Introduction to the Emerald Ash Borer *Agrilus planipennis* and the Latest Research

D. Barry Lyons
Canadian Forest Service
Sault Ste. Marie, Ontario

Federal Government Roles in Forest Invasive Alien Species

Natural Resources Canada | Ressources naturelles Canada

Natural Resources Canada
Canadian Forest Service

vs.

Canadian Food Inspection Agency | Agence canadienne d'inspection des aliments

Canadian Food
Inspection Agency

Science-Based Policy
Organization

Regulatory Agency
Plant Protection Act

Emerald Ash Borer Science Committee
(Barry Lyons, CFS-GLFC, Chair)

science-based advice → CFIA

- Biology/ Signs & Symptoms
- Survey/Monitoring (Development of Detection Tools)
- Chemical Control (Systemic Insecticides)
- Biological Control (Parasitoids and Pathogens)

- Quarantines/Regulations
- Outreach/Communications
- Cultural Controls (Sanitation)

Host Range (*Fraxinus* spp.?? – ashes)

China

- *Fraxinus chinensis* var. *chinensis*
- *F. chinensis* var. *rhynchophylla*
- *F. mandshurica*
- *F. velutina*

Japan (*A. planipennis ulmi*)

- *F. mandshurica* var. *japonica*
- *Juglans mandshurica* var. *sieboldiana*
- *Pterocarya rhoifolia*
- *Ulmus davidiana* var. *japonica*

Northeastern North America

- *F. pennsylvanica* – green ash (red ash)
- *F. nigra* – black ash
- *F. americana* – white ash
- *F. profunda* – pumpkin ash
- *F. quadrangulata* – blue ash ???

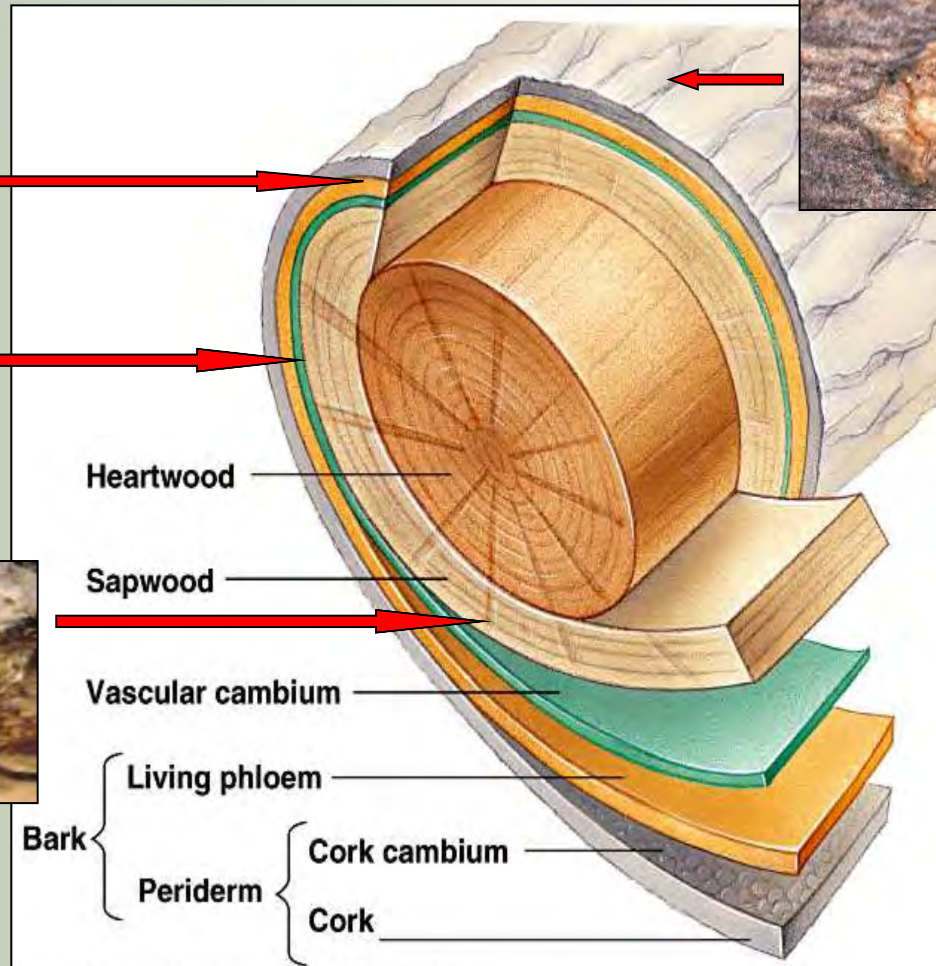
Europe

- *F. excelsior* – European/common ash


2003

2004

Life Cycle



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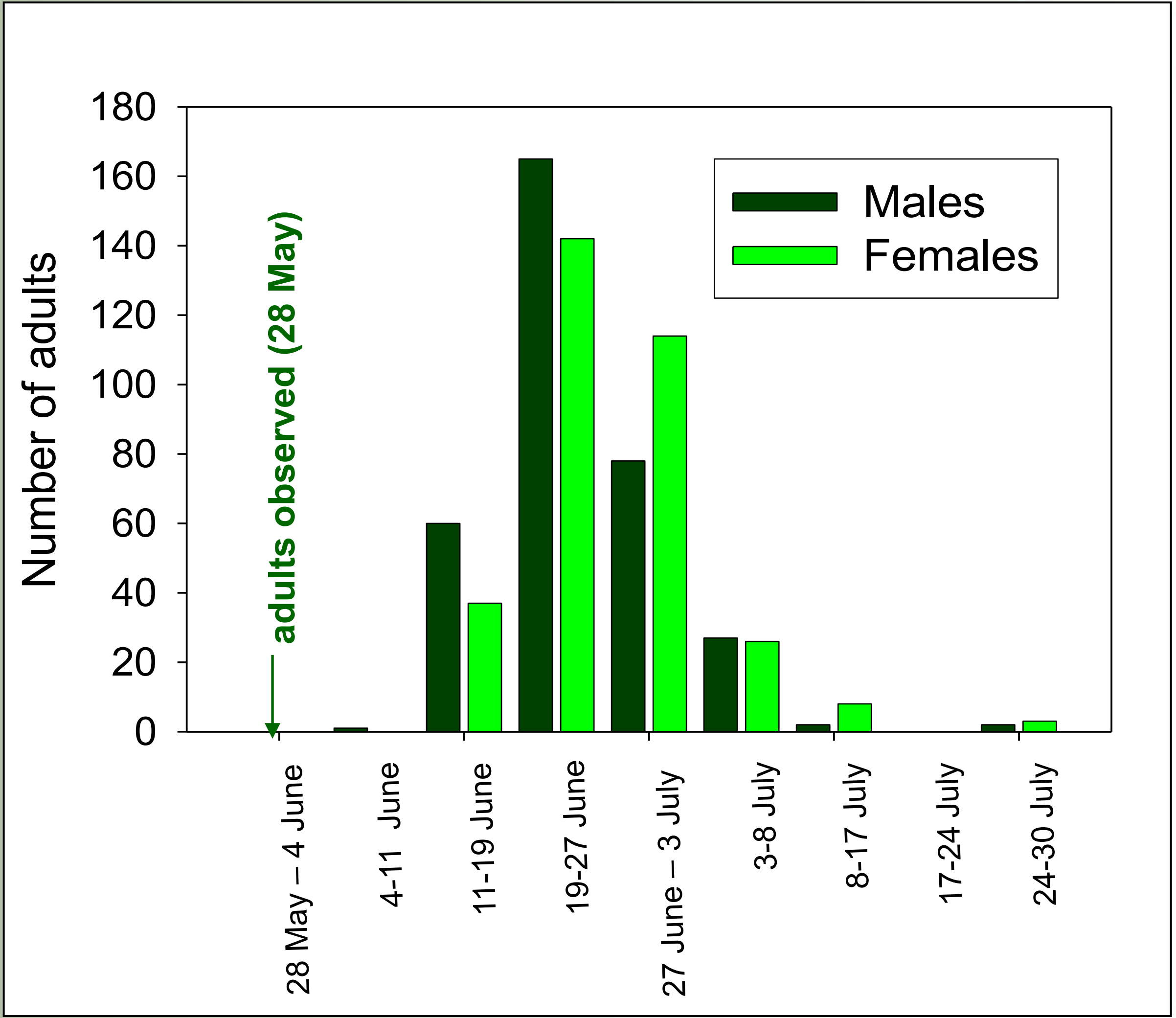
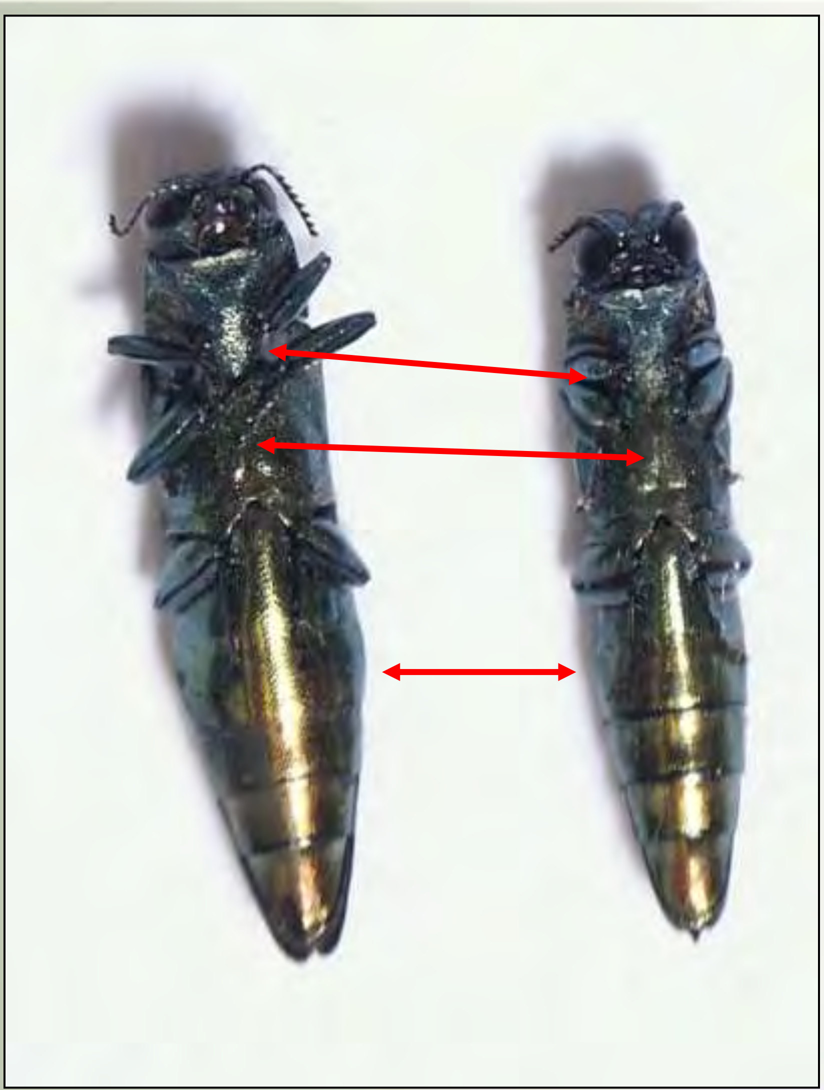
Tree Anatomy

