


Tiny Wasps to the Rescue: Sustainable Management of Invasive Insects

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Arboricultural Association® cares for trees

MARYLAND DEPARTMENT OF AGRICULTURE

USDA

The Arboricultural Association's National Amenity Conference
-Protect and Survive-
Exeter University, UK
September 10-13, 2017

Invasive Species – Yikes!

- **Introduction of exotic invasive species is on the upswing world-wide**
- **Economically and ecologically devastating**

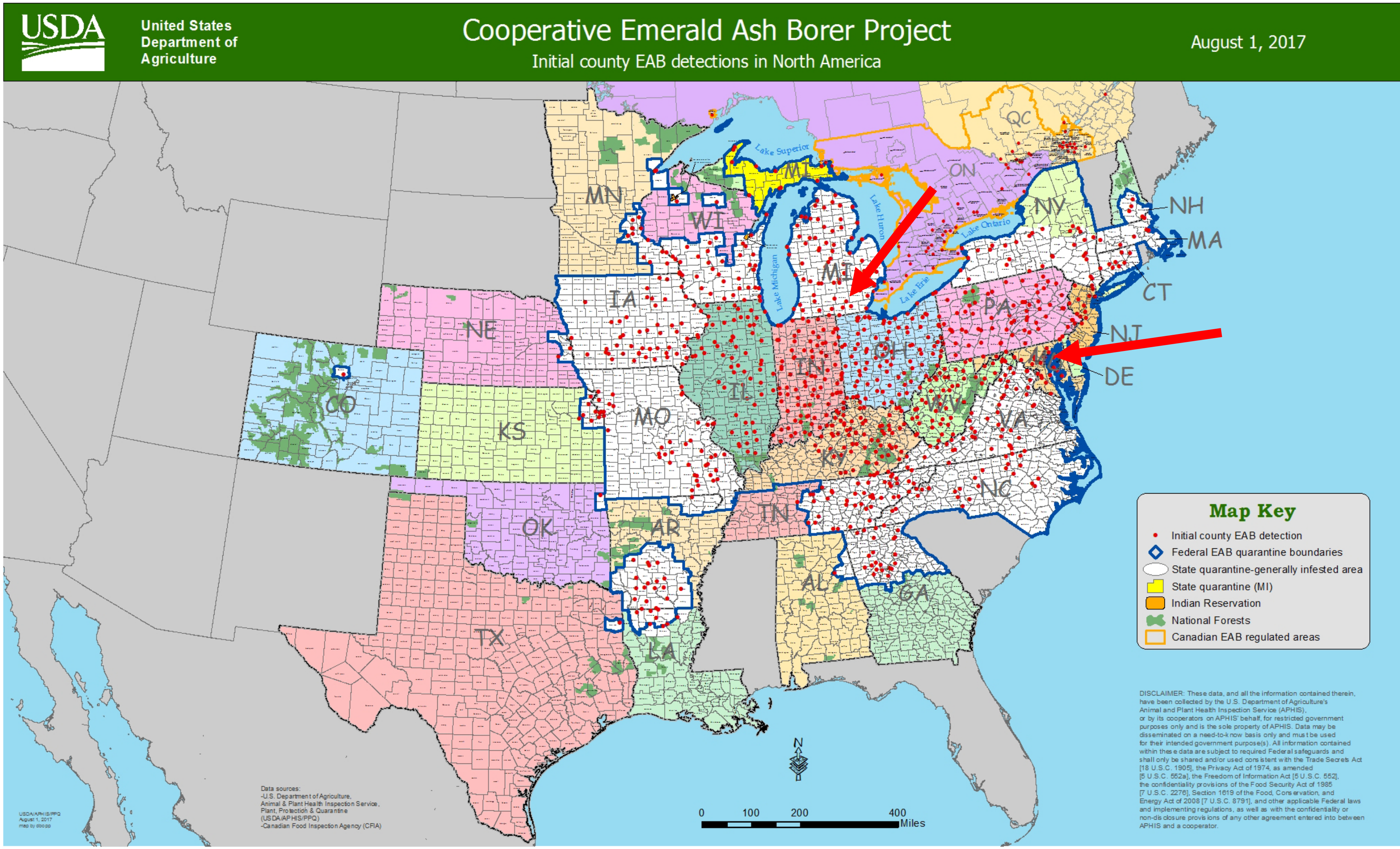
Biological Control Efforts against Emerald Ash Borer in MD and MI, USA

