada

Edward R. Wilson and Sandy M. Smith

Faculty of Forestry, University of Toronto, Canada



Session 1. Biosecurity: The Challenges

51st Arboricultural Association National Amenity Conference

Protect and Survive: 1st International Conference on Arboricultural Biosecurity

University of Exeter, Exeter, England

11 September 2017