Adult Emergence - 2003



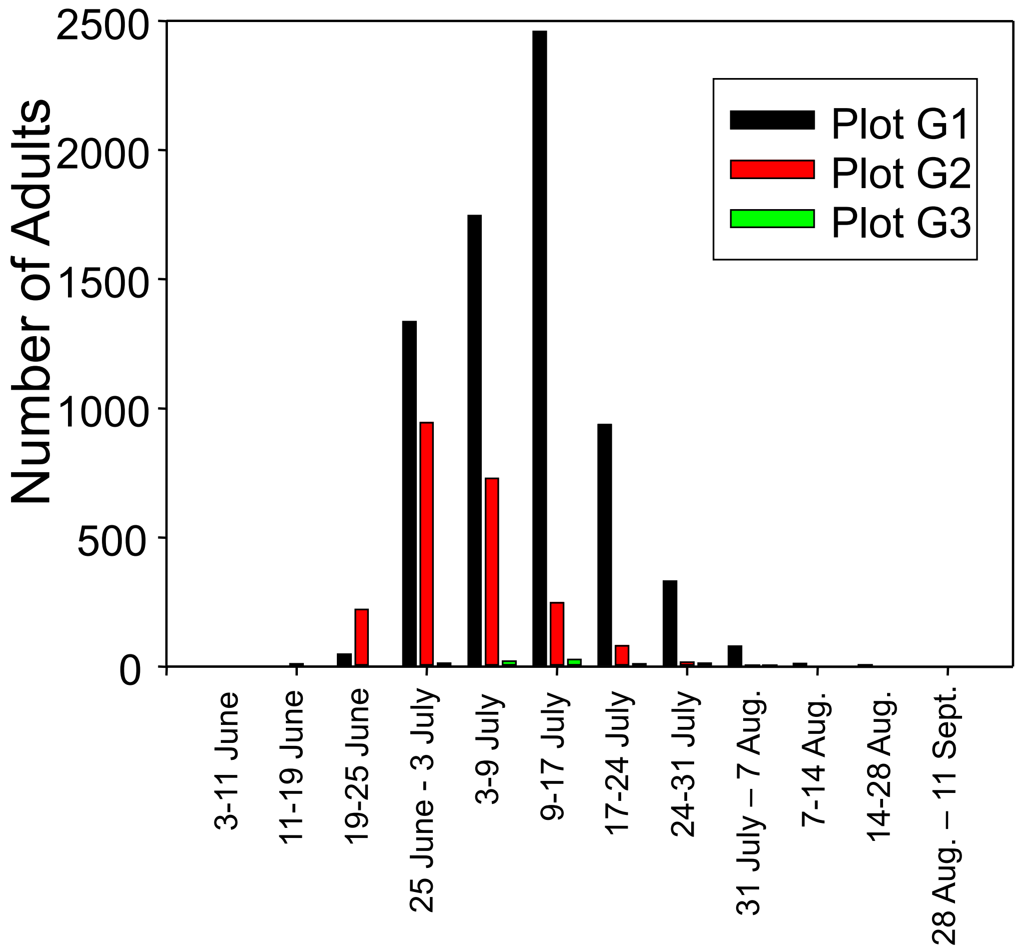
Adult

Female



Male

Adult Activity Period – 2003

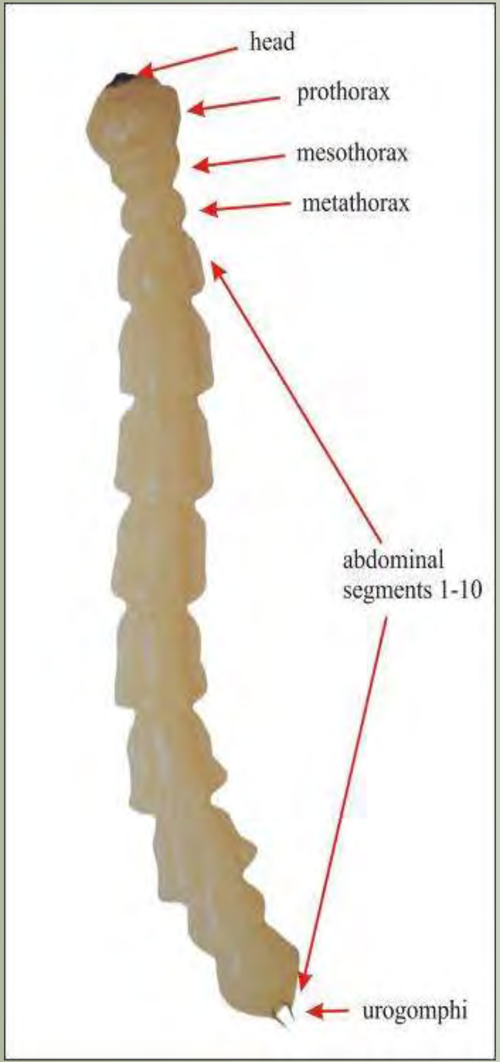


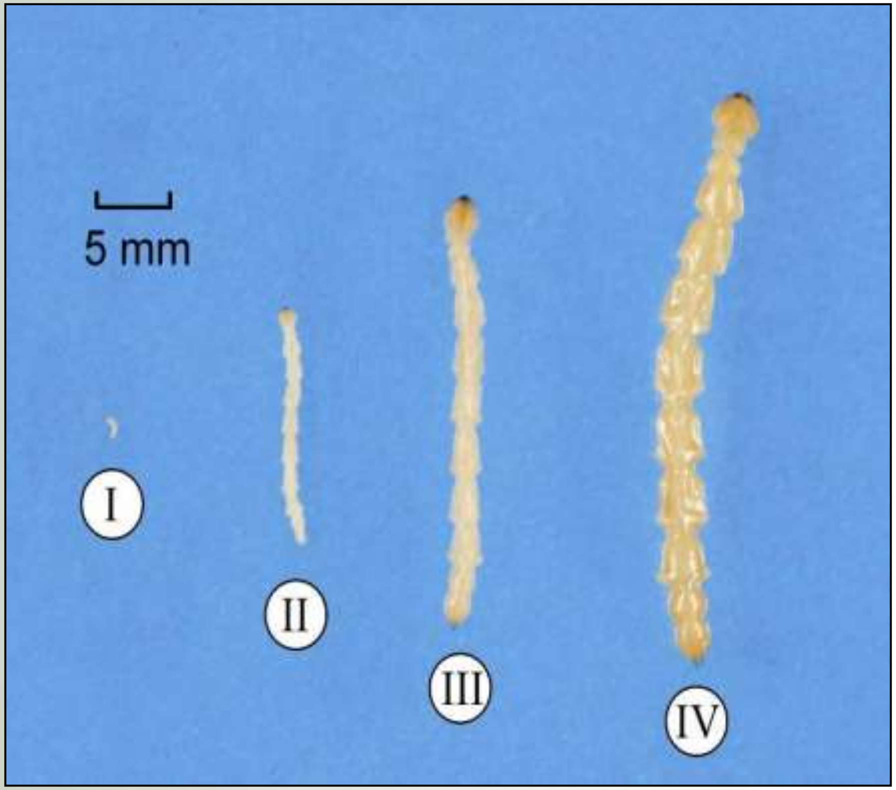
Eggs (after Yu 1992)

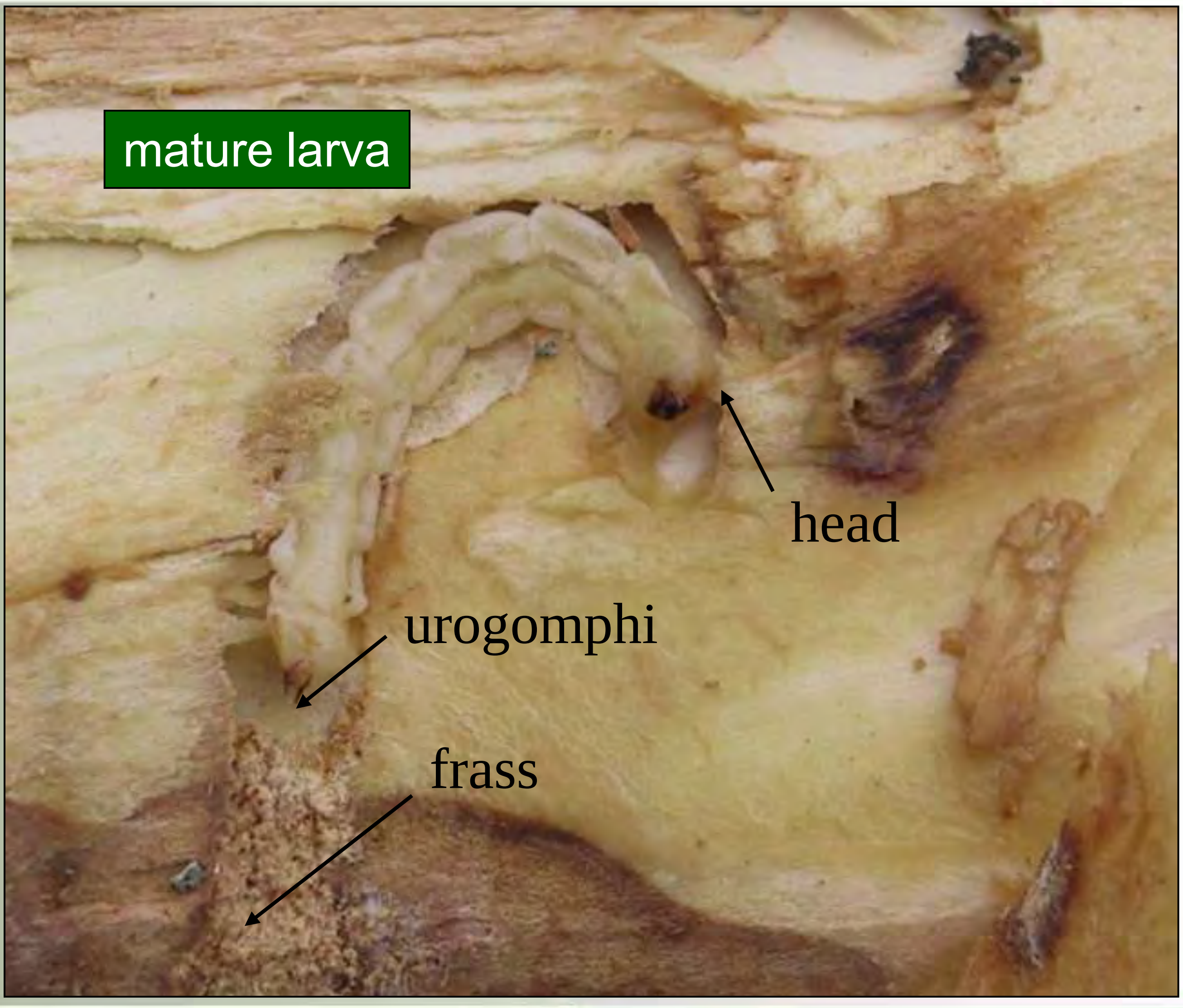
- eggs laid in sunny bark crevices and on the base of the trunk
- only one egg at each site
- cream-colored -> yellowish brown
- oblate, 1.0 by 0.6 mm slightly protruding in center, with reductus (fold) extends radially toward edges

TOO SMALL TO DETECT DURING SURVEY

Larva


head
prothorax
mesothorax
metathorax
abdominal segments 1-10
urogomphi

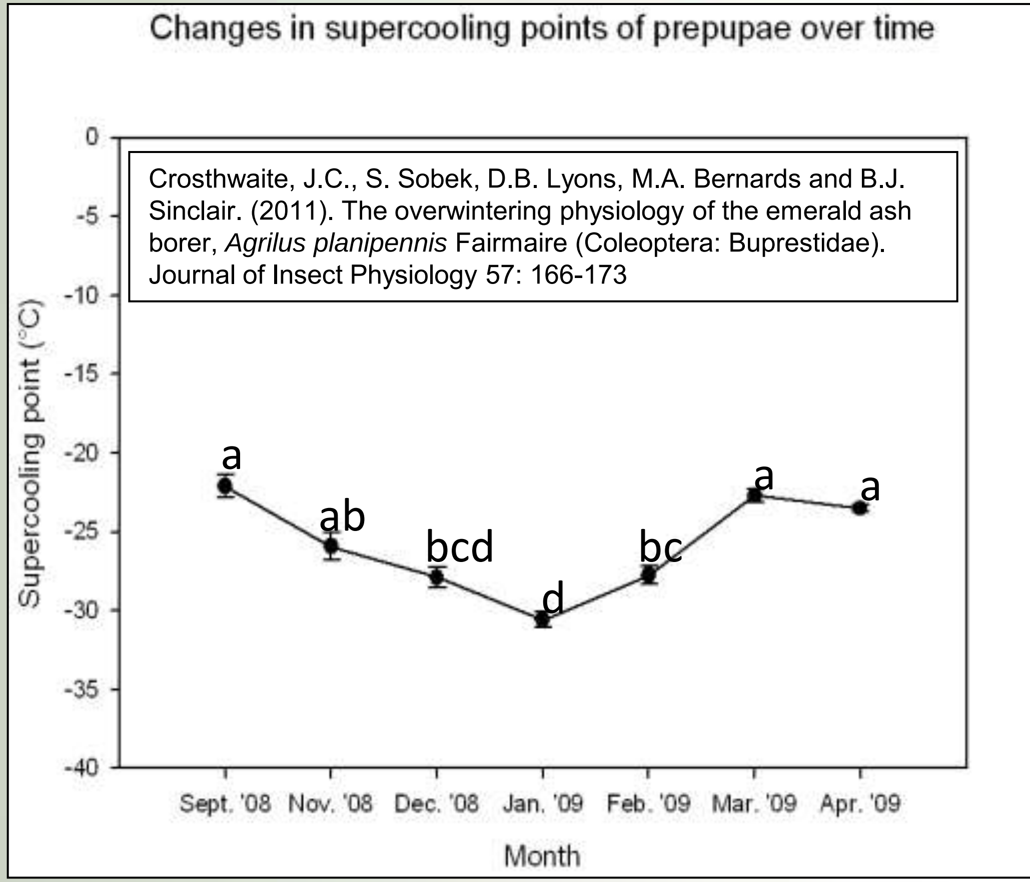

5 mm
I
II
III
IV


mature larva
head
urogomphi
frass

Overwintering Stage
(n = 2909)

Overwintering Physiology or Emerald Ash Borer
B. Sinclair (UWO) & K. Cuddington (U of W) et al.

- Freeze-intolerant prepupae
- Extremely low SCPs (-30 °C) in midwinter
- High Conc. Glycerol
- SCP is likely to be lower lethal temperature
- Warm snaps affect ability to supercool
- Decrease in supercooling ability not fully reversible

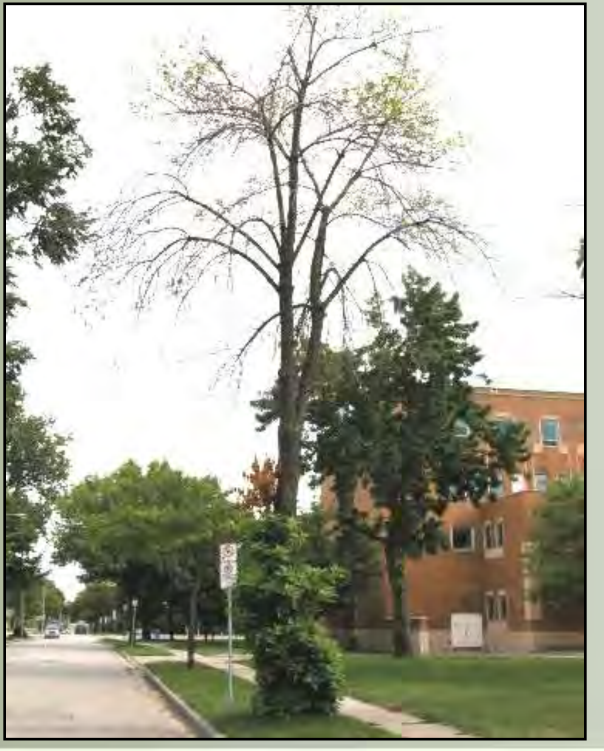


Sobek, S., J.C. Crosthwaite, D.B. Lyons and B.J. Sinclair. (submitted) Could phenotypic plasticity limit an invasive species? Incomplete reversibility of mid-winter deacclimation in emerald ash borer. Biological Invasions

Elements of an Emerald Ash Borer Management Plan

Action?