- **Understanding the role of indigenous and exotic natural enemies is critical towards sustainable management of invasive insects**
- **Surveys of EAB infested ash to ID native natural enemies attacking EAB and estimate impact**
- **Foreign exploration to native range to ID / collect natural enemies impacting EAB, release in U.S. and determine dispersal and impact**
- **Help inform government agencies and practitioners on sustainable management of invasive insects**

Overview – Emerald ash borer

1. **Emerald ash borer (EAB) distribution and impact**
2. **Parasitoid release and recovery projects (MD and MI)**
3. **Impact of biological control on emerald ash borer populations (MD and MI)**
4. **Ongoing projects**

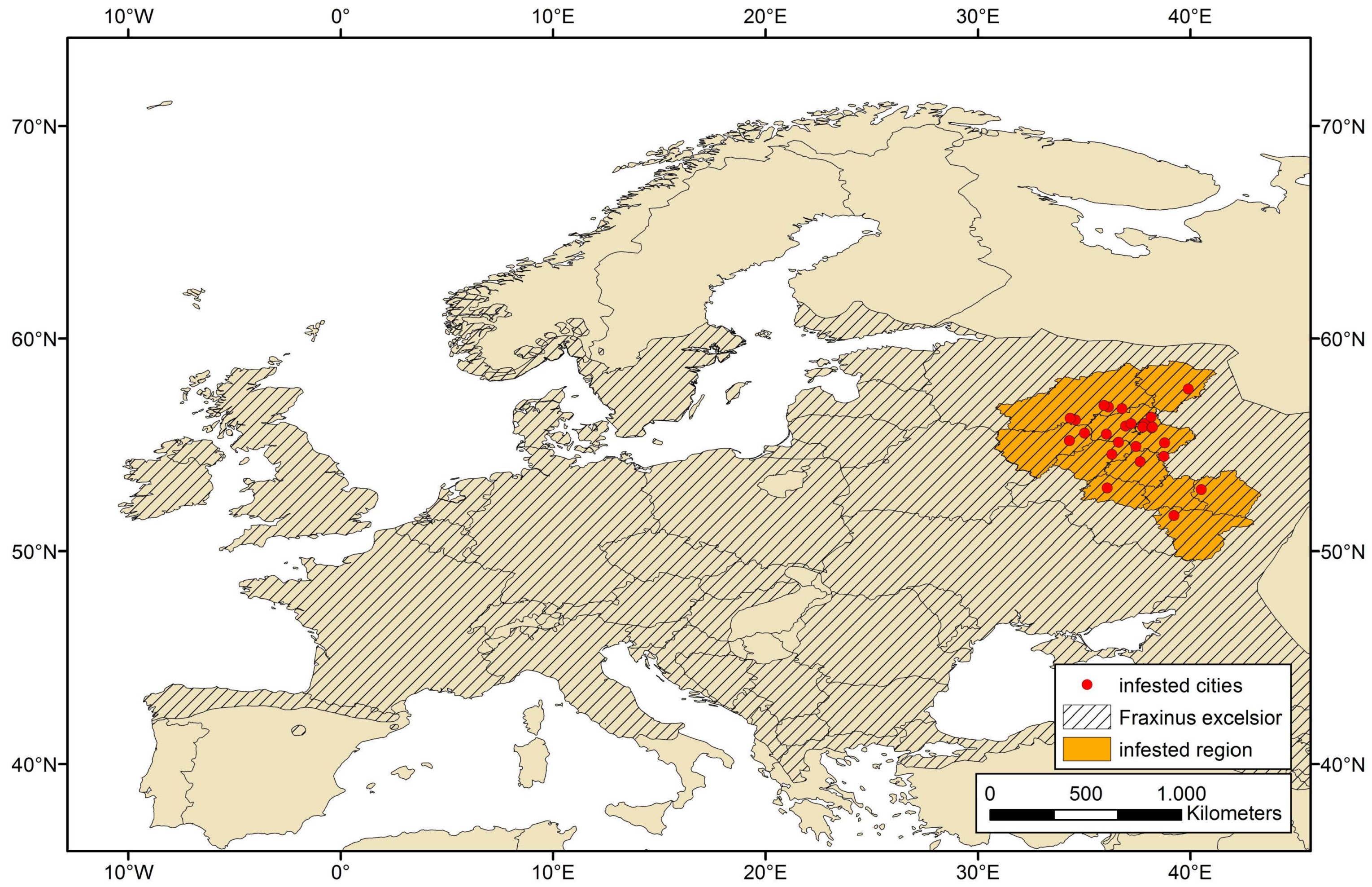
Emerald ash borer - 31 states, 2 Canadian provinces



http://www.emeraldashborer.info

2002 - First detected in North America

Reported Distribution of EAB and *Fraxinus* in Europe



From: Valenta, V.; Moser, D.; Kuttner, M.; Peterseil, J.; Essl, F. A high-Resolution Map of Emerald Ash Borer Invasion Risk for Southern Central Europe. Forests 2015, 6, 3075-3086.

