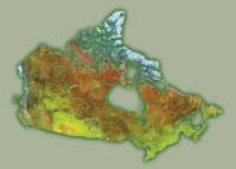
Emerald ash borer detection and monitoring in Canada

Krista Ryall and Peter Silk

- Natural Resources Canada
- Canadian Forest Service, Sault Ste. Marie, ON & Fredericton NB
- OECD & DEFRA CONFERENCE ON EAB & BBB, VIENNA, AUSTRIA, OCT 1-4, 2018.



Acknowledgements

- OECD & DEFRA
- Hugh Evans, Mariella Marzano and Gernot Hoch; conference organizers
- The beautiful city of VIENNA!
- The Silk Group: Lucas Roscoe, Peter Mayo, Gaetan LeClair, Dave MaGee (UNB), Deepa Abeysekera, Glen Forbes, Rosanna Lamb, Matt Brophy, Martin Williams
- Best wishes to Krista Ryall !
- The Ryall Group: Gene Jones, Jeff Fidgen

EAB…a green calamity!

- Originally from Asia
- Detected in North America in 2002
- Established since early 1990s
- North American *Fraxinus* spp. extremely vulnerable
- Causing widespread mortality, killing tens of millions of ash trees
- Estimated $3-10 billion US for tree removal and replacement

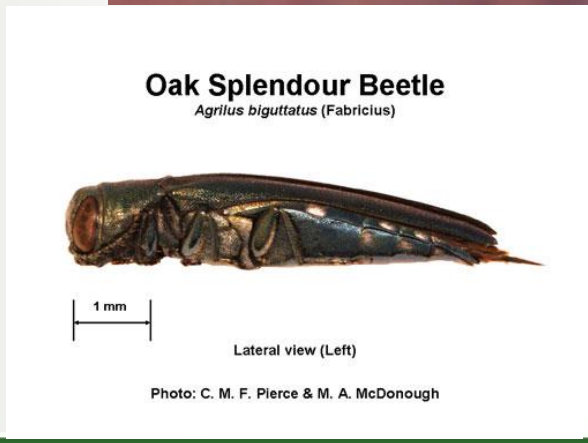
- The genus *Agrilus* contains nearly 3000 species
- Some *Agrilus* are invasive and increasingly problematic in North America
- Little known about chemical ecology of this group

Ash mortality caused by EAB

Other *Agrilus*

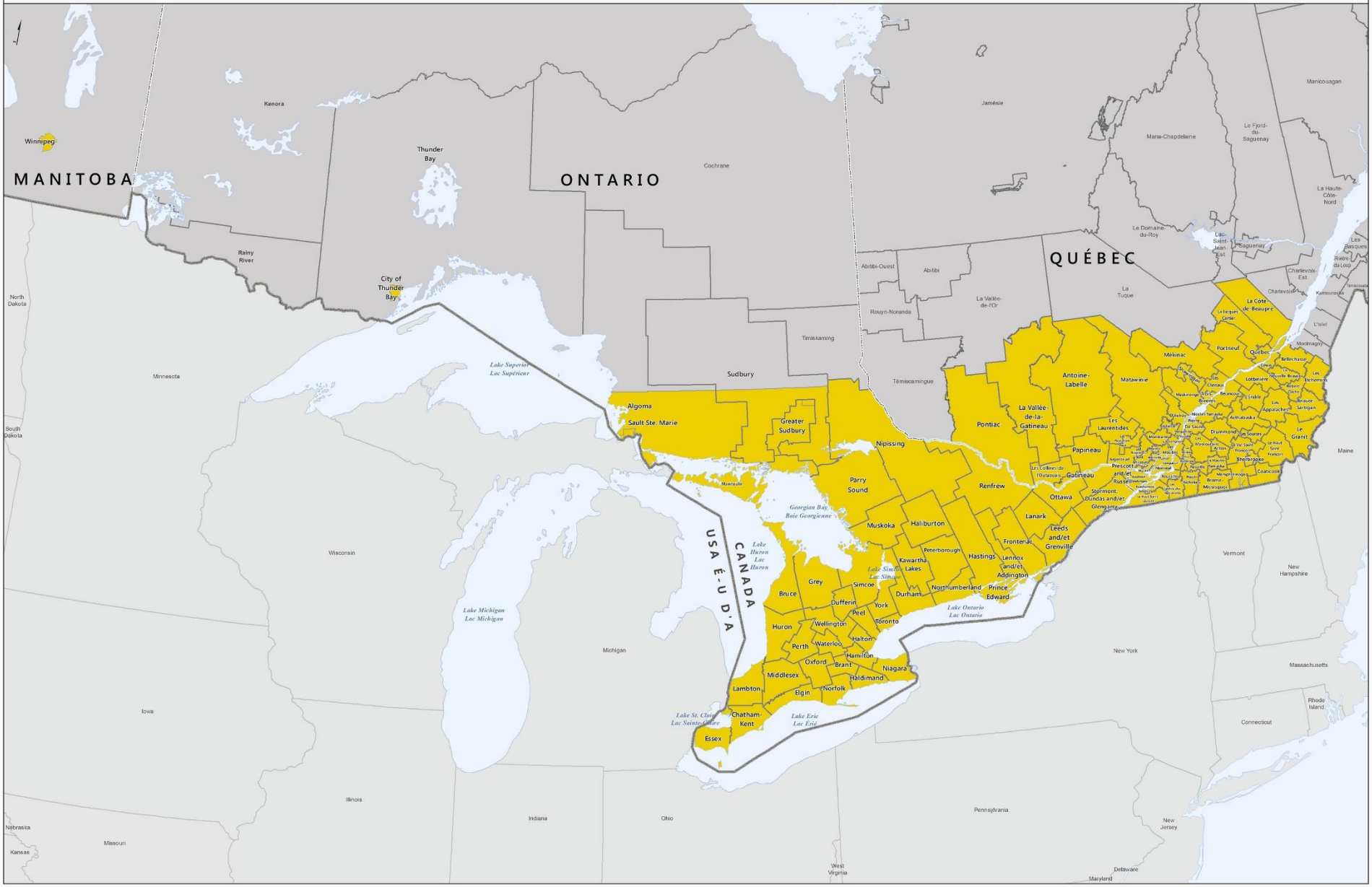
- Already introduced in Canada:
  - Emerald ash borer, *A. planipennis*
  - Goldspotted oak beetle, *A. coxalis*
  - European oak borer, *A. sulcicollis*

- Concern over additional species being introduced from Europe:
  - oak splendor beetle, *A. biguttatus*
  - beech splendour beetle, *A. viridis*



EMERALD ASH BORER REGULATED AREAS OF CANADA

LIEUX RÉGLEMENTÉS POUR L'AGRILE DU FRÊNE AU CANADA



0 25 50 100 Km

0 25 50 100 Mi

Map Projection Canada Albers Equal Area Conic | Projection cartographique conique équivalente d'Albers Canada