- No → DEAD ASH TREES
- Yes → Emerald Ash Borer Dynamic Management Plan



Emerald Ash Borer Dynamic Management Plan

1. Survey/Monitoring
2. Outreach/Communications
3. Quarantine/Regulations
4. Cultural Controls/ Sanitation
5. Biological Controls
6. Chemical Controls

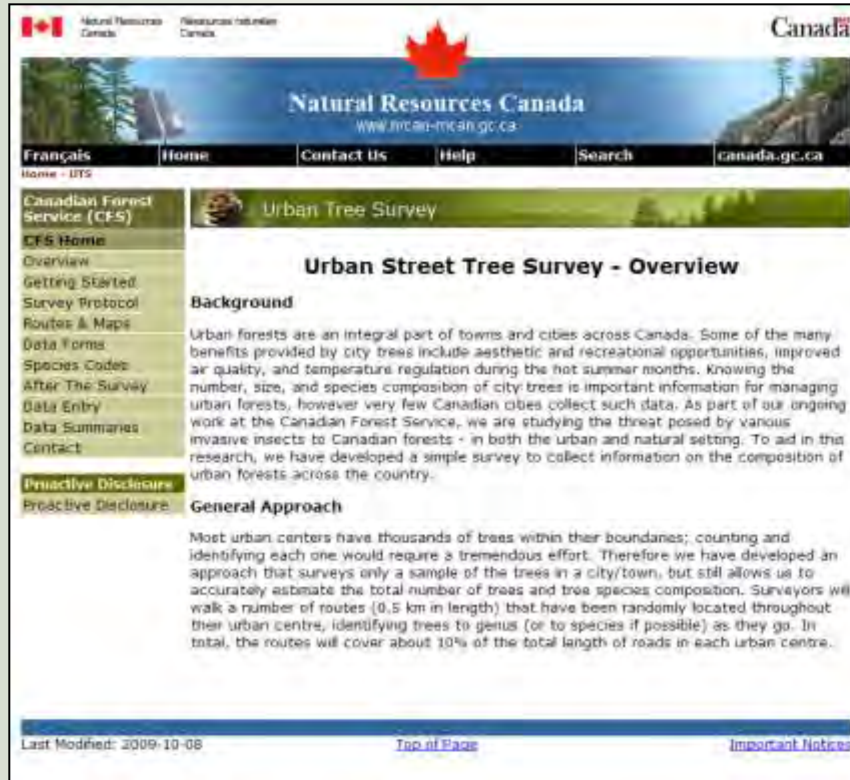

NORTH AUGUSTA
HALF ASH CLUB

Assessing Canada's Urban Jungle
- A street tree survey to aid in alien species research

J. Pedlar (CFS-GLFC) et al.

Survey Overview

- Most urban centres have thousands of trees within their boundaries
- Our approach surveys only a sample of the trees in an urban centre
- Participants walk a number of routes (0.5 km in length) that have been randomly located throughout their urban centre, identifying trees as they go
- In total, the routes cover about 10% of the total length of roads in each urban centre



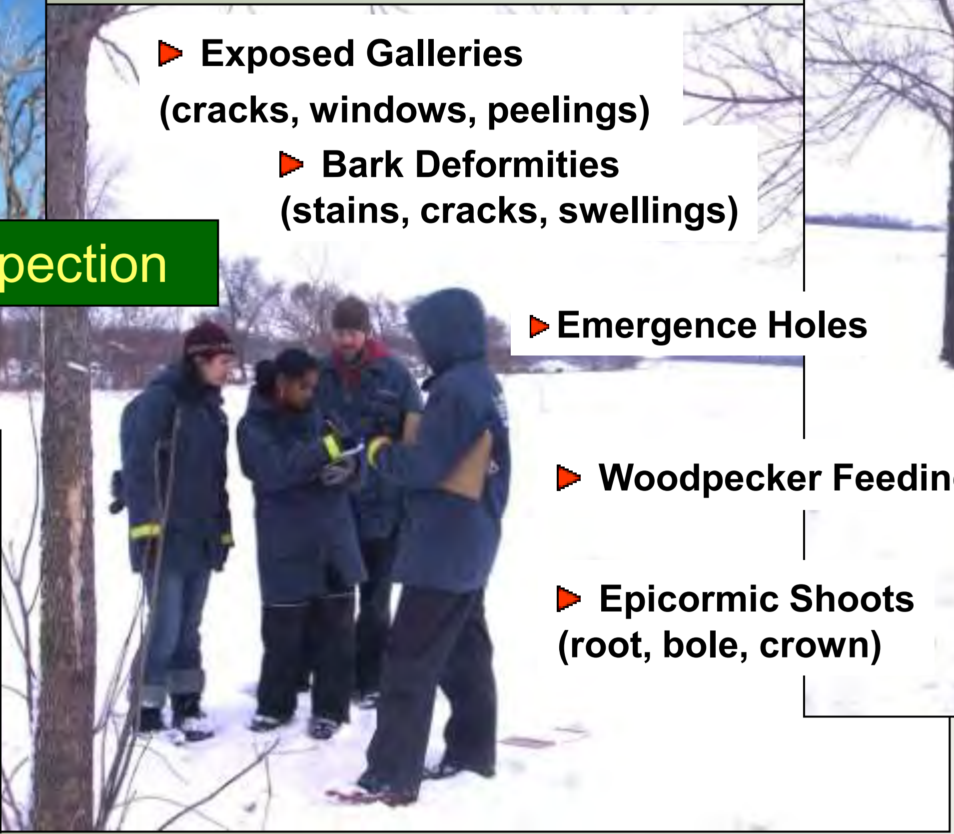
Monitoring - Detection/Delimitation Surveys

Results so far...

- numerous surveys carried out by the Ontario Stewardship Rangers this summer
- interest shown by the Ontario Field Naturalists as well
- surveys also carried out by GLFC employees when possible

City	Province	% Ash
Chatham	Ontario	0.6
Bracebridge	Ontario	0.0
Guelph	Ontario	6.3
Huntsville	Ontario	1.5
London	Ontario	3.3
Meaford	Ontario	8.2
Owen Sound	Ontario	6.7
Parry Sound	Ontario	19.8
Porcupine	Ontario	1.7
Sault Ste Marie	Ontario	2.2
Sudbury	Ontario	4.9
Timmins	Ontario	0.4
Bathurst	NB	4.0
Oromocto	NB	0.4
Fredericton	NB	0.0
Moncton	NB	0.1
Mean		3.7

Monitoring - Detection/Delimitation Surveys

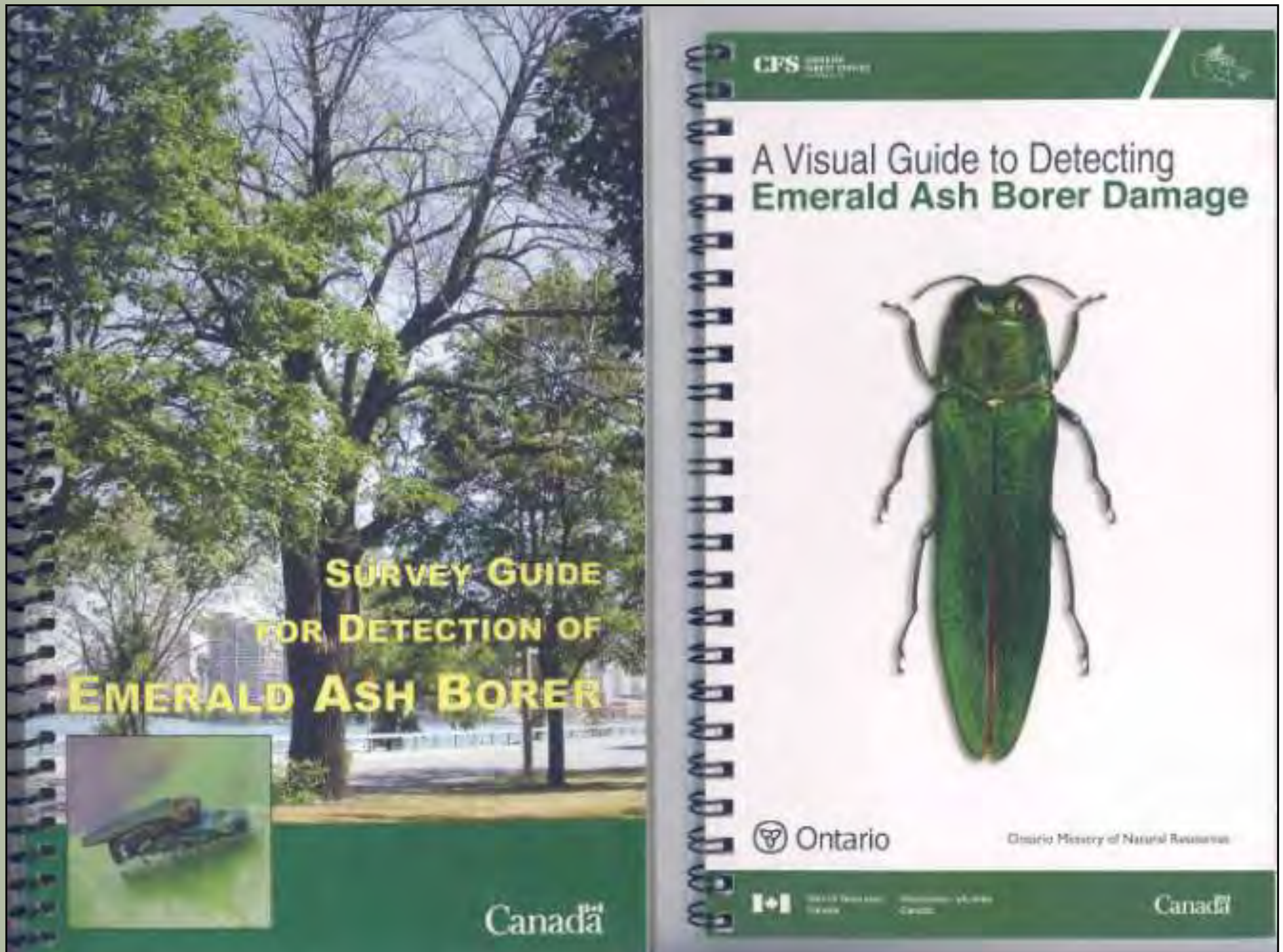


visual inspection

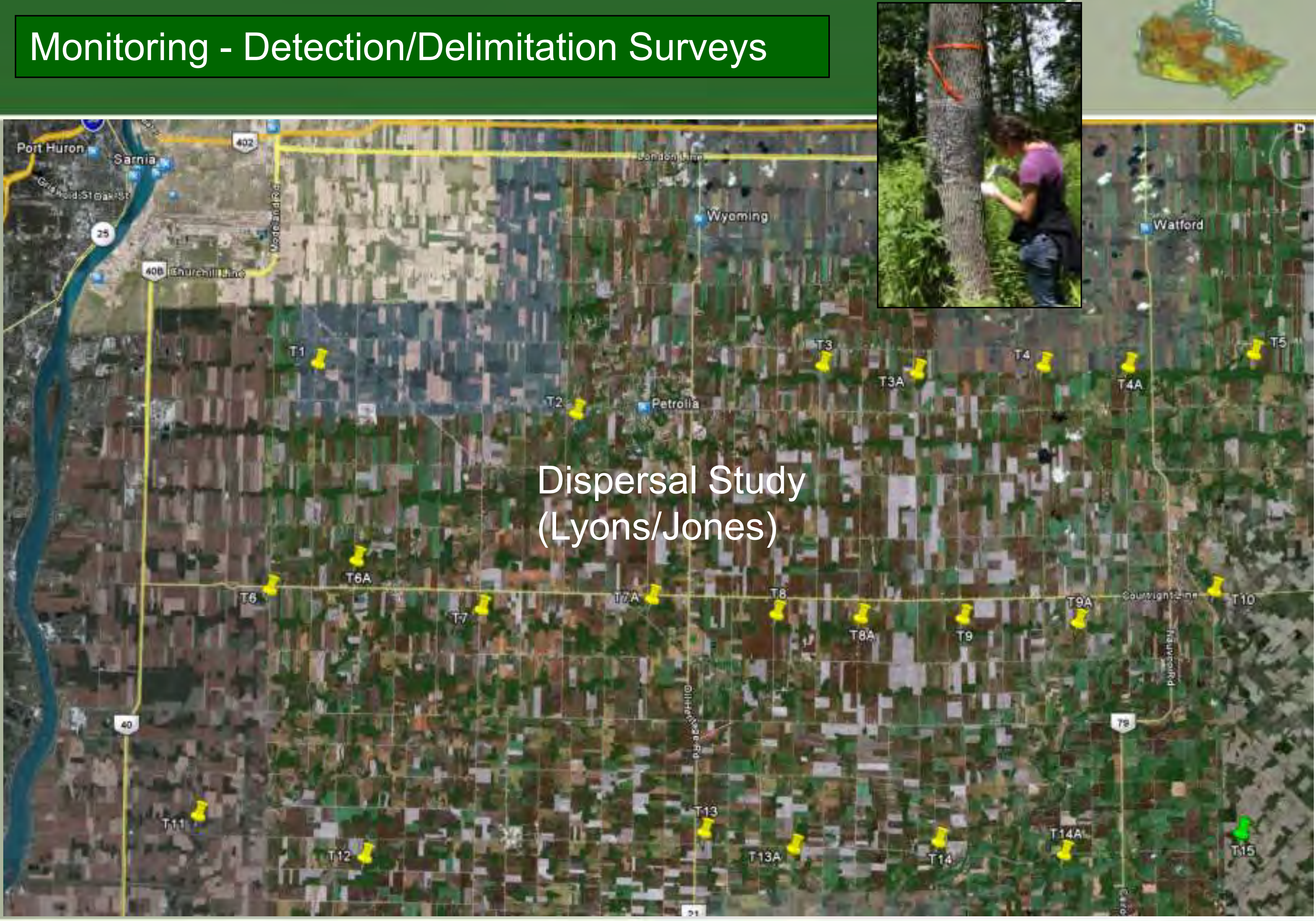
- Exposed Galleries
  (cracks, windows, peelings)
- Bark Deformities
  (stains, cracks, swellings)
- Emergence Holes
- Woodpecker Feeding Holes
- Epicormic Shoots
  (root, bole, crown)

trap tree

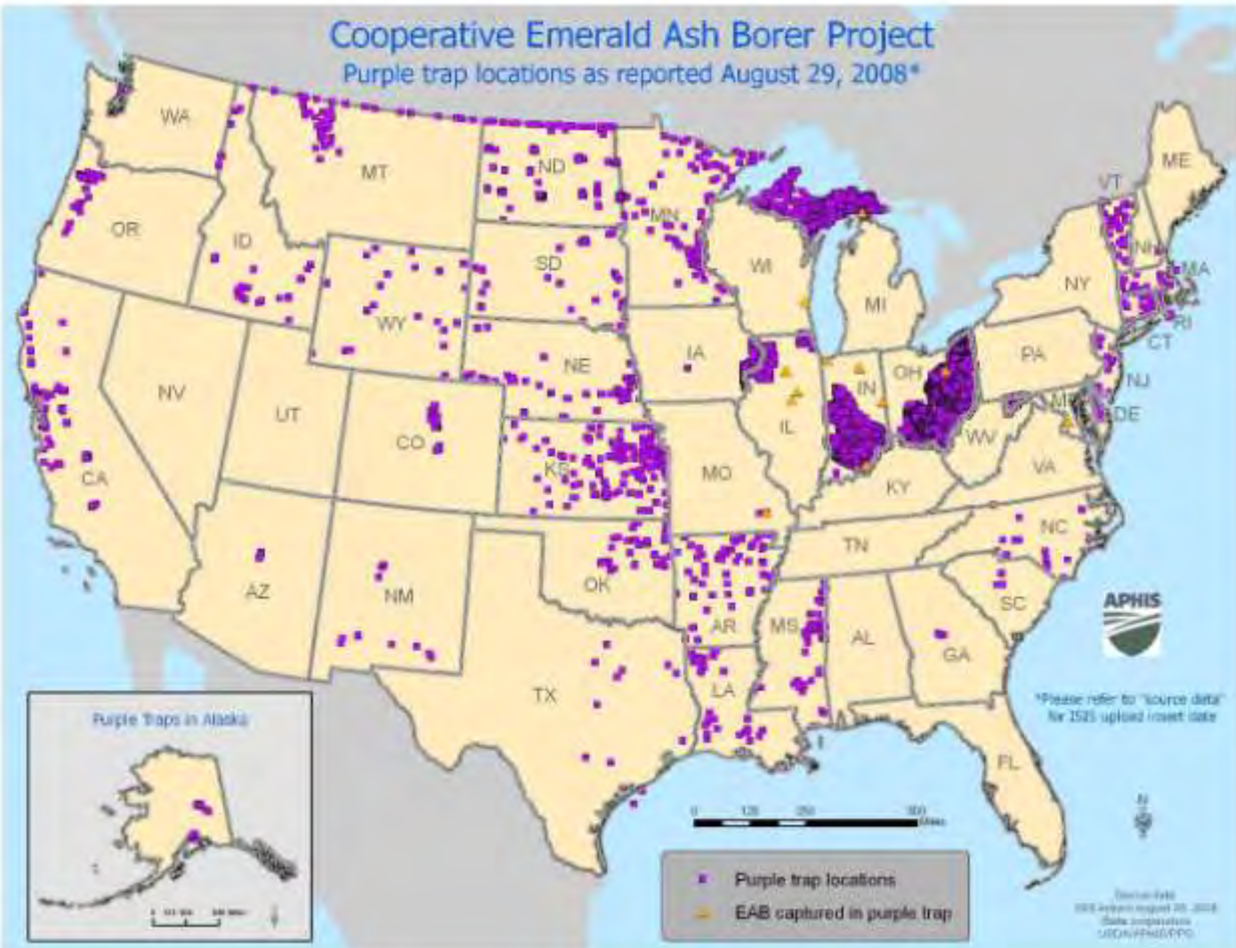
Monitoring - Detection/Delimitation Surveys