1- 2 year generation in MD

EAB life cycle

Native natural enemies - new associations with EAB

***Atanycolus* spp.**

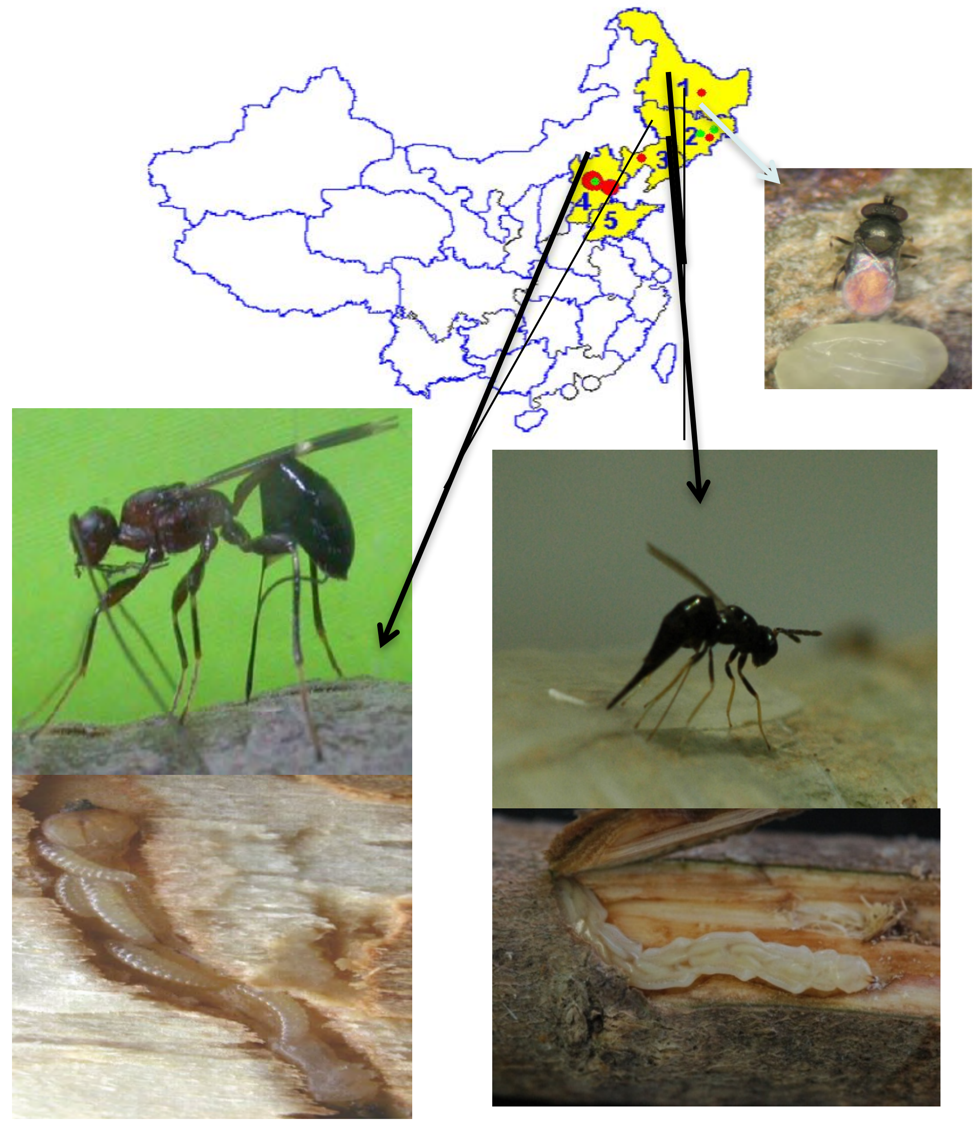
Phasgonophora sulcata

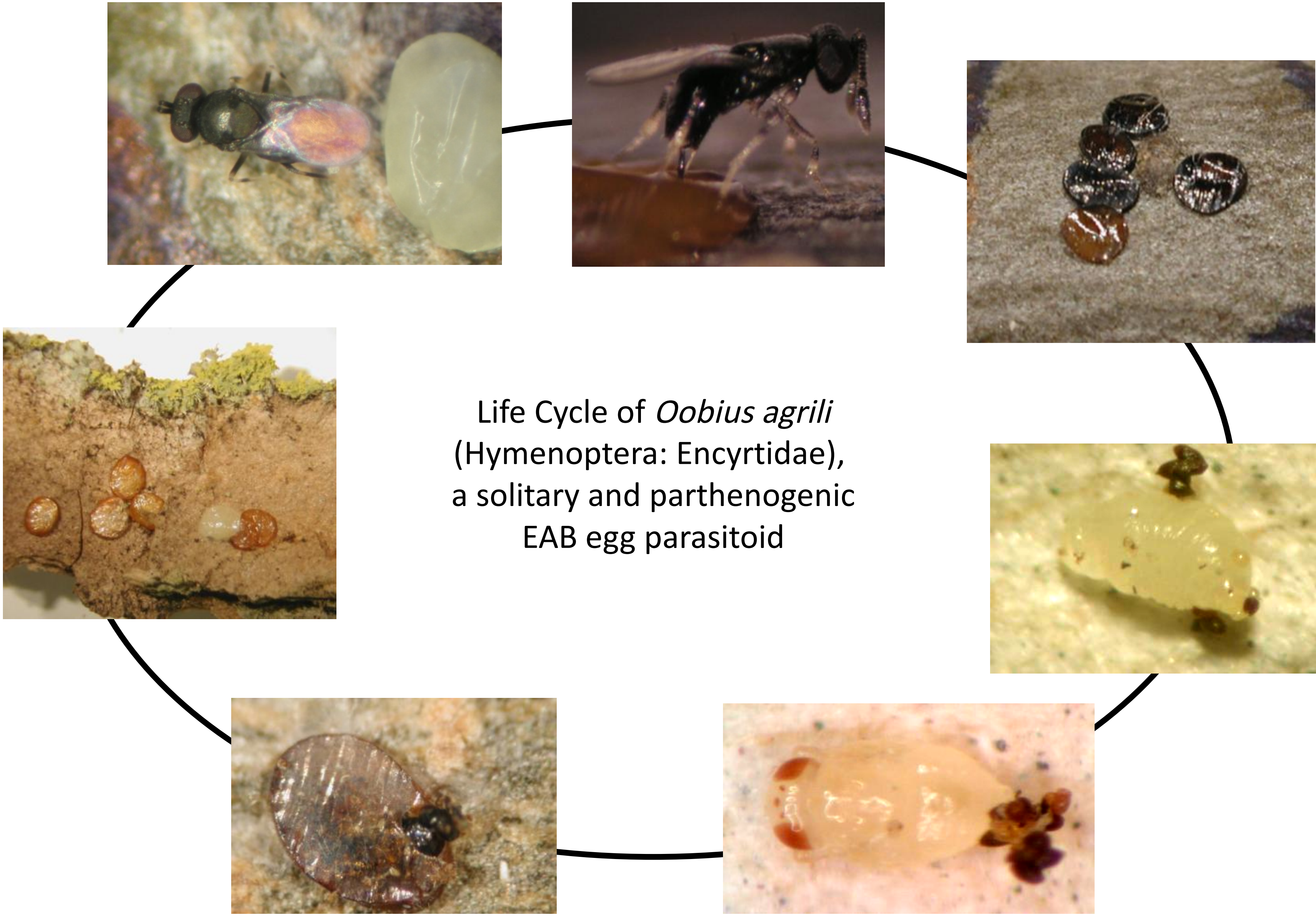
Generalists

Avian predators - woodpeckers

Exotic natural enemies - Classical Biological Control

- **Re-establishing associations**
- **Releases first started in MI in 2008**
- **26 U.S. states released with one or more species of these agents as of 2017**

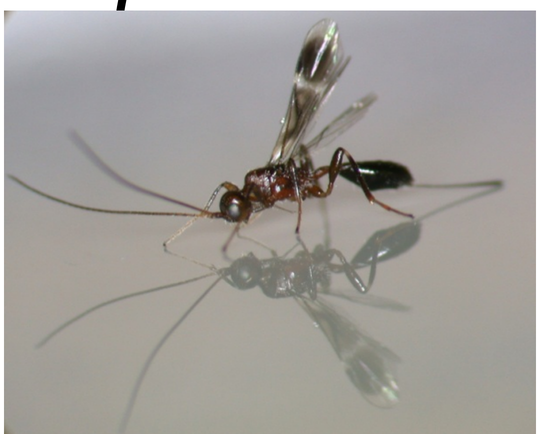



Life Cycle of *Oobius agrili*
(Hymenoptera: Encyrtidae),
a solitary and parthenogenic
EAB egg parasitoid