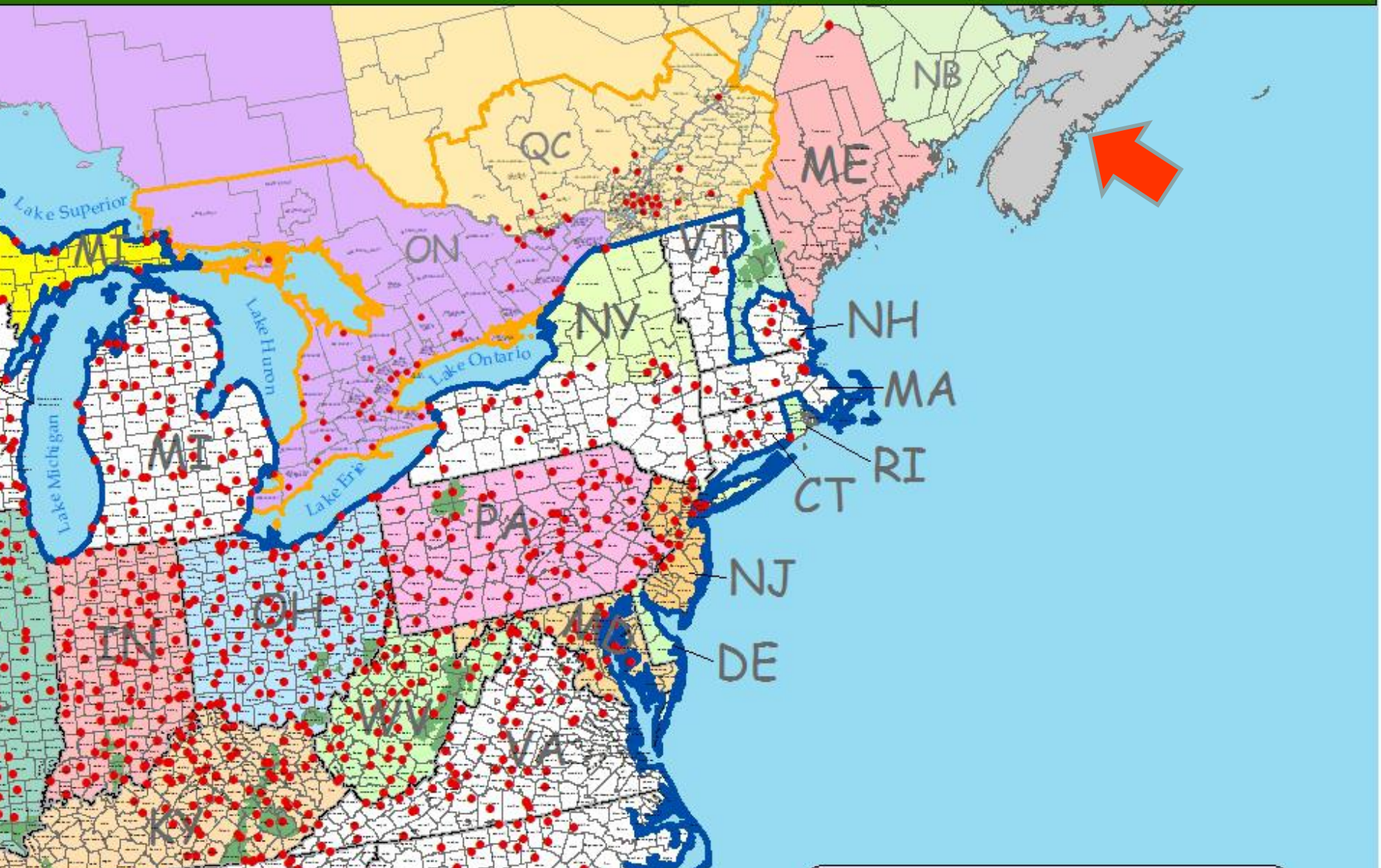
Areas regulated | Lieux réglementés

Yr/An : 2017
Mo/M : 12

sh Borer Project

in North America

August 1, 2018



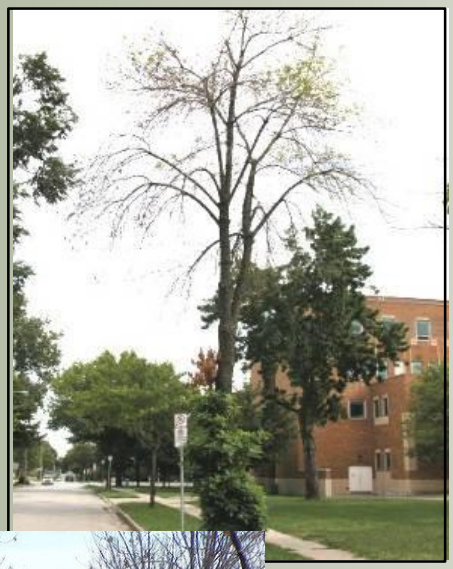
Elements of an Emerald Ash Borer Management Plan

Action?

No

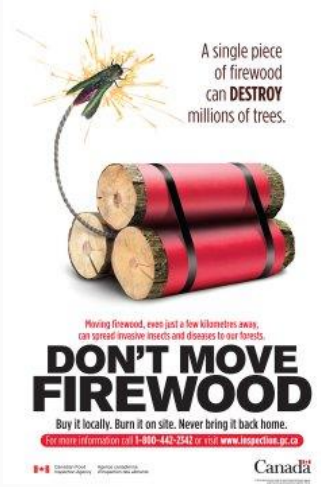
Yes

DEAD ASH TREES



Emerald Ash Borer
Dynamic Management Plan

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



eg. Treeazin®

Visit EAB & BBB before they visit you!!!

Early detection / monitoring

- Difficult to detect new infestations
- Trees often heavily infested before visual signs are apparent
- Need for effective sampling tools & methods
- Early detection approaches in Canada:

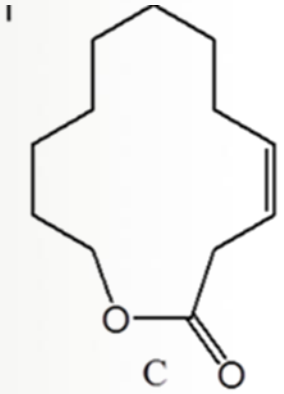
  1) Trapping….semiochemistry (pheromones, host volatiles; Silk & Ryall 2015)

  2) Sampling branches from asymptomatic trees (Ryall et al., 2011; Turgeon et al. 2015)

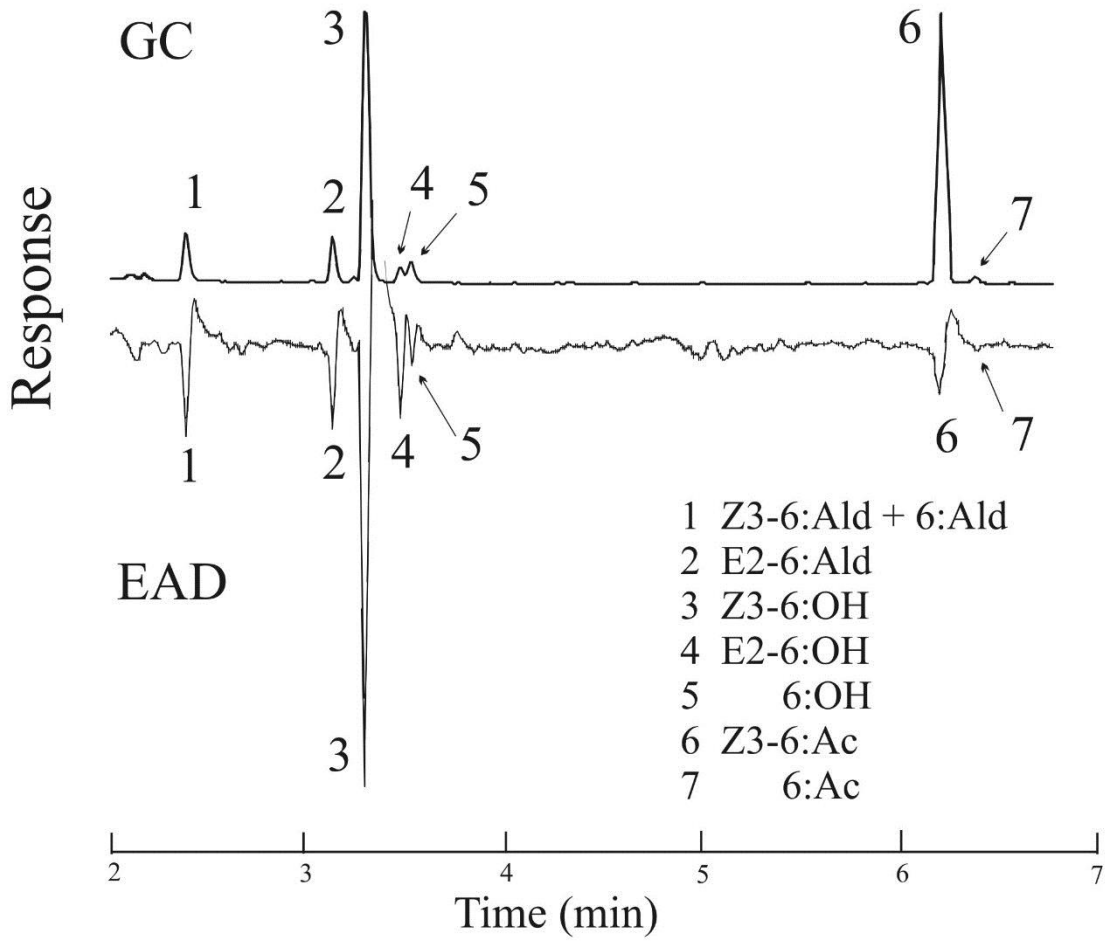
Research into *Agrilus* semiochemistry

- Host volatiles
  - Two classes of host volatiles often increase trap captures as compared to unbaited control
    - Green leaf volatiles ((3*Z*)-hexenol)
    - Bark sesquiterpenes (Manuka/Phoebe/cubeb oil)
    - (3*Z*)-hexenol, in particular, increases captures of EAB