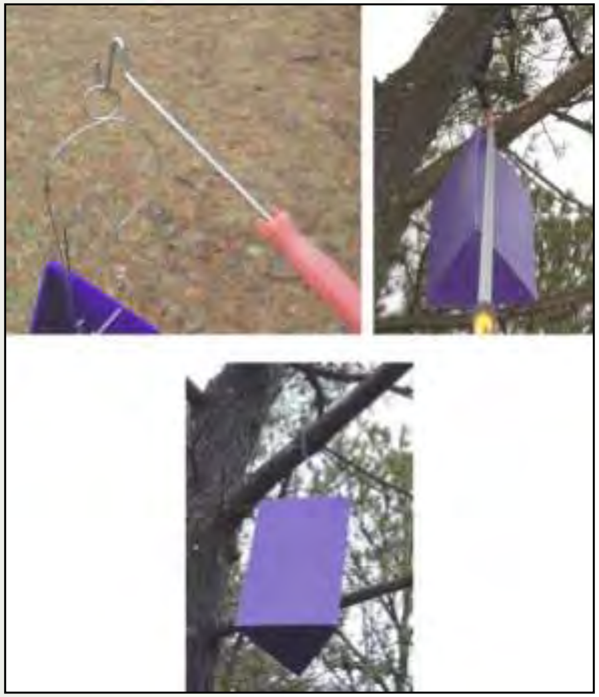


Monitoring - Detection/Delimitation Surveys



Monitoring - Detection/Delimitation Surveys

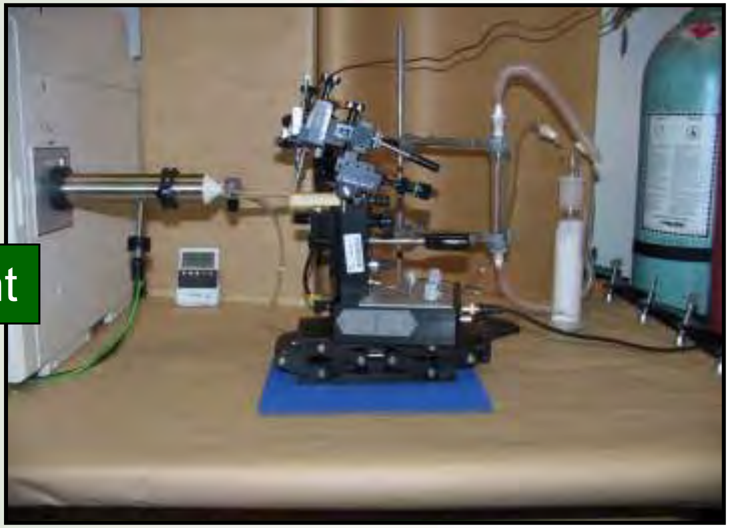




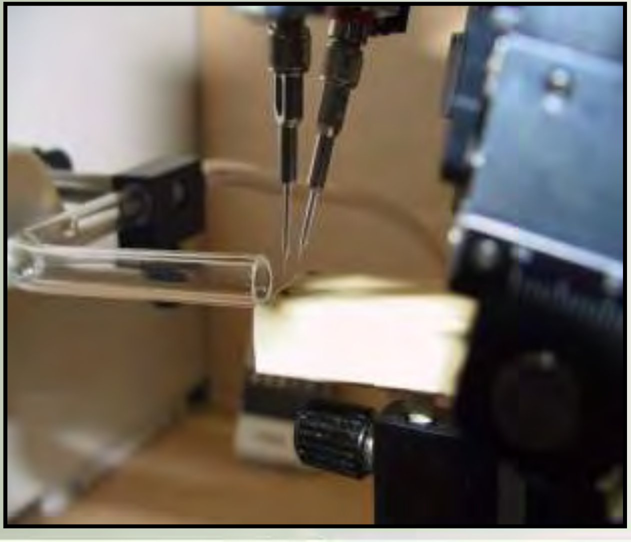
- 84,000 traps
- 1.5 mile spacing
- manuka oil lures
- 100 mile band

USDA-APHIS

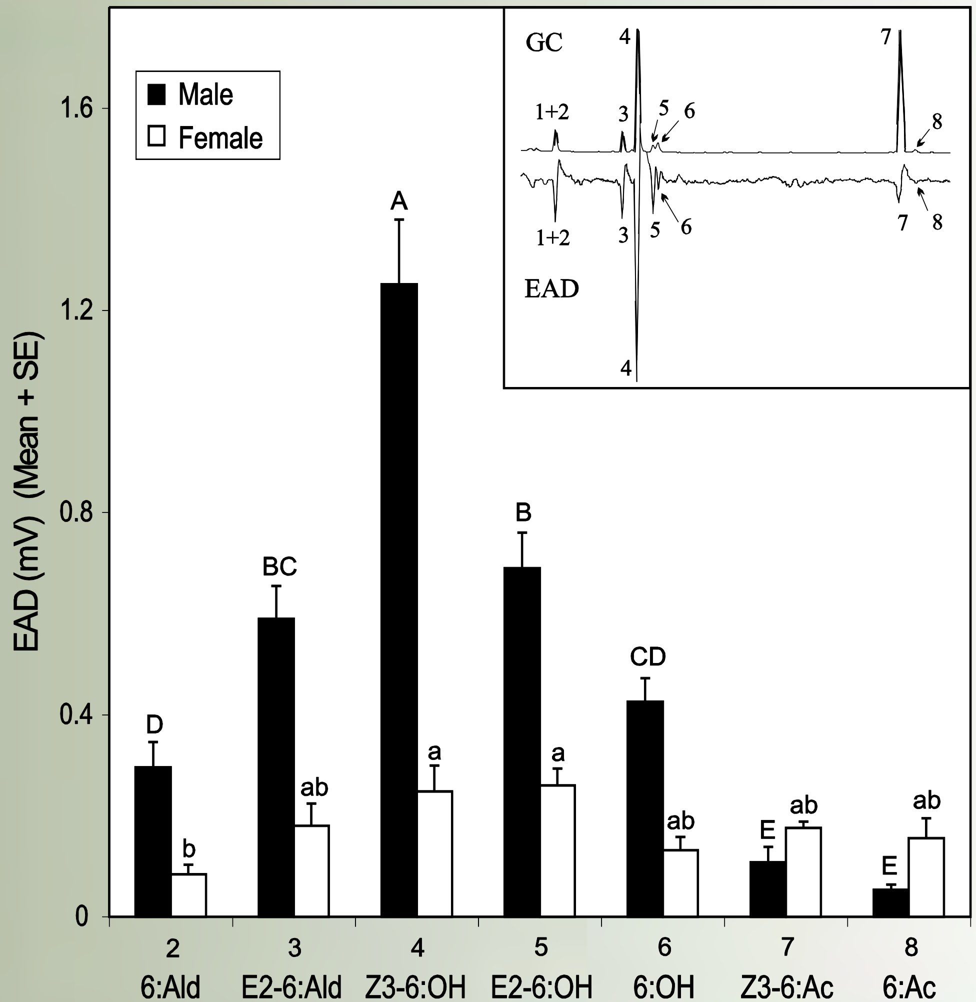
Monitoring - Detection/Delimitation Surveys



GC-EAD – G. Grant



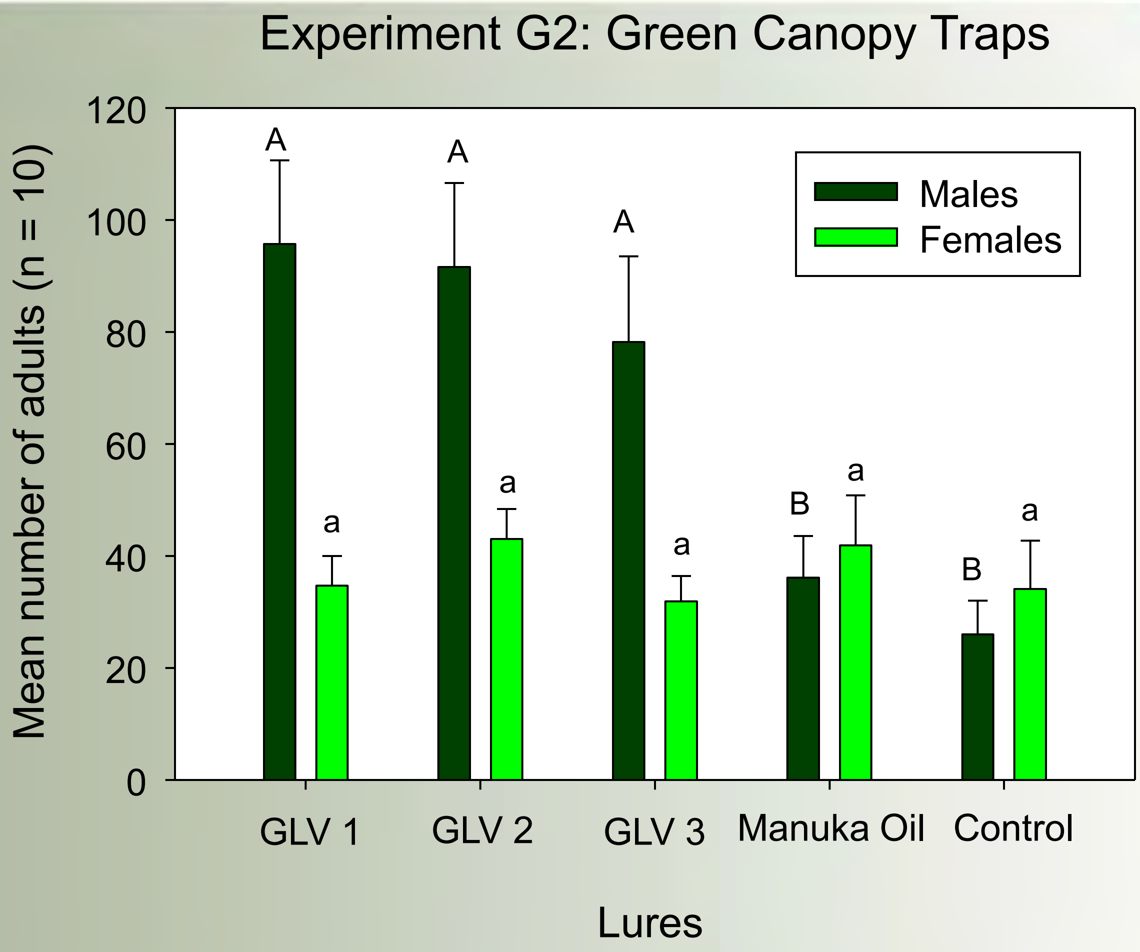
Monitoring - Detection/Delimitation Surveys



Monitoring - Detection/Delimitation Surveys

Semiochemical Testing – Grant/Ryall/Silk/Lyons

Monitoring - Detection/Delimitation Surveys



• Grant, G.G. K. L. Ryall, D.B. Lyons and M.A. 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.
• Grant, G.G., T.M. Poland, T. Ciaramitaro, D.B. Lyons and G.C. Jones. (accepted). Comparison of male and female emerald ash borer (Coleoptera: Buprestidae) responses to phoebe oil and (Z)-3-hexenol lures in light green prism traps. Journal of Economic Entomology.

Monitoring - Detection/Delimitation Surveys

Aspects of the Pheromone Chemistry of the Emerald Ash Borer, *Agrilus planipennis*
P. Silk (CFS-AFC) & K. Ryall (CFS-GLFC) et al.