- First evidence of buprestid pheromone
- (3Z)-dodecen-12-olide [(3Z)-lactone]
- - (3Z)-lactone highly EAD- active
  - (3*Z*)-lactone increases captures of male EAB

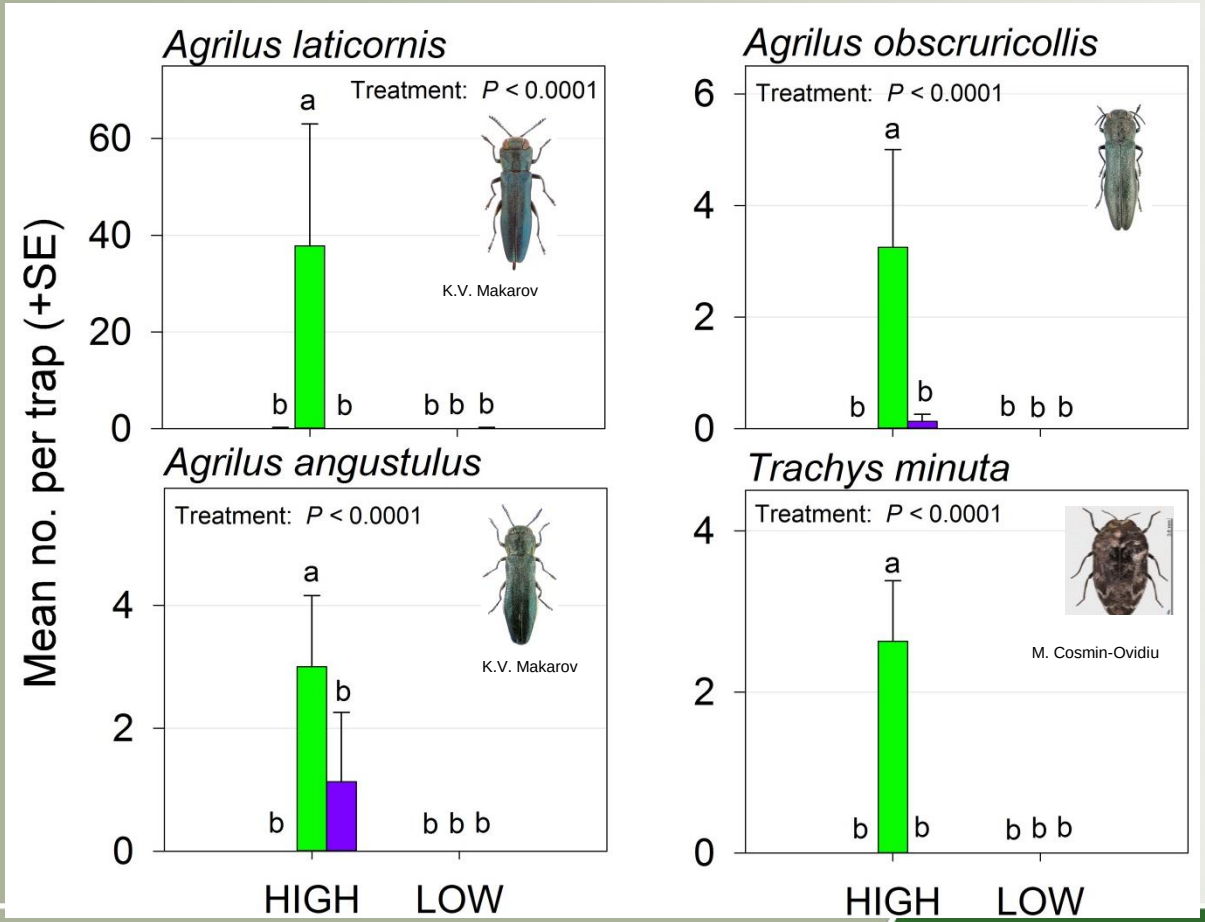


GC-EAD Response from Male EAB Antenna to Aeration Extract of White Ash Foliage



TRAP COLOR??

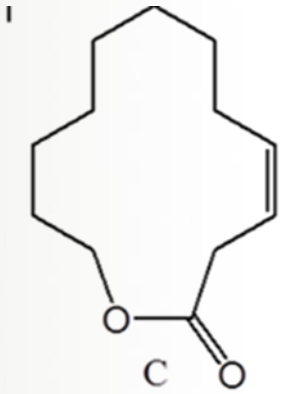
Green traps placed in the upper canopy are better at detecting some buprestid spp.



Sweeney et al. 2015 results, unpublished

Volatile EAB pheromone?

- (3Z)-dodecen-12-olide, ‘(3Z)-lactone’, detected from EAB (Bartelt et al. 2007)
- EAB males could find females without use of sight, but **not** without antennae (Pureswaran & Poland 2009)
- Numerous studies showing synergy between **host volatiles** and pheromones in cerambycids (Silk et al. 2007; Sweeney et al. 2010)
- Host volatiles identified as attractive to EAB include green leaf volatiles and bark sesquiterpenes



Biological activity of (3Z)-lactone

- Conducted a series of trapping experiments to test interactions between lactone and host volatiles
- Adding (3Z)-lactone to green sticky prism traps baited with (3Z)-hexenol (host volatile) consistently increases trap captures
- Highest captures when traps placed in south aspect up in tree canopy
- (3Z)-lactone-baited traps had highest trap captures and detection rates at very low insect densities

Evidence for a Volatile Pheromone in *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) That Increases Attraction to a Host Foliar Volatile

PETER J. SILK,[1,2] KRISTA RYALL,[3] PETER MAYO,[1] MATTHEW A. LEMAY,[1] GARY GRANT,[3,4] DAMON CROOK,[5] ALLARD COSSÉ,[6] IVICH FRASER,[7] JON D. SWEENEY,[1] D. BARRY LYONS,[3] DOUG PITT,[8] TAYLOR SCARR,[9] AND DAVID MAGEE[10]

Environ. Entomol. 40(4): 904–916 (2011); DOI: 10.1603/EN11029

Attraction of *Agrilus planipennis* (Coleoptera: Buprestidae) to a Volatile Pheromone: Effects of Release Rate, Host Volatile, and Trap Placement

KRISTA L. RYALL,[1] PETER, J. SILK,[2] PETER MAYO,[2] DAMON CROOK,[3] ASHOT KHRIMIAN,[4] ALLARD A. COSSÉ,[5] JON SWEENEY,[2] AND TAYLOR SCARR[6]

Environ. Entomol. 41(3): 648–656 (2012); DOI: http://dx.doi.org/10.1603/EN11312

Effects of Pheromone Release Rate and Trap Placement on Trapping of *Agrilus planipennis* (Coleoptera: Buprestidae) in Canada

KRISTA L. RYALL,[1,2] PETER J. SILK,[3] JEFF FIDGEN,[1] PETER MAYO,[3] ROBERT LAVALLÉE,[4] CLAUDE GUERTIN,[5] AND TAYLOR SCARR[6]

Environ. Entomol. 44(3): 734–745 (2015); DOI: 10.1093/ee/nvv048

Entomologia Experimentalis et Applicata

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Efficacy of the pheromone (3*Z*)-lactone and the host kairomone (3*Z*)-hexenol at detecting early infestation of the emerald ash borer, *Agrilus planipennis*

Krista L. Ryall[1]*, Jeffrey G. Fidgen[1], Peter J. Silk[2] & Taylor A. Scarr[3]

2011: LOW DENSITY SITES

(3Z)-lactone increases both detection rate and trap captures

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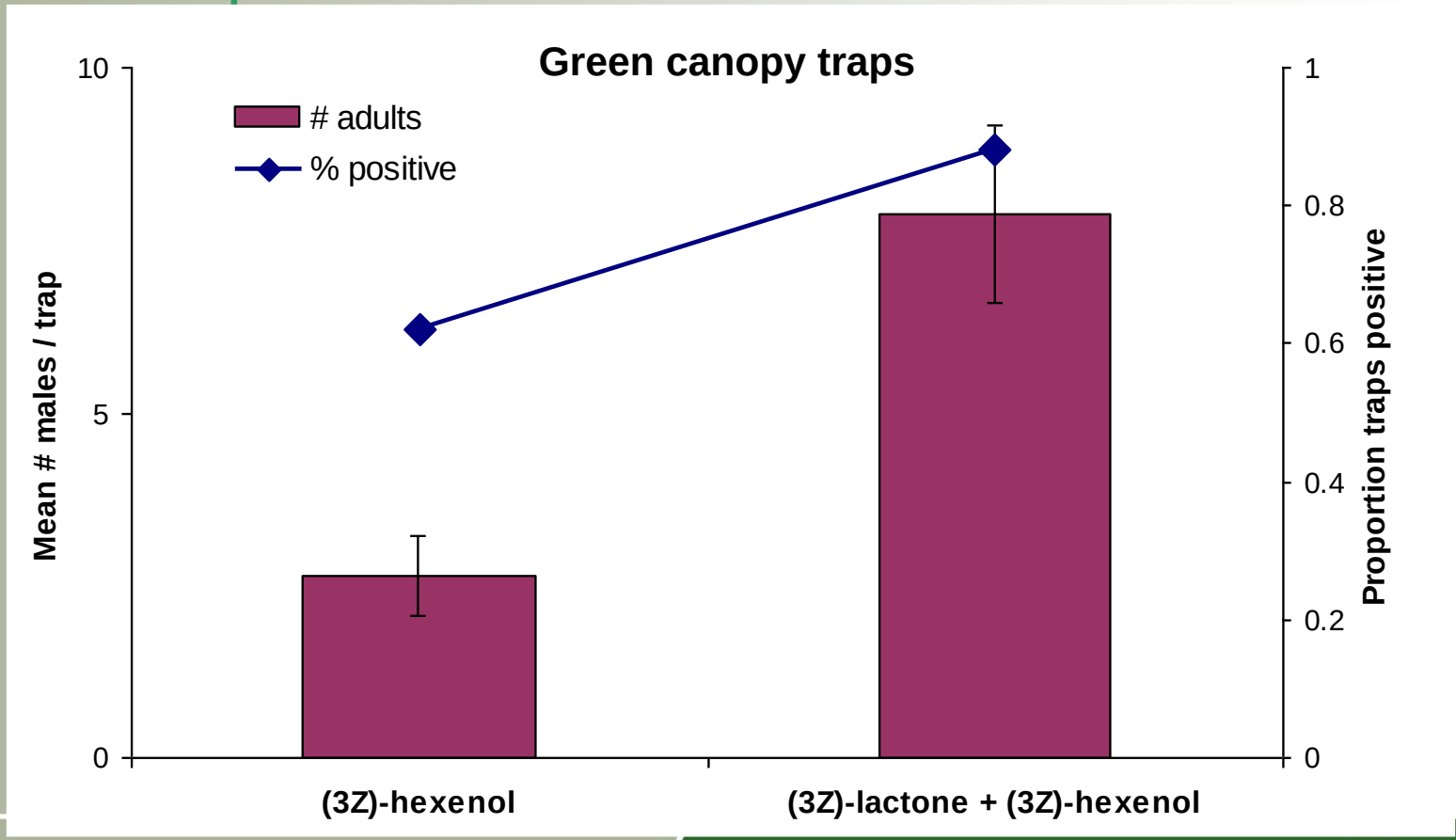


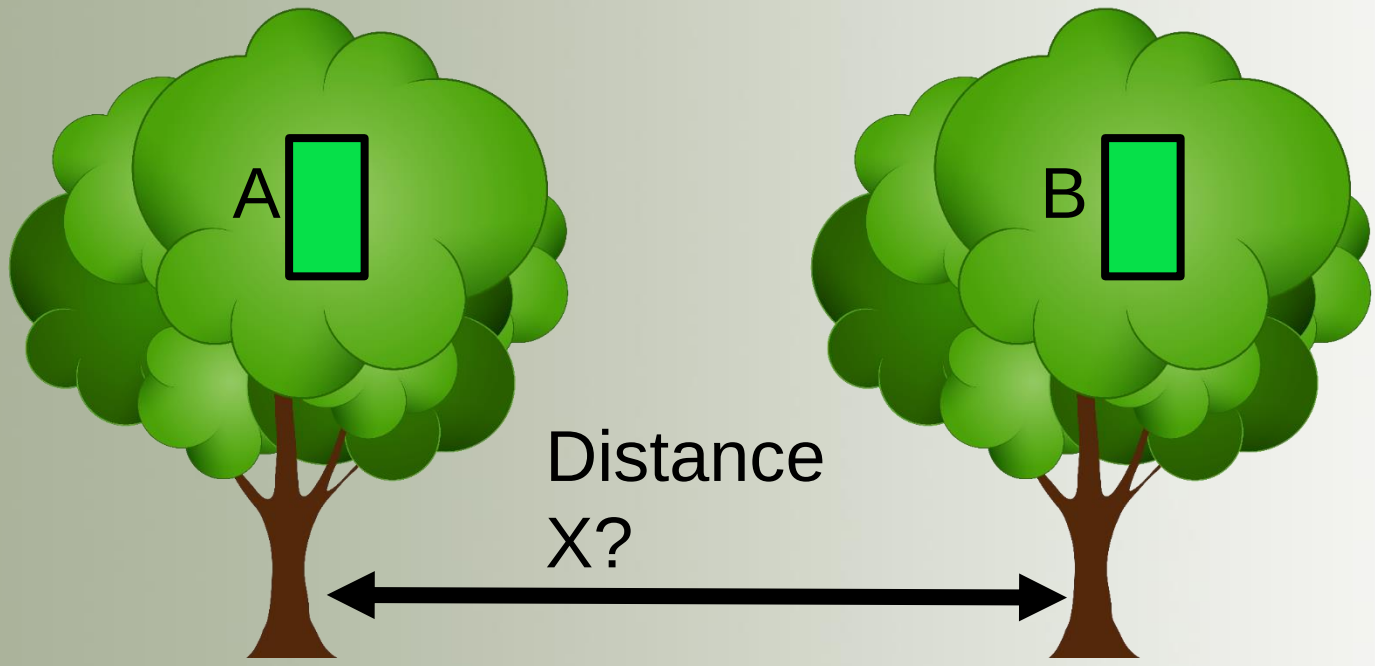
Trap-Lure option

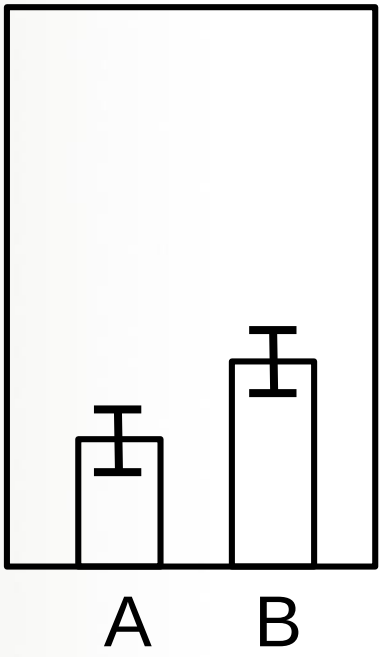
- 3.0 mg (3Z)-lactone
  - Co-baited with (3Z)-hexenol
  - Green prism trap
  - Deployed IN the canopy
  - Deployed in a sunny location
- Sold commercially in Canada, USA and Europe.

aPhinity EAB

ACTIVE SPACE OF THE TRAP??