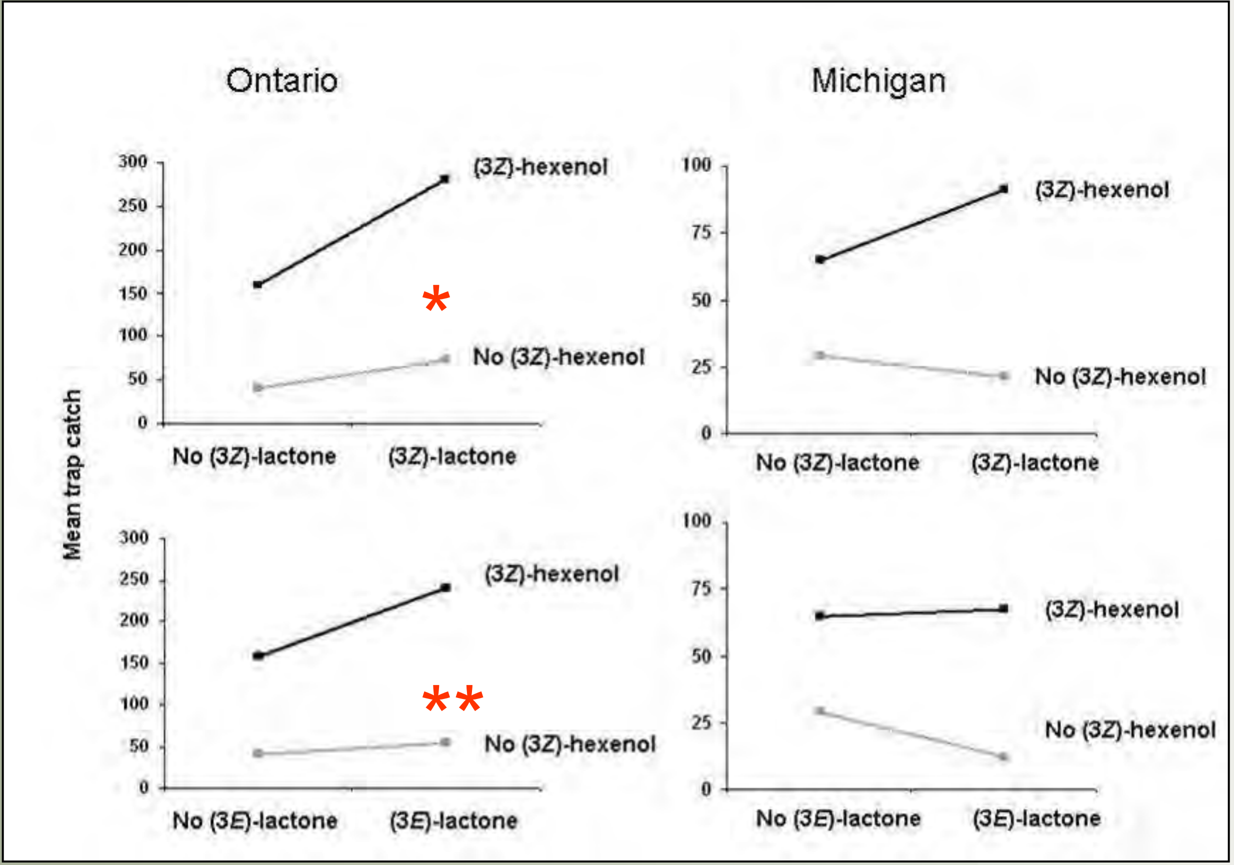
- Difficult to detect early infestation
- Trees asymptomatic for several years
- Need for effective lure to deploy with traps

- Improve understanding of the chemical ecology of EAB
- Develop chemical lure for better monitoring and detection tool for EAB
    1. Test female-produced lactone pheromone for biological activity in the field
    2. Identify contact pheromone and test for biological activity in the field

• Silk, P.J., 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.

Monitoring - Detection/Delimitation Surveys

Hypothesized host volatiles necessary to synergize attraction for EAB males, similar to brown spruce long- horned beetle (Silk et al. 2007)



* significant increase in male captures with (3Z)-lactone

** significant interaction (increase in male captures with (3E)-lactone + (3Z)-hexenol

- Silk, P.J., K. Ryall, P. Mayo, M.A. Lemay, G. Grant, D. Crook, A. Cossé, I. Fraser, J.D. Sweeney, D.B. Lyons, D. Pitt, T. Scarr and D. MaGee. (internal review). Evidence for a volatile sex pheromone in *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) that synergizes attraction to a host foliar volatile.

Monitoring - Detection/Delimitation Surveys

Sampling urban trees for EAB: developing an early-detection

K. Ryall, J. Fidgen and J. Turgeon

- Sample **two** branches per tree
  - open grown, semi-mature tree
  - 20 -50 cm DBH
  - minimum 5-8 cm dia
  - one 50-cm sample per branch
  - from any crown level or aspect
    - Mid crown, south aspect
  - carefully dissect bark

Natural Resources Canada Ressources naturelles Canada

Frontline

Forestry Research Applications

Canadian Forest Service - Sault Ste. Marie Technical Note No. 111

Detection of Emerald Ash Borer in Urban Environments Using Branch Sampling

K. L. Ryall, J. G. Fidgen, J.J. Turgeon

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Fig. 1), a non-native insect pest of Asian origin, presently infests large numbers of ash (*Fraxinus spp.*) trees in Ontario and Québec and could soon spread to other provinces.

Fig. 1. Adult emerald ash borer

One of the many requirements for effective management of EAB is early detection of infestations, when densities are still low and before signs and symptoms are obvious. *Visual surveys* rely on external signs and symptoms (e.g., exit holes, larval tunnels seen through cracks in the bark, feeding by woodpeckers or squirrels) that may not be noticeable for 2 to 3 or more years after the arrival of the population, particularly if the infestation begins in the upper part of the tree. *Sticky traps* baited with an attractant have the potential to detect EAB adults in an area before signs or symptoms become visible, but may not necessarily provide information on the infestation status of individual trees.

Fig. 2. Healthy-looking ash trees with no visible sign or symptom, but determined to be infested with EAB using branch sampling.

Ryall et al. (2010) sampled many ash trees with no obvious sign or symptom of EAB attack (Fig. 2) and showed that *branch sampling* was an effective method of detecting EAB-infested trees; indeed, 74% of the infested trees would have been discovered if the method described below had been used. The purpose of this note is to describe this basic sampling technique.

Canada

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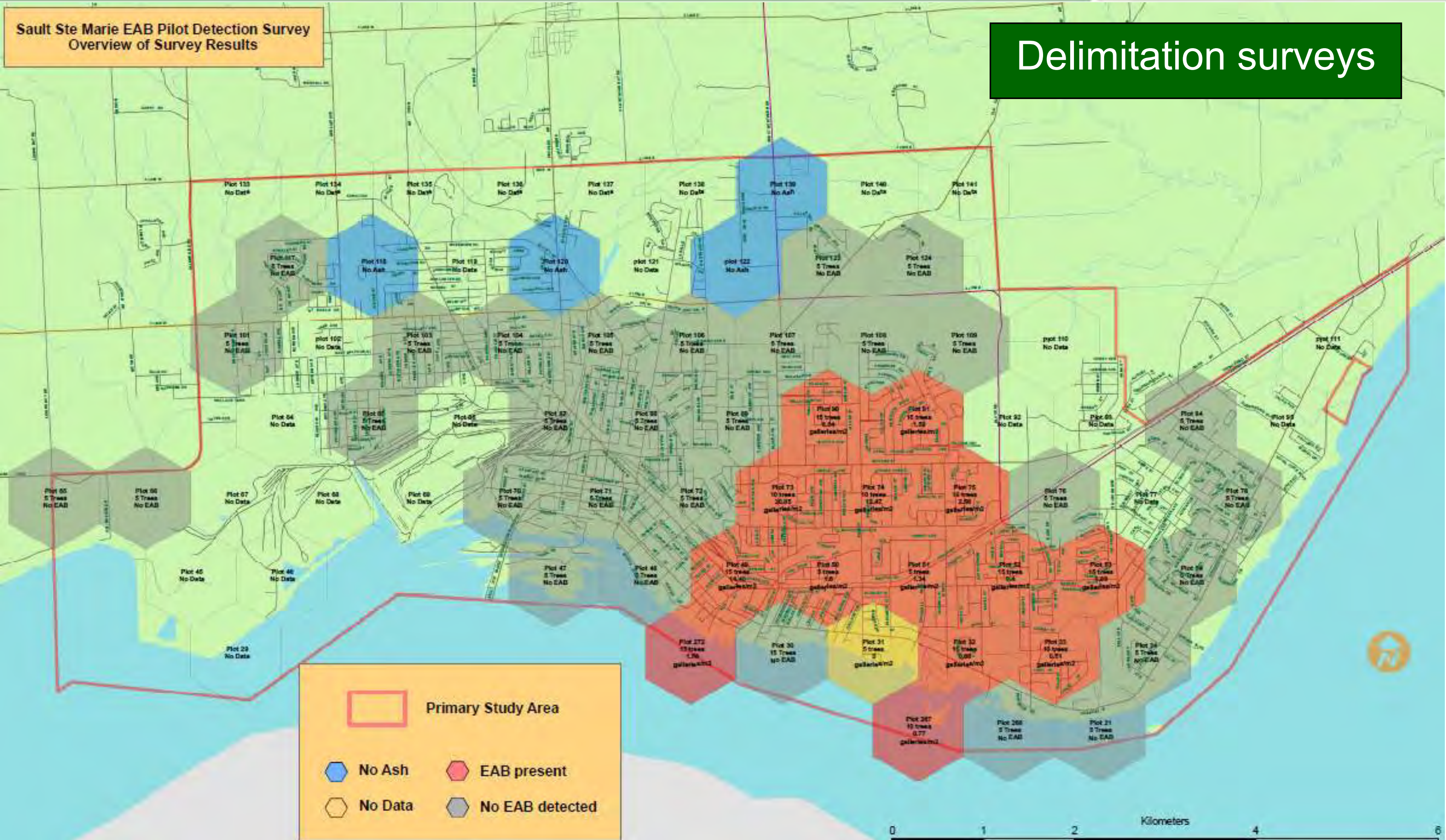
Canada

Monitoring - Detection/Delimitation Surveys

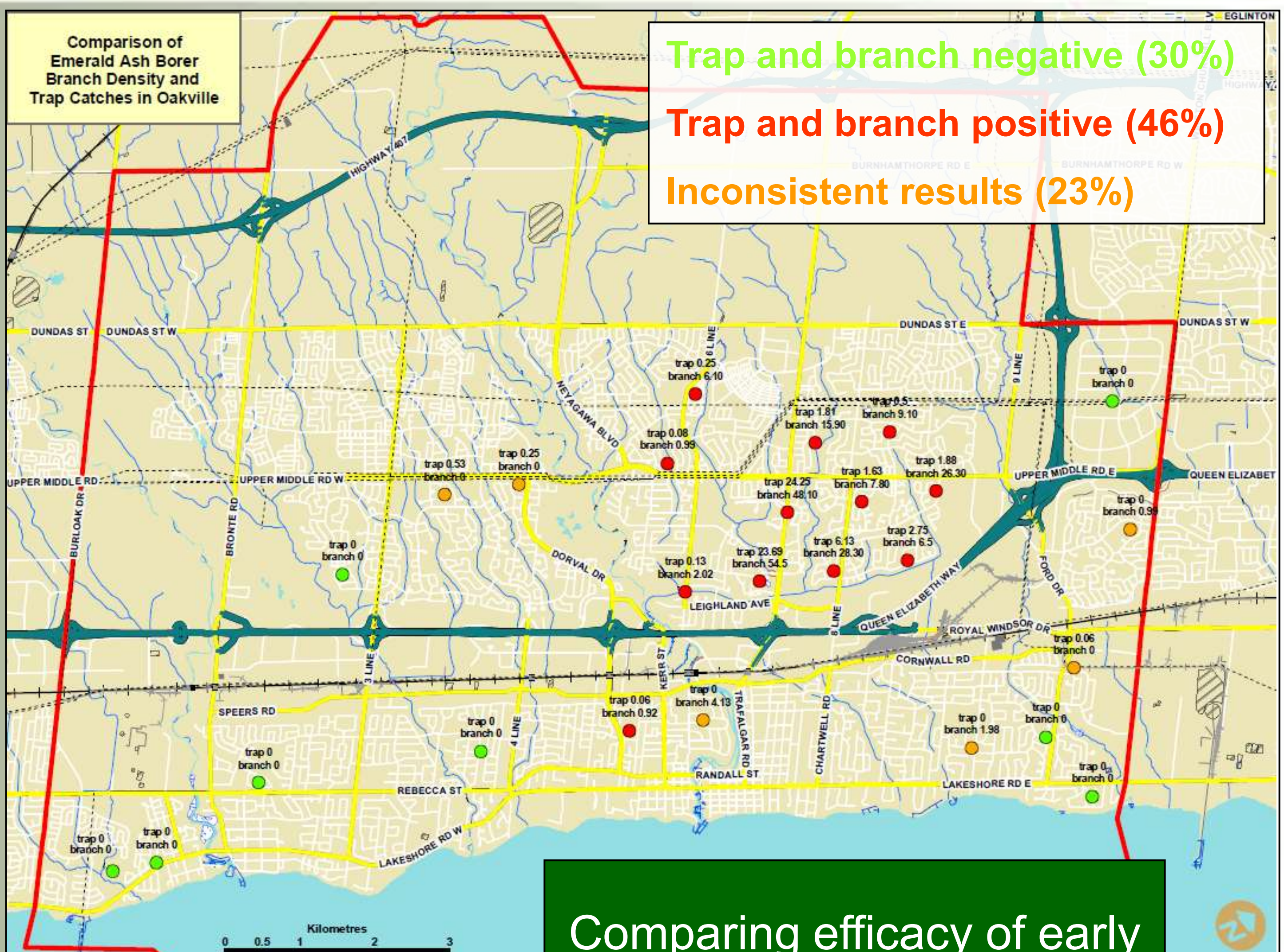
K. Ryall (CFS-GLFC) et al.

Delimitation surveys



Monitoring - Detection/Delimitation Surveys

K. Ryall (CFS-GLFC) et al.



Trap and branch negative (30%)

Trap and branch positive (46%)

Inconsistent results (23%)

Comparing efficacy of early detection methods

Chemical Control

- Chemical Controls
  - Foliage/Trunk Sprays
    - Product?
    - Efficacy?
    - Public Concern?
  - Systemic Trunk Injections
    - Confidor
    - Ecoprid/ Ecoject System
    - TreeAzin Ecoject System
    - ACECAP 97

Chemical Control

TreeAzin

- natural product insecticide
- CFS proprietary formulation
- registered in US for organic production on greenhouse and outdoor food crops
- temporary registration of Neemix 4.5 in 2000 for control of sawflies by aerial application
- low risk of impact on non-target organisms
- no bioaccumulation

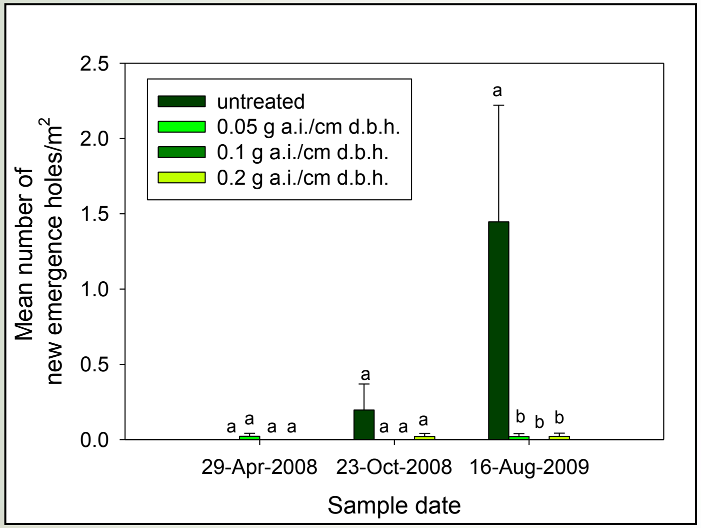
EcoJect™ System for Pest Management

- Simple to use;
- Minimum exposure risk;
- Light weight;
- Moderate pressure:
  - rapid injection times
  - reduced damage to host.