Non-competitive trapping:





A = 3Z-6OH, B = 3Z-6OH + pheromone

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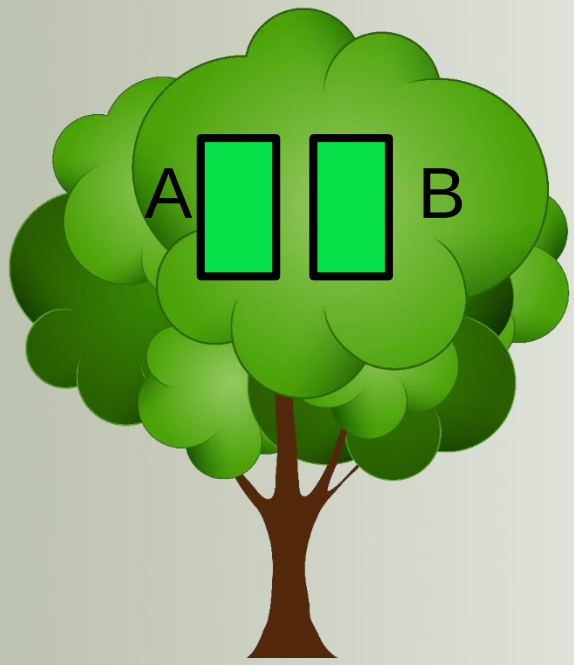
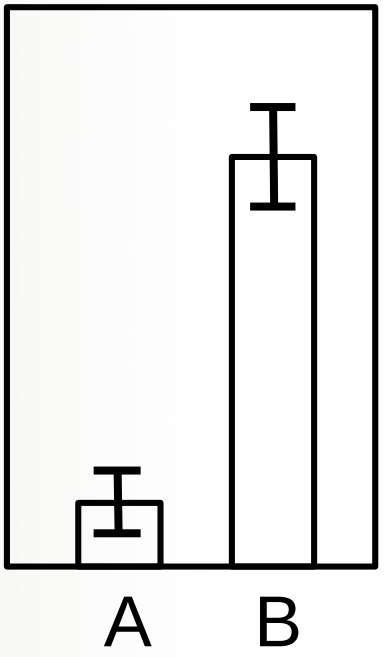
Competitive trapping: pheromone is likely short-range





A = 3Z-6OH, B = 3Z-6OH + pheromone

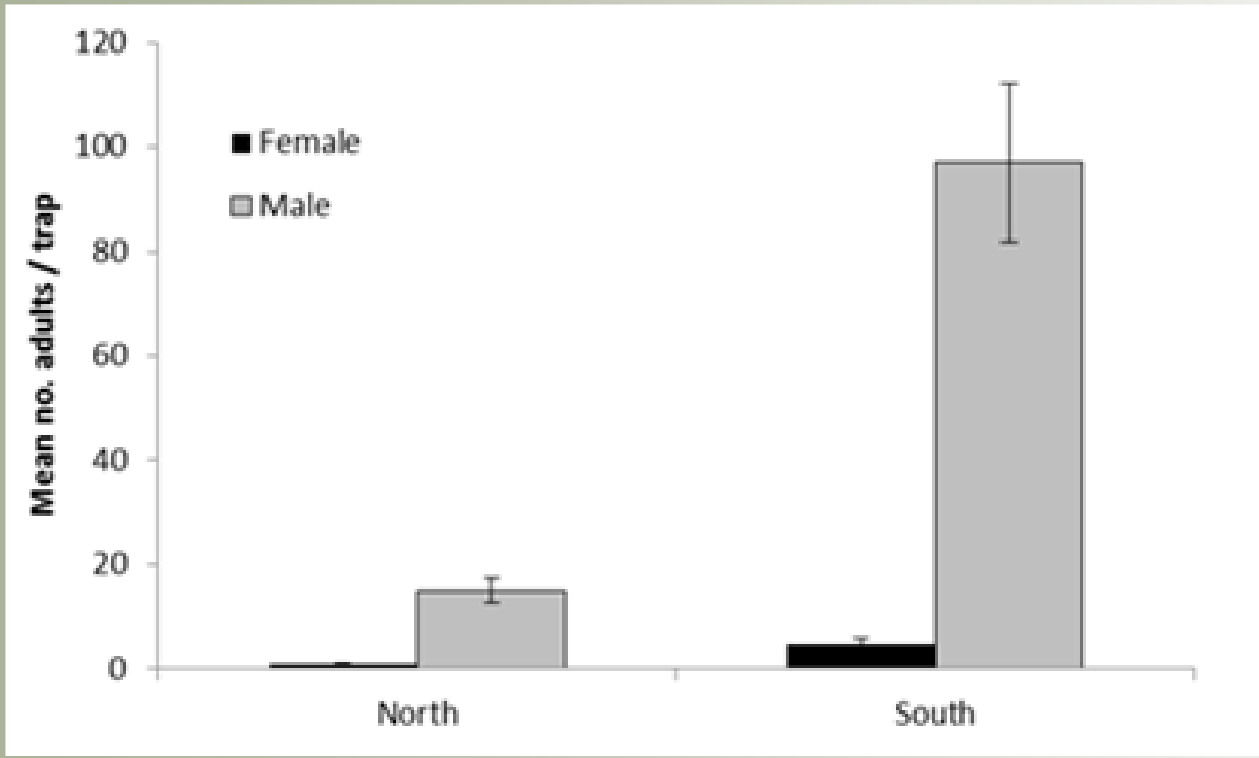
Trap placement: Sunshine?

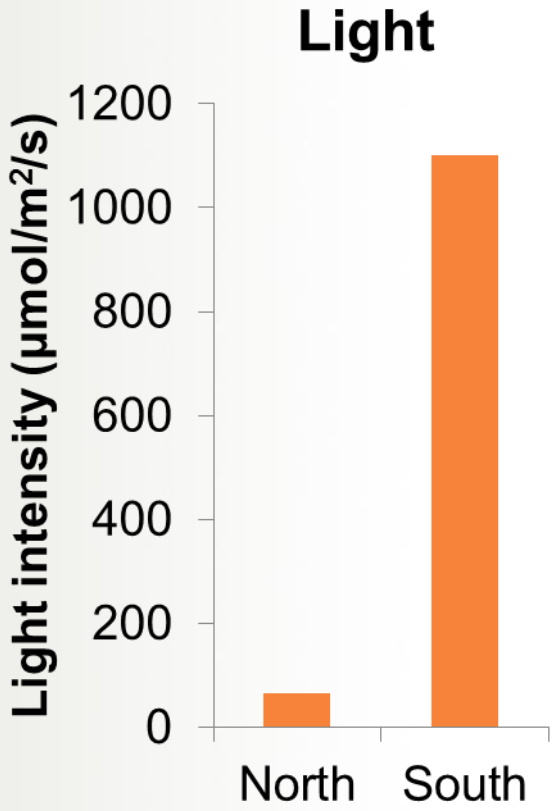
- Buprestids reported to be ‘sun loving’ beetles
- Some set up (2012-2013) conducted in shaded locations (due to tall buildings in urban areas or traps placed close to bole)

- Could this reduce the effect of (3Z)-lactone pheromone?

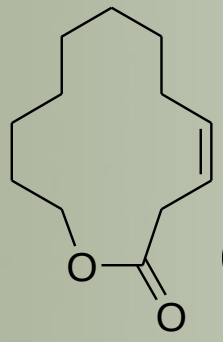
- Aspect experiment (2014):
  - Sunny south vs. shady north side of trees
  - All baited with (3Z)-lactone + (3Z)-hexenol

Sunshine results

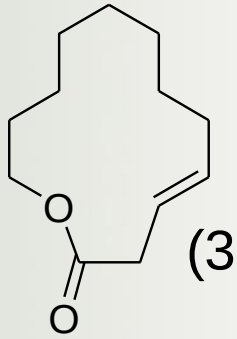




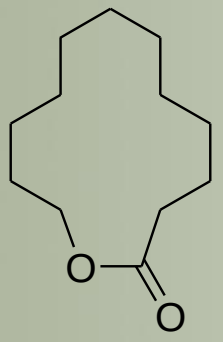
3 Macrocyclic Lactones Show Behavioural Activity Towards EAB



(3*Z*)-Dodecen-12-olide



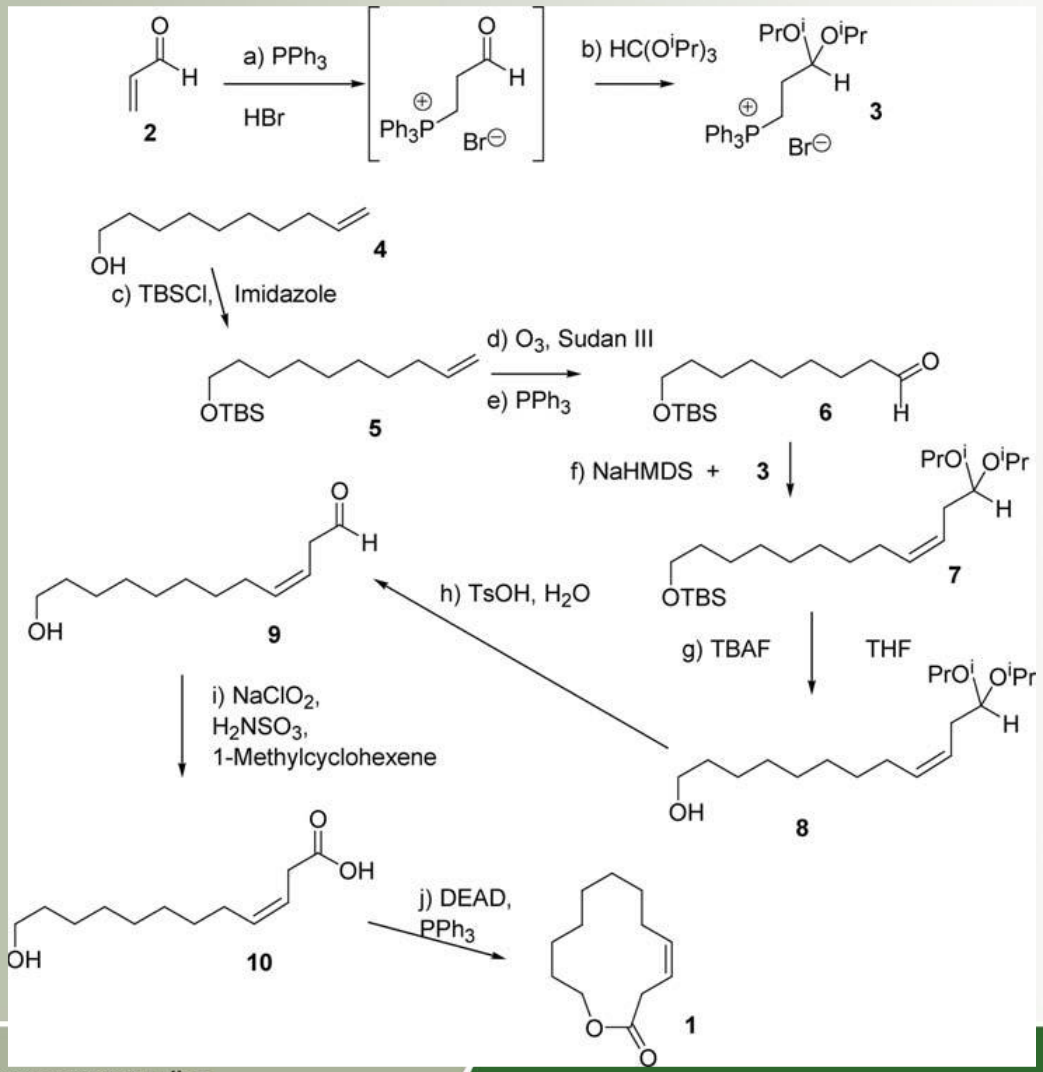
(3*E*)-Dodecen-12-olide



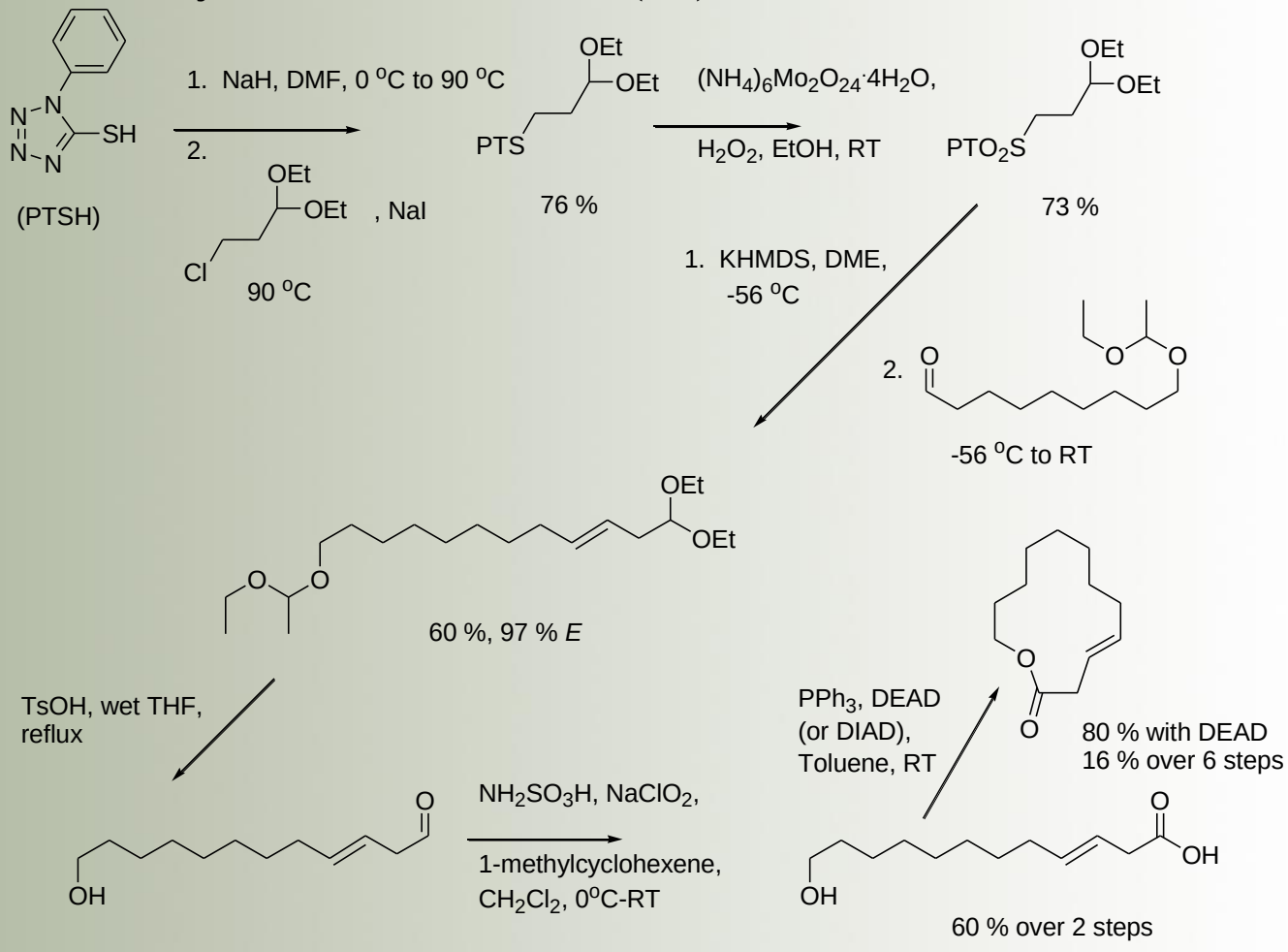
12-Dodecanolide (saturated lactone analog)

They possess the same carbon-oxygen skeleton, but differ in the presence and placement of the carbon-carbon double bond.