Chemical Control

Dutton, Ontario Service Centre (Hwy 401) - 2007

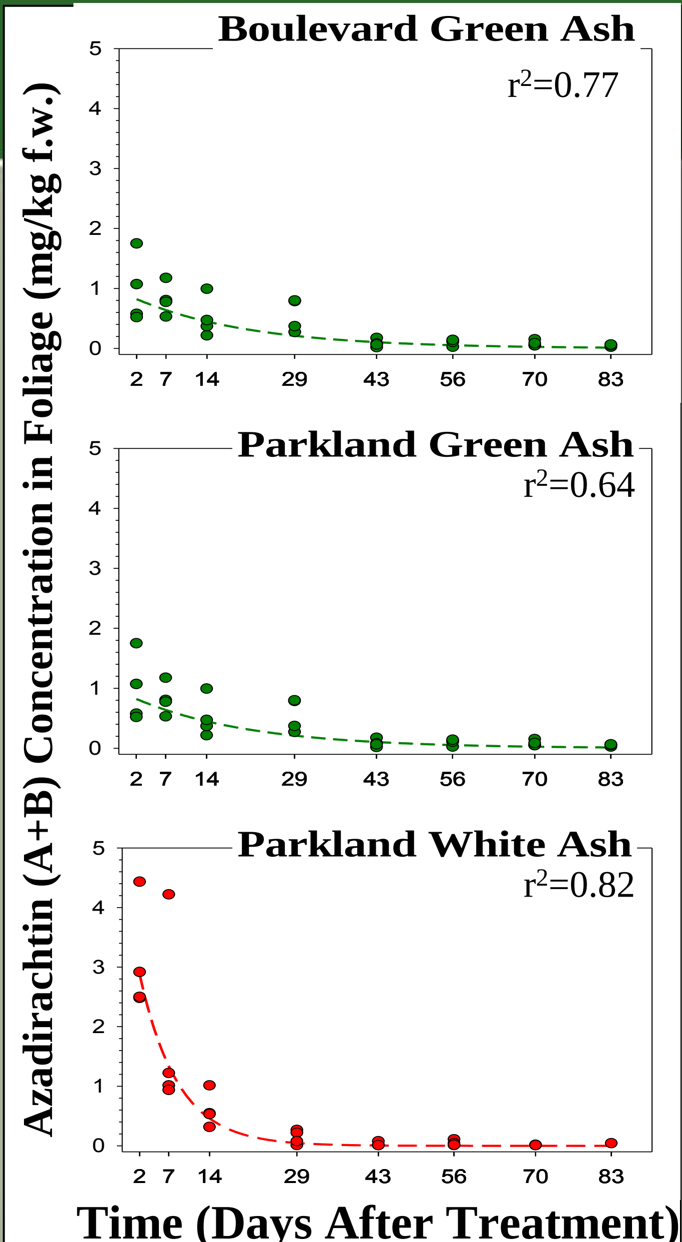
- three dosages, 0.05, 0.1 and 0.2 g azadirachtin/cm dbh



Systemic Insecticides for Control of Emerald Ash Borer

D. Thompson (CFS-GLFC) et al.

- London, Ontario
- TreeAzin™ 50 mg/mL or 5% total azadiracthins (A+B)
- Treatment rate = 0.2 g a.i./cm dbh
- Standard protocol
- 4 injection ports per tree
- 8 mL EcoJect cannisters; 8 per tree
- All trees injected June 26, 2007
- Foliage sampling throughout growing season 2, 7, 14, 29, 43, 56, 70 and 83 as well as 365 DAT



Chemical Control

Dissipation

D. Thompson (CFS-GLFC) et al.

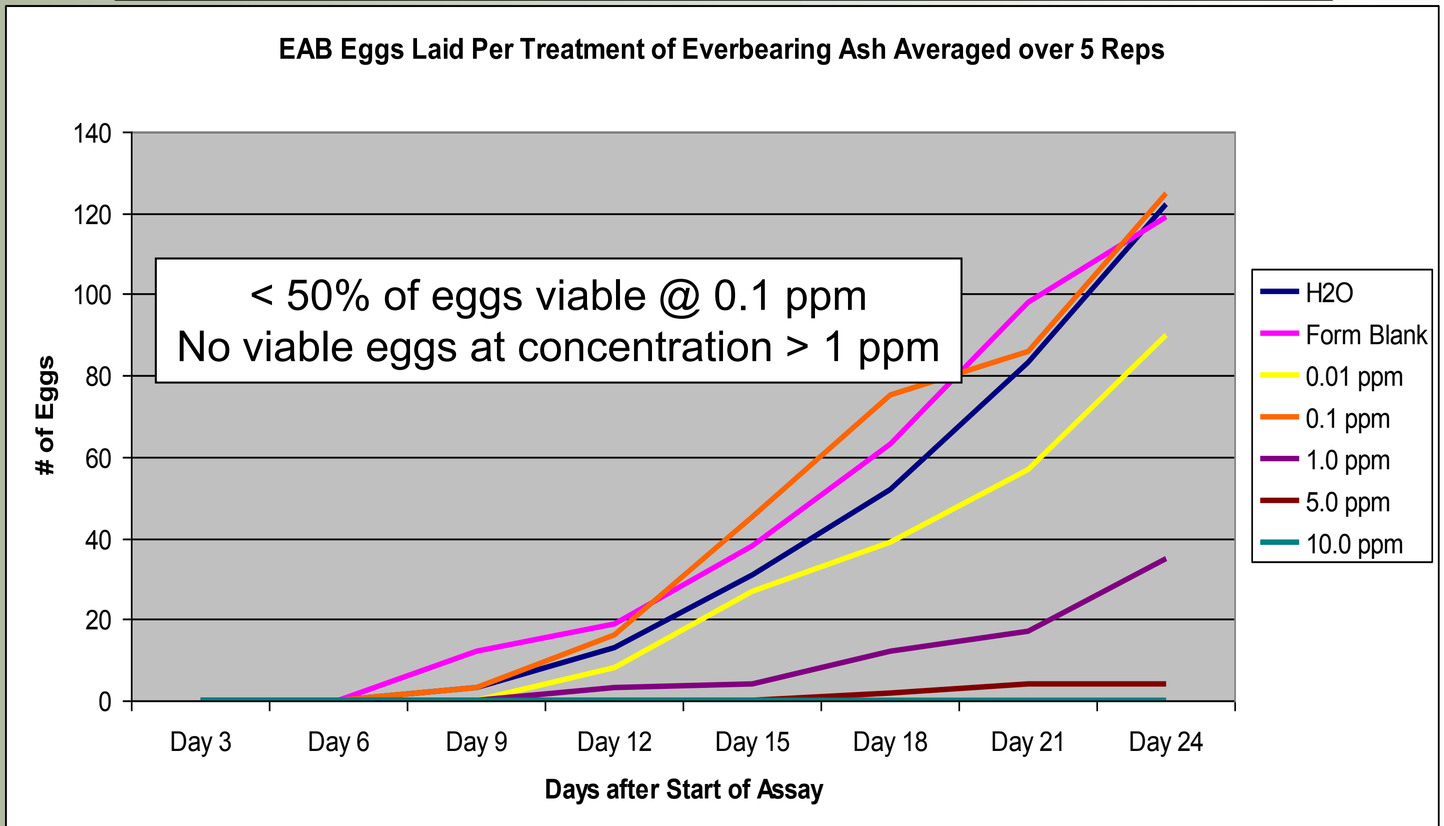
- Rapid uptake
- In all cases, foliar residues declined significantly with time ($P < 0.0001$)
- Dissipation via exponential kinetics
- DT_{50} ranged from 5.1 to 12.3 d
- DT_{90} ranged from 15.6 to 44.1 d
- At the time of leaf senescence, foliar residues levels ~ LOQ (0.01 mg/kg f.w.).
- Minimal residues at leaf fall – no non-target effects

• Grimalt Brea, S., D. Thompson, D. Chartrand, J. McFarlane, B. Helson, J. Meating and T. Scarr (submitted). Foliar residue dynamics of azadirachtins following direct stem injection into white and green ash trees for control of emerald ash borer. Pest Management Science

Chemical Control

Fecundity Effects - Dose Response

D. Thompson (CFS-GLFC) et al.

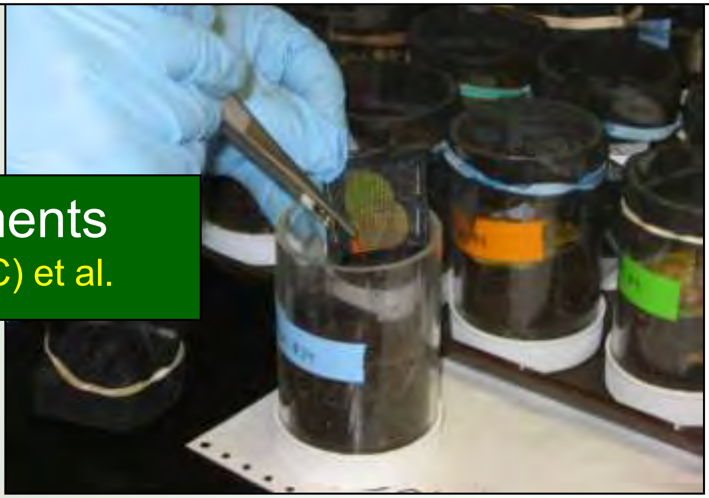


Double whammy effect – may explain two year protection

Chemical Control

- Assess risk of non-target impacts from systemic insecticides
- Imidacloprid, at realistic concentrations, likely to inhibit leaf litter breakdown processes
- Negative implications for organic matter processing, nutrient cycling
- Know these risks; use accordingly
- Azadirachtin (TreeAzin): not so….

Ecological Impacts…



Microcosm experiments
D. Kreutzweiser (CFS-GLFC) et al.

Chemical Control

22-DEC-2009 2009-4832

FOR EMERGENCY USE ONLY

For sale and use in Ontario and Québec for management of emerald ash borer in ash trees until August 31, 2010

TREEAZIN SYSTEMIC INSECTICIDE
A solution containing azadirachtin for tree injections

Commercial

Registration number: 28929 Pest Control Products Act

BioForest Technologies Inc.
105 Bruce St.
Sault Ste. Marie, ON
P6A 2X6

KEEP OUT OF THE REACH OF CHILDREN

READ THIS LABEL BEFORE USING

Net contents: 1 or 2 litre

Guarantee: Azadirachtin .... 50 grams per litre (5% by weight or volume)

POTENTIAL SKIN SENSITIZER

IRRITANT TO EYES AND SKIN.

CAUTION **POISON**

DIRECTIONS FOR USE
This formulation is to be used only with the EcoJect® System for tree injections against emerald ash borer (*Agrilus planipennis* Fairmaire) in ash (*Fraxinus*) trees.

The maximum application rate is 5 mL TreeAzin per centimeter diameter of the tree at breast height (dbh). Apply TreeAzin (undiluted) using the EcoJect® System. Apply into drilled holes every 15 cm of tree circumference at a height between 15 cm and 30 cm above ground level on the trunk of each tree. One application per tree between May 15 and August 31, 2010.

Inject 2 mL TreeAzin per cm dbh when being used as a prophylactic or early therapeutic treatment in trees up to about 30 cm dbh. In larger trees or heavily attacked trees, inject up to 5 mL per cm dbh. Seal drilled holes after treatment.

DO NOT apply by air.

DO NOT contaminate irrigation or drinking water supplies or aquatic habitats by cleaning of equipment or disposal of wastes.

PRECAUTIONS

Potential skin sensitizer

Harmful if swallowed or absorbed through skin. Do not swallow.

May irritate eyes and skin. Avoid contact to the eyes and skin or on clothing.

Practice good personal hygiene. At all times when handling TreeAzin plan events in such a way as to minimize personal exposure. Locate wash stations with an adequate supply of fresh water on work vehicles. Wash thoroughly with soap and water after handling and before eating or smoking. Bathe or take a hot shower using plenty of soap after working with TreeAzin.

Wear long-sleeved shirt and long pants, or coveralls over short sleeves and short pants, chemical-resistant gloves and goggles or a face shield during handling, loading, application, removal, clean-up and repair of product and injection equipment. Entry to treated areas by bystanders is restricted until all insecticide is injected into the trees and drilled holes are sealed.

Physical and Chemical Hazards
Flammable. Do not use or store near heat or open flame.

Product Information Label (pages 1 & 2/5)

TreeAzin received an Emergency Registration in 2008, 2009 and 2010

6. Chemical Control – ACECAP 97

2007-1058
18-JUN-2010

Page 1 of 12

COMMERCIAL

ACECAP® 97
SYSTEMIC INSECTICIDE IMPLANTS

FOR CONTROL OF CERTAIN DESTRUCTIVE PESTS OF ORNAMENTAL AND FOREST TREES

SYSTEMIC INSECT CONTROL FOR TREES

GUARANTEE:
Acephate (O,S-dimethyl acetylphosphoramidothioate)....................0.773g/implant cartridge

DANGER POISON

READ THE LABEL AND THIS BROCHURE BEFORE USING

KEEP OUT OF REACH OF CHILDREN

SEE ADDITIONAL PRECAUTIONARY STATEMENTS

REGISTRATION NO. 21568 PEST CONTROL PRODUCTS ACT

FOR:
Arysta LifeScience Corporation
8-1 Akashi-cho, Chuo-ku
Tokyo 104-6591, Japan

Arysta LifeScience North America, LLC
15401 Weston Parkway, Suite 150
Cary, North Carolina
27513

For product information call: 1-866-761-9397

Treatment reduces populations of emerald ash borer larvae and the damage they cause, but may not provide control of this pest

Page 8 of 12

SITE	PEST	RATE (a.i.)	APPLICATION INSTRUCTIONS AND LIMITATIONS
ASH	Emerald Ash Borer	773 mg/cartridge 1 cartridge per 10.16 cm	Preventative treatment should be made by applying implants early April – early June. Treatment reduces populations of emerald ash borer larvae and the damage they cause, but may not provide control of this pest.
		773 mg/cartridge 1 cartridge per 10.16 cm	Apply in early spring prior to larvae feeding.
		773 mg/cartridge 1 cartridge per 10.16 cm	Apply in early spring prior to larvae feeding.
		773 mg/cartridge 1 cartridge per 10.16 cm	Apply when wingless forms are first noticed.
			Apply when insects first appear.
		773 mg/cartridge 1 cartridge per 10.16 cm	Apply in early spring prior to larvae feeding.
ELM	Aphids (Woolly)	773 mg/cartridge 1 cartridge per 10.16 cm	Apply only when heavy production of white waxy material becomes evident.
	Elm Leaf Beetle Larvae		Apply as eggs are hatching or when larvae are first noticed.
	Elm Spanworm		Apply in early spring prior to larvae feeding.
FIR	Spruce Coneworm Western Spruce Budworm	773 mg/cartridge 1 cartridge per 10.16 cm	Apply immediately prior to or at budswell.
FLOWERING CHERRY	Eastern Tent Caterpillar	773 mg/cartridge 1 cartridge per 10.16 cm	Apply when insects first appear.
HICKORY	Elm Spanworm	773 mg/cartridge 1 cartridge per 10.16 cm	Apply in early spring prior to larvae feeding.