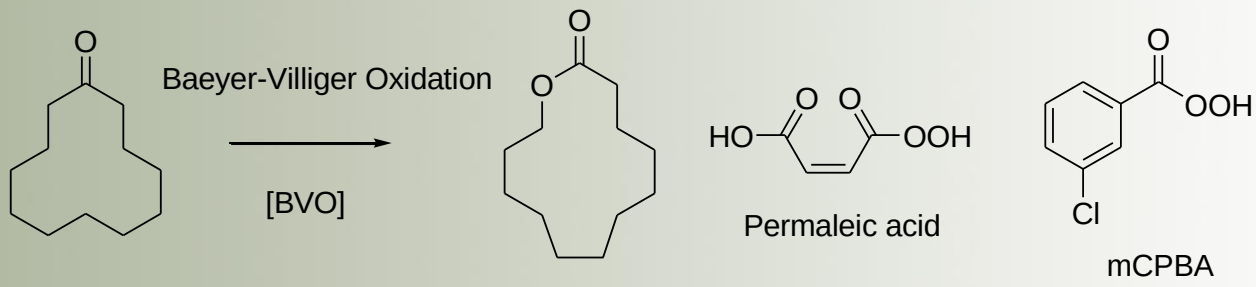
Synthesis of *Z*-Lactone, (3*Z*)-Dodecen-12-olide



Synthesis of *E*-Lactone, (3*E*)-Dodecen-12-olide



Synthesis of Saturated Lactone Analog 12-Dodecanolide



Baeyer-Villiger Oxidation (BVO) of cyclododecanone

Entry	Conditions	Time	Percent Yield of 12-dodecanolide
1	10 equiv. *m*CPBA, 2 equiv. $NaHCO_3$, CH_2Cl_2, RT.	2.5 Months	59[a]
2	2.1 equiv. *m*CPBA, 0.04 equiv. $TsOH{\cdot}H_2O$, CH_2Cl_2, RT	3.5 Weeks	87[b]
3	10 equiv. H_2O_2 (35 wt% aqueous), 31 equiv. $(CF_3CO)_2$, 1 equiv. $Na_2HPO_4{\cdot}7H_2O$, CH_2Cl_2, RT.	11 Days	72[c]
4	Permaleic acid (generated *in situ* from maleic anhydride, 35 wt% aqueous H_2O_2, and acetic anhydride), CH_2Cl_2, RT	5 Days	75[b]

[a]~98% Consumption of ketone by GC/MS.
[b]~99.8% Consumption of ketone by GC/MS.
[c]100% Consumption of ketone by GC/MS.

J Chem Ecol (2015) 41:294–302
DOI 10.1007/s10886-015-0562-1

A Biologically Active Analog of the Sex Pheromone of the Emerald Ash Borer, *Agrilus planipennis*

P. J. Silk[1] · K. Ryall[2] · P. Mayo[1] · D. I. MaGee[3] · G. Leclair[1] · J. Fidgen[2] · R. Lavallee[4] · J. Price[1] · J. McConaghy[1]

- Antennal responses similar to (3Z)-lactone
- In trapping trials, 5.0 mg saturated analog equivalent to 3.0 mg (3Z)-lactone
- Plasticity of response of the lactones!!!

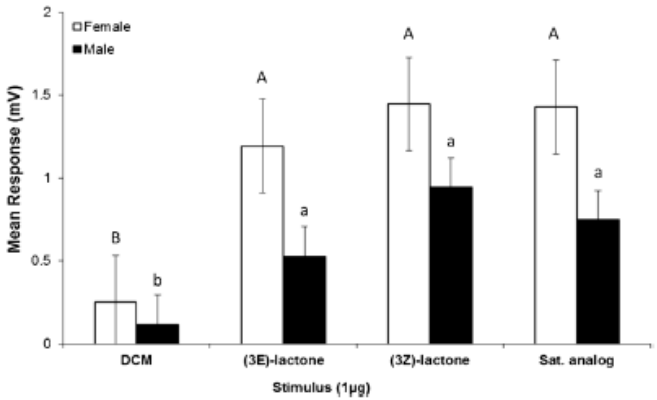
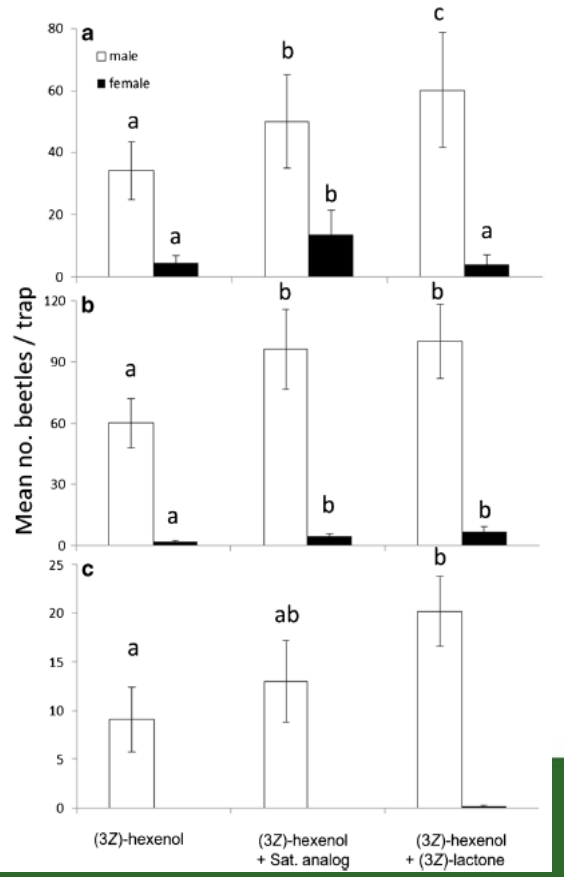
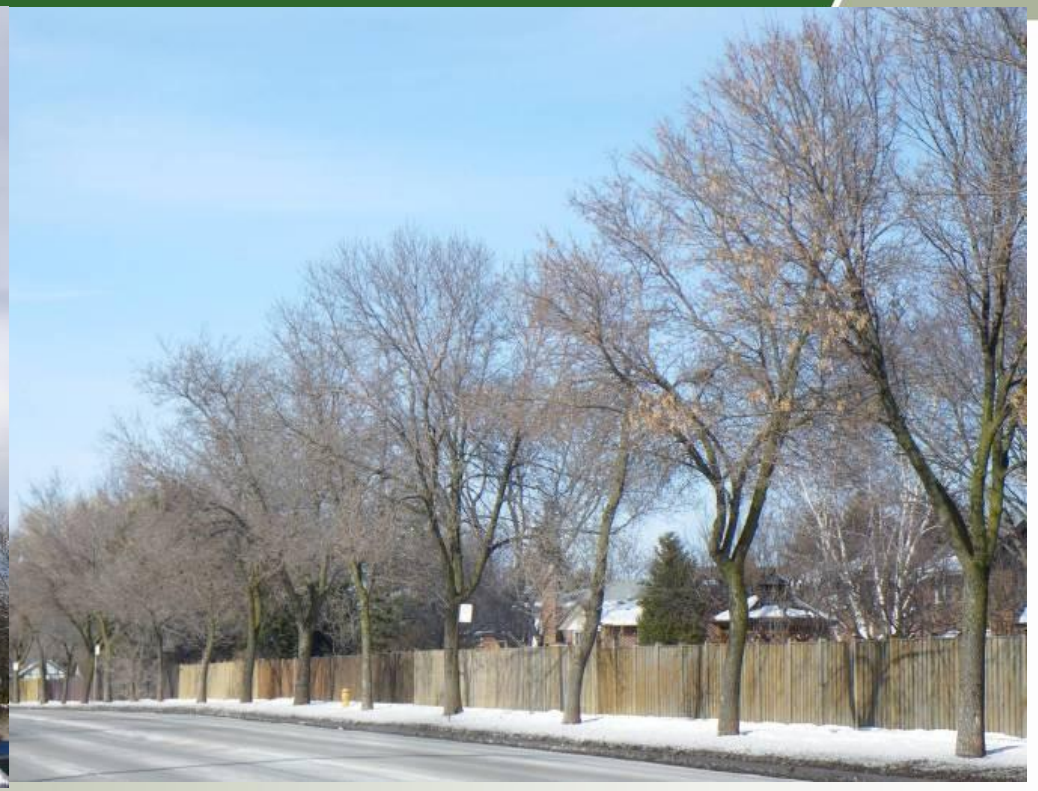


Fig. 4 Mean EAG responses of male and female EAB to dichloromethane (DCM), the (3*E*)-lactone **2**, the (3*Z*)-lactone **1** and the saturated lactone **3** (± SE) (means with same letter did not differ significantly $P<0.05$ after ANOVA and testing of the significance of differences between means by Tukey's test)

J Chem Ecol (2015) 41:294–302



2. Branch Sampling of asymptomatic trees



Failure to detect early…

BRANCH SAMPLING

Detectability of the Emerald Ash Borer (Coleoptera: Buprestidae) in Asymptomatic Urban Trees By Using Branch Samples

KRISTA L. RYALL,[1] JEFFREY G. FIDGEN, AND JEAN J. TURGEON

Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, ON, Canada P6A 2E5

Environ. Entomol. 40(3): 679–688 (2011); DOI: 10.1603/EN10310

- Branch sampling method
  - Open-grown urban street trees
  - Remove 2 branches from mid-crown
  - ‘Whittle’ bark from basal 50 cm of a 75 cm long branch piece
  - 75% probability of detection
  - Detects low-density EAB infestation
  - Can be carried out with yearly pruning operations in fall

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, primarily 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

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

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. *Girdle 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.

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.

Recommended method

- Sample **two** branches per tree
  - ONE 50-cm sample / branch
  - Carefully dissect bark
- 80% chance of detection
  - (at >8 galleries/sq m)

Natural Resources Canada Ressources naturelles Canada

Frontline

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Fig. 1. Adult emerald ash borer

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

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.

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

Peeling Procedure

Hypothesis Supported!!

- Sampled 48 infested trees showing no signs or symptoms of emerald ash borer attack

Method	# infested trees detected	Accuracy
Visual inspection	0 of 48	0
Bole window	11 of 47	23
Crown sampling	45 of 48	**94**

Deploying Branch Sampling

- Used grid sampling, 1-km spacing
- Sampled 5 suitable ash trees (street trees)
  - Quantified EAB gallery density
  - SSM and Oakville examples

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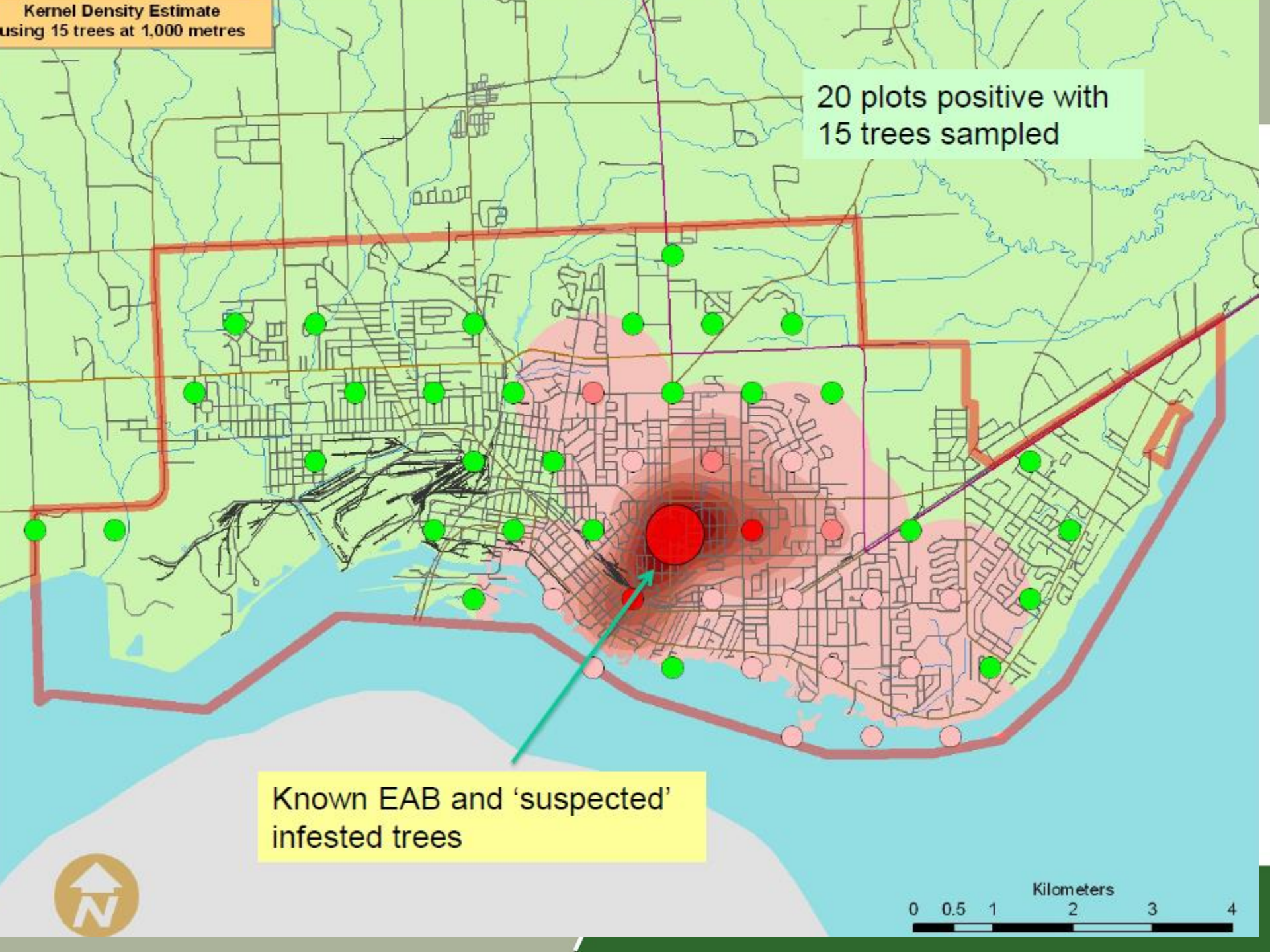
Kernel Density Estimate
using 15 trees at 1,000 metres
20 plots positive with
15 trees sampled
Known EAB and 'suspected'
infested trees
Kilometers
0 0.5 1 2 3 4

Emerald ash borer detection and monitoring in Canada?

- First evidence of a pheromone in Buprestidae
- Provided improved tools for detection and monitoring
- The CFS & CFIA, Canada recommends using the 3Z-hexenol/3Z-lactone green sticky prism trap to detect EAB and branch sampling to delimit infestations.
- We have increased our understanding of plasticity in pheromone response
- Ongoing work:
  - Evaluating analog for detection surveys
  - Further testing of fluorinated analogs
  - Evaluating effective range of pheromone…active space??
  - Investigate pheromones in other *Agrilus* sp
  - Studying acoustic signals in EAB…now published in EEA.