Chemical Control – United States

Herms, D.A., D.G. McCullough, D.R. Smitley, C. Sadof, R.C. Williamson and P. L. Nixon. 2009. Insecticide options for protecting ash trees from emerald ash borer. (available at www.emeraldashborer.info)

Insecticide Formulation	Active Ingredient	Application Method	Recommended Timing
Professional Use Products			
Merit® (75WP, 75WSP, 2F)	Imidacloprid	Soil injection or drench	Mid-fall and/or mid- to late spring
Xytect™ (2F, 75WSP)	Imidacloprid	Soil injection or drench	Mid-fall and/or mid- to late spring
IMA-jet®	Imidacloprid	Trunk injection	Early May to mid-June
Imicide®	Imidacloprid	Trunk injection	Early May to mid-June
Pointer™	Imidacloprid	Trunk injection	Early May to mid-June
TREE-äge™	Emamectin benzoate	Trunk injection	Early May to mid-June
Inject-A-Cide B®	Bidrin®	Trunk injection	Early May to mid-June
Safari™ (20 SG)	Dinotefuran	Systemic bark spray	Early May to mid-June
Astro®	Permethrin	Preventive bark and foliage cover sprays	2 applications at 4-week intervals; first spray should occur when black locust is blooming (early May in southern Ohio to early June in mid-Michigan)
Onyx™	Bifenthrin		
Tempo®	Cyfluthrin		
Sevin® SL	Carbaryl		
Homeowner Formulation			
Bayer Advanced™ Tree & Shrub Insect Control	Imidacloprid	Soil drench	Mid-fall or mid- to late spring

Biological Control

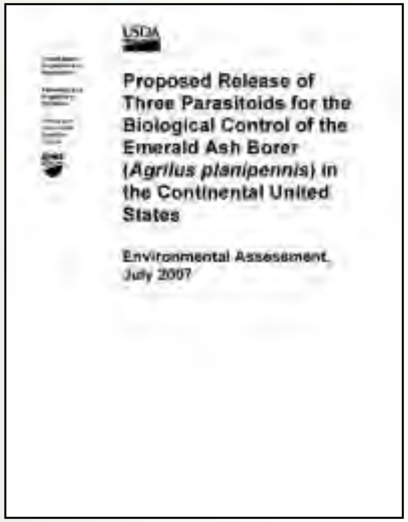
- Biological Controls
  - Augmentative Biological Control
    Local Exploration
    - Parasitoids
    - Pathogens
  - Classical Biological Control
    Foreign Exploration
    - Parasitoids
    - Pathogens

Classic Biocontrol/Foreign Exploration USDA-FS and USDA-APHIS

Spathius agrili Yang (Hymenoptera: Braconidae)

Tetrastichus planipennisi Yang (Hymenoptera: Eulophidae)

Oobius agrili Zhang and Huang (Hymenoptera: Encyrtidae)



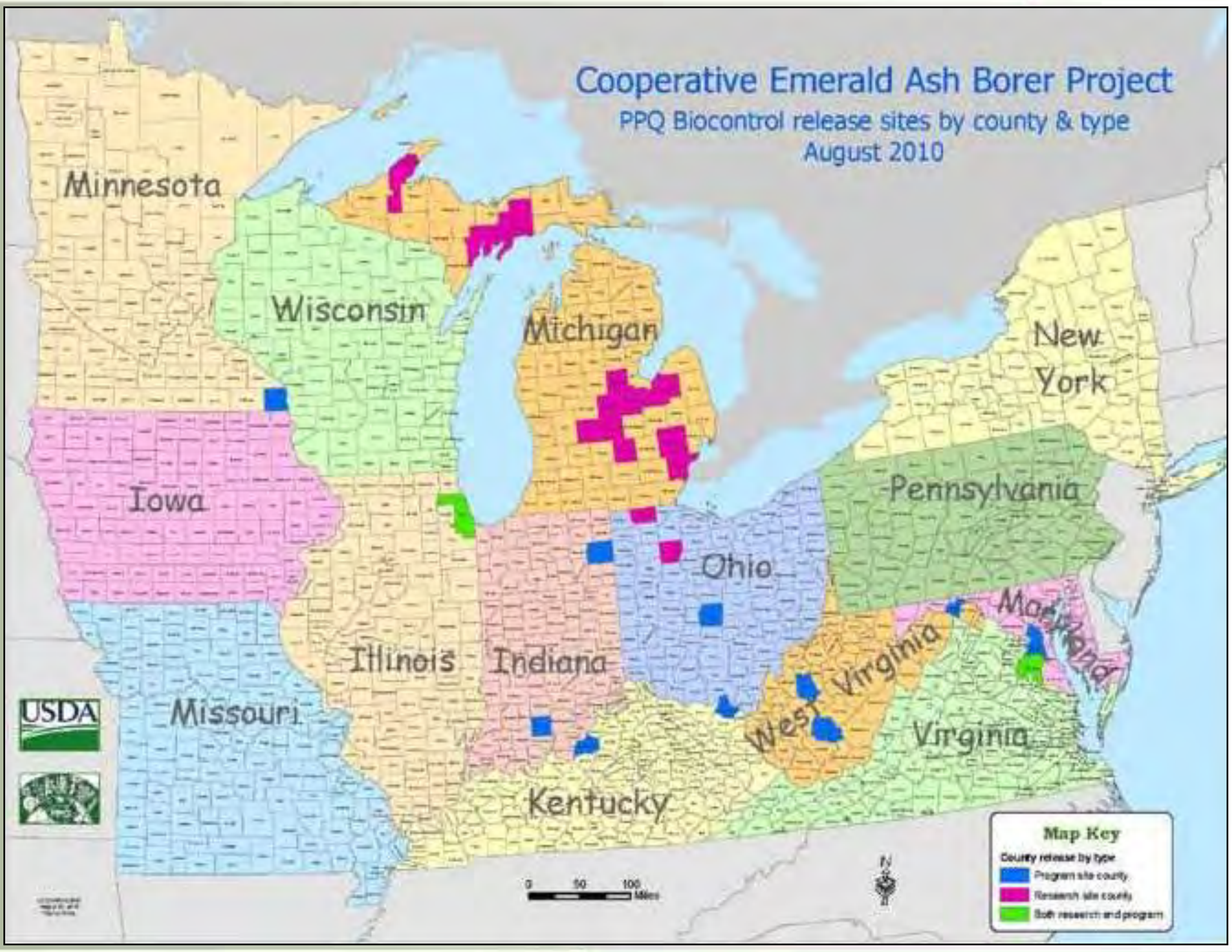
USDA

Proposed Release of Three Parasitoids for the Biological Control of the Emerald Ash Borer (*Agrilus planipennis*) in the Continental United States

Environmental Assessment, July 2007

USDA-APHIS biocontrol production laboratory - Brighton, Michigan (full time operation January 2009)

Classic Biocontrol/Foreign Exploration



Surveys for EAB Natural Enemies in Michigan

(Liu *et al.* 2003)

Larval/Pupal Parasitoids (0.7% parasitism)

Spathius simillimus Ashmead (Braconidae) (= *S. floridanus* Ashmead?)

Heterospilus sp. (Braconidae)

Phasgonophora sulcata Westwood (Chalcididae)

Balcha sp. (Eupelmidae) (= *B. indica* Mani & Kaul)) – exotic species

Eupelmus sp. (Eupelmidae)

Egg Parasitoid (>6000 eggs reared – remains only)

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.

Parasitoids of EAB in western Pennsylvania (Duan *et al.* 2009)

Species	No. of Individuals	Relative abundance (%)	Parasitism† (%)
Balcha indica (Eupelmidae)	32	82.0	2.9
Eupelmus pini (Eupelmidae)	1	2.6	0.1
Dolichomitus vitticrus (Ichneumonidae)‡	2	5.1	0.2
Orthizema sp. (Ichneumonidae)‡	1	2.6	0.1
Cubocephalus sp. (Ichneumonidae)‡	3	7.7	0.3

† 1091 EAB
‡ could not be associated with EAB life stages

- only female *B. indica* observed, associated with larval, prepupal and pupal remains
- both eupelmids successfully reared on late instar larvae, prepupae and pupae
- both reproduced via thelytokous parthenogenesis

Duan, J. J., R. W. Fuester, J. Wildonger, P. B. Taylor, S. Barth, and S. E. Spichiger. 2009. Parasitoids attacking the emerald ash borer (Coleoptera: Buprestidae) in western Pennsylvania. Florida Entomologist 92: 588-592.

Leluthia astigma (Ashmead) (Hymenoptera: Braconidae: Doryctinae) (Kula *et al.* 2010)

- Delaware Co., Ohio
- 2567 EAB larvae/prepupae were found – 45 parasitoid cocoons, 10 parasitoid larvae – 2.1% parasitism
- F_1 larvae observed feeding externally on non-feeding EAB larvae – idiobiont ectoparasitoid literature records and/or specimens examined from **Canada**; QC: **United States**; AZ, CA, IN, IA, KS, MD, NY, OH, NC, OK, PA, TX, UT, VA, WV, WY: Mexico; JA, SO.

Kula, R. R., K. S. Knight, J. Rebbeck, L. S. Bauer, D. L. Cappaert, and K. J. K. Gandhi. 2010. *Leluthia astigma* (Ashmead) (Hymenoptera: Braconidae: Doryctinae) as a parasitoid of *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae: Agrilinae), with an assessment of host associations for Nearctic species of *Leluthia* Cameron. Proceedings of the Entomological Society of Washington 112: 246-257.

Augmentative Biological Control/Local Exploration

Atanycolus cappaerti Marsh and Strazanac (Hymenoptera: Braconidae)

- parasitism rates of 9 to 71%
- bivoltine
- adults long lived (mean female = 31.7 d)
- apparent synchrony problem: at least the first generation of wasps will die before new generation are large enough for parasitization (i.e., they're stuck with the EAB in 2nd of 2-year life cycle)
- also develop on *A. liragus* and *A. bilineatus*

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.

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.

Augmentative Biological Control/Local Exploration

Methods

red oak (*Quercus rubra*) infested with *Agrilus bilineatus*

white birch (*Betula papyrifera*) infested with *Agrilus anxius*

trembling aspen (*Populus tremuloides*) infested with *Agrilus liragus*

green ash (*Fraxinus pennsylvanica*) infested with *Agrilus planipennis*

Species of Hymenopterous parasitoids reared form bolts from four tree species infested with four species of *Agrilus*, the relative abundance of each species and its potential as an *Agrilus* parasitoid.

	Host Tree				
Species	***Fraxinus***	***Betula***	***Populus***	***Quercus***	***Agrilus* host**
Braconidae					
Aliolus stictopleurus Martin	U				no
Atanycolus disputabilis (Cresson)		C			unknown
Atanycolus hicoriae Shenefelt	VC	VC			yes
Atanycolus longicauda Shenefelt	C				unknown
Atanycolus cappaerti Marsh and Strazanac	C	C			yes
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

Augmentative Biological Control/Local Exploration

Phasgonophora sulcata Westwood
(Hymenoptera: Chalcididae)

Balcha indica (Mani & Kaul)
(Hymenoptera: Eupelmidae)

<u>Rearing (Essex Co. site 1 - 2006)</u>

54 *P. sulcata*
9 B. indica
6 Atanycolus spp.
146 *A. planipennis*
Parasitism = 32.1%

<u>Rearing (Essex Co. site 2 - 2006)</u>

8 *P. sulcata*
0 *B. indica*
3 *Atanycolus* spp.
648 *A. planipennis*
Parasitism = 1.2%

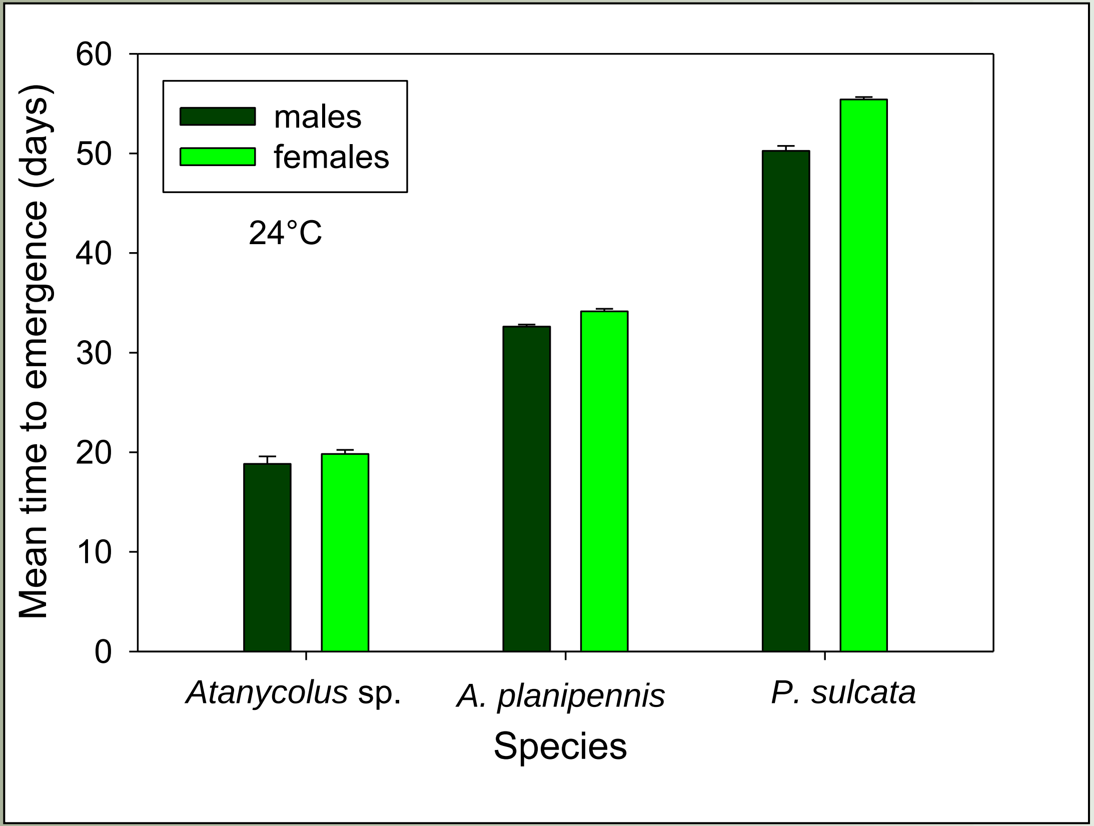
<u>Sticky Band Captures (Essex Co. site 1 - 2007)</u>

407 *P. sulcata*
600 *A. planipennis*
Parasitism = 40.7%

Augmentative Biological Control/Local Exploration

Atanycolus spp.

Emergence Data McKeough Dam - 2010



Sex Ratio

Species	n	Female (%)
Atanycolus sp.	55	69.1*
A. planipennis	645	48.1
P. sulcata	355	73.5*

* significantly different from 1:1 (chi-square)

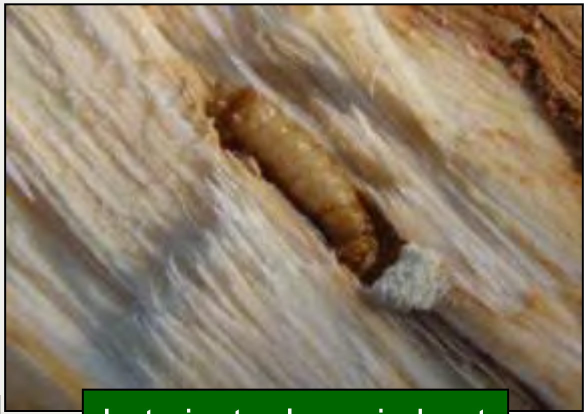
Parasitism Rates

Species	Parasitism (%)
Atanycolus sp.	5.2
P. sulcata	33.6
Overall	38.9

Augmentative Biological Control/Local Exploration

Eggs dissected from female

Early instar larva dissected from host



Late instar larva in host

Pupa dissected from host

- solitary
- endoparasitoid
- koinobiont?

Adult visible within host

Life Stages of *Phasgonophora sulcata*

Conclusions

- many species of native parasitoids have made the host switch from native *Agrilus* species to *A. planipennis*
- potential biological control agents are Braconidae and Chalcidoidea
- *P. sulcata* is capable of building to high population densities on *A. planipennis* but only in declining populations
- *P. sulcata* is synchronized with larval stages of *A. planipennis*
- species is solitary koinobiont endoparasitoid
- *P. sulcata* has bred in laboratory but effective rearing techniques need to be developed
- mating conditions for *P. sulcata* unknown

Biological Control – Native Entomopathogens
George Kyei-Poku

Biological Control – Entomopathogens
George Kyei-Poku

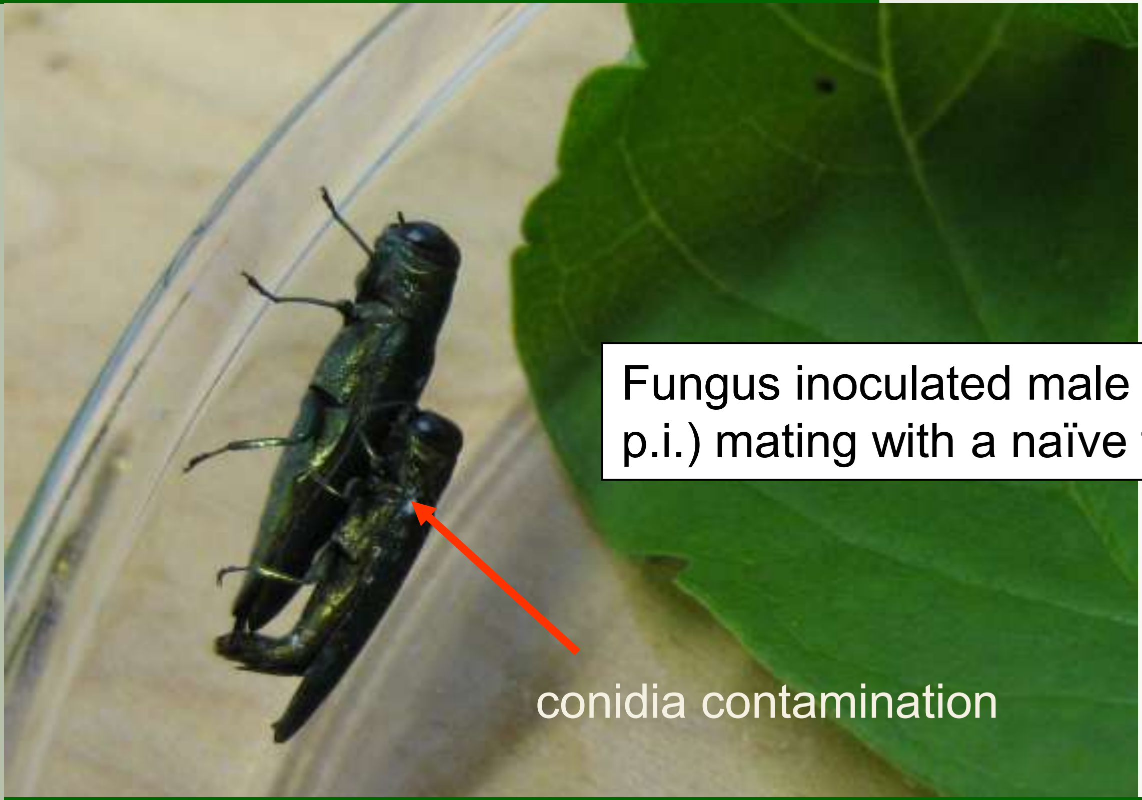

Mycosed larva


Fungus growing on frass scooped from galleries

Biological Control – Entomopathogens
George Kyei-Poku

Metarhizium anisopliae growing on EAB

Virulence of *Beauveria* spp. against EAB



Fungus inoculated male (0-1 days p.i.) mating with a naïve female

Horizontal transmission studies of *Beauveria* spp. against EAB

Biological Control – Entomopathogens
Development of an Autocontamination Trap

Robert Lavallée, George Kyei-Poku and Kees van Frankenhuyzen

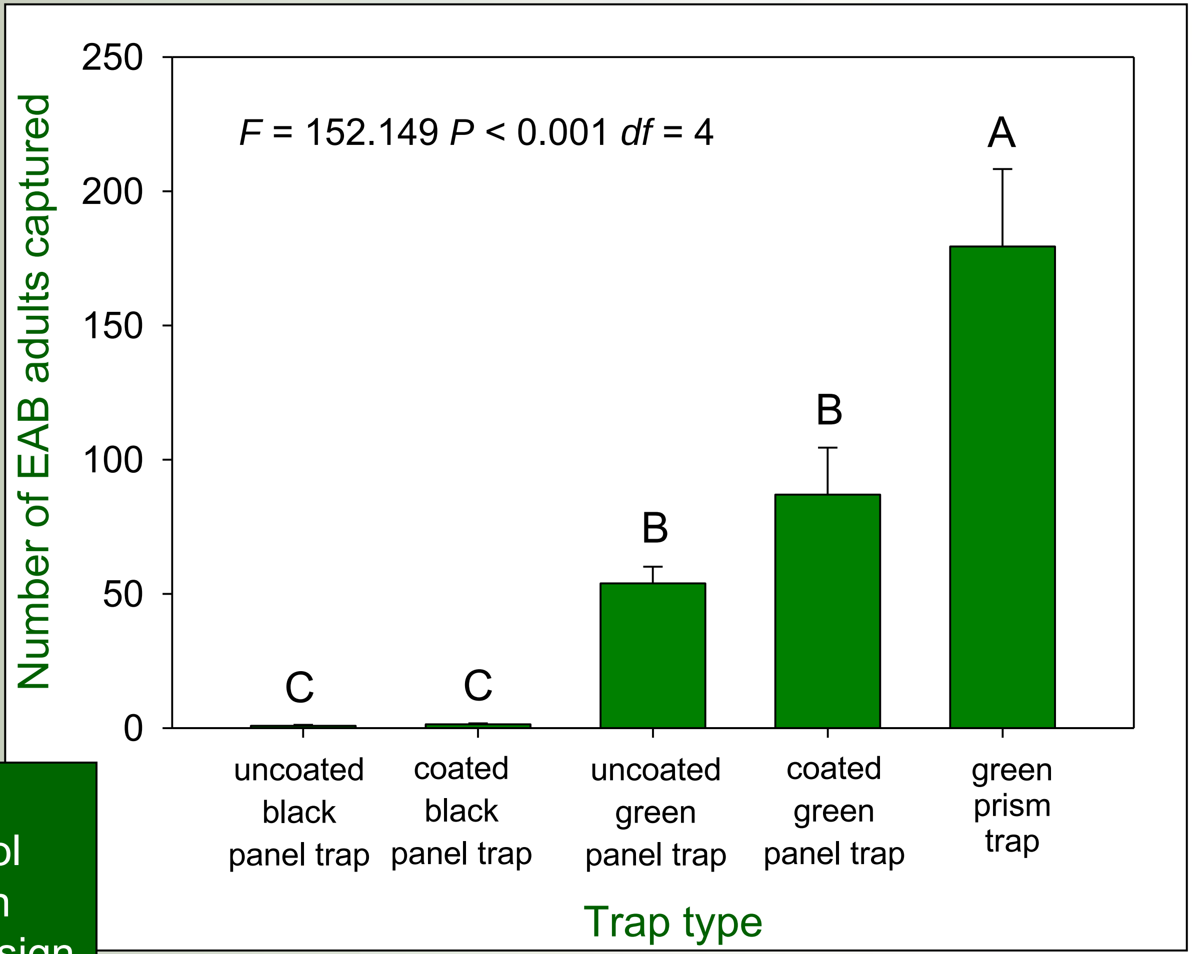

Black Intercept™
Panel Trap


Green Intercept
Panel Trap


Green Prism
Trap

uncoated or coated with Insect-a-Slip Barrier
(Fluon – fluoropolymer resin)

Biological Control – Entomopathogens
Development of an Autocontamination Trap

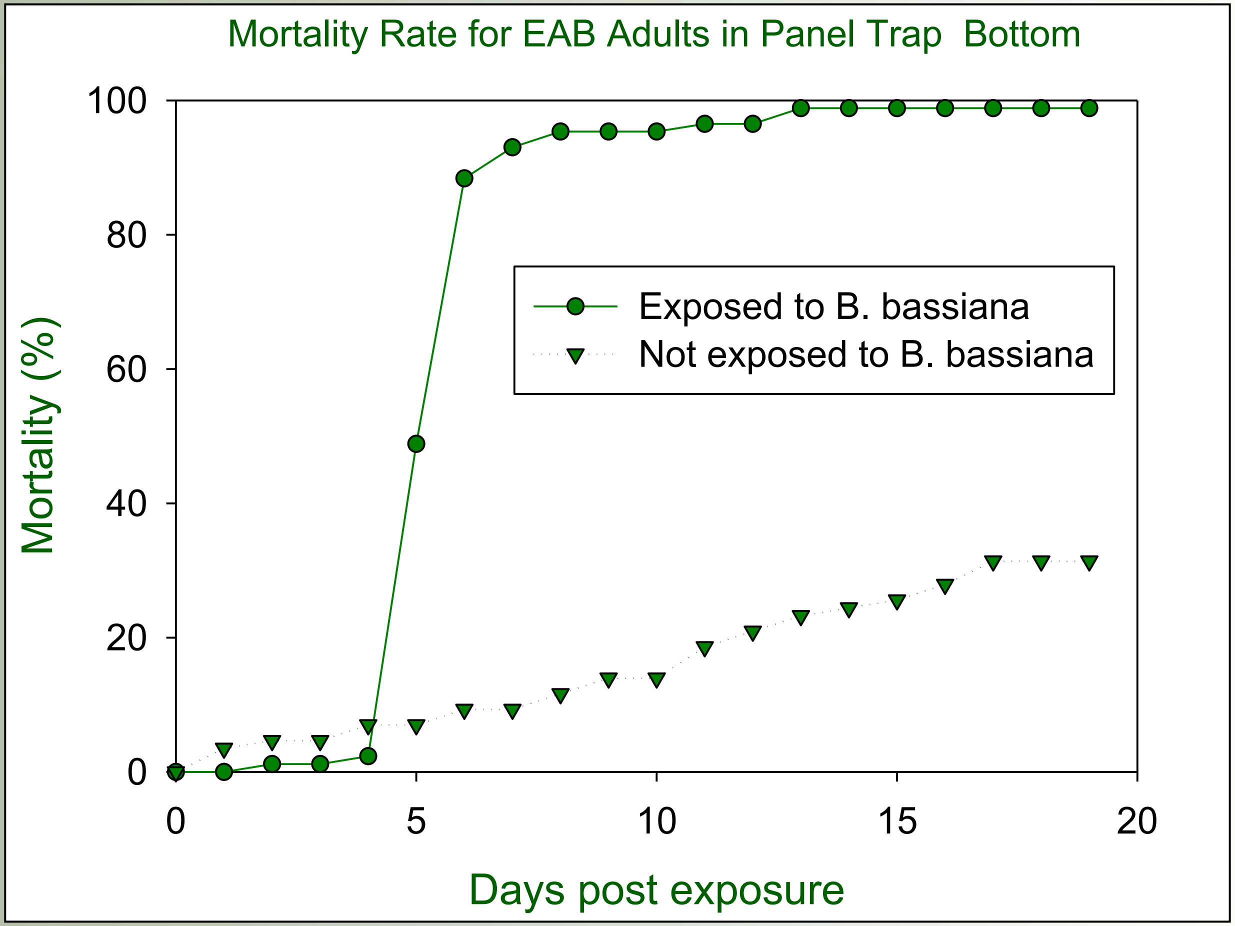


- no fungus – salt solution
- all baited with Z-(3)-hexenol
- young green ash plantation
- complete random block design
- n = 10

Biological Control – Entomopathogens
Development of an Autocontamination Trap

Beauveria bassiana
(strain CFL-INRS)

Biological Control – Entomopathogens
Development of an Autocontamination Trap




The End
Questions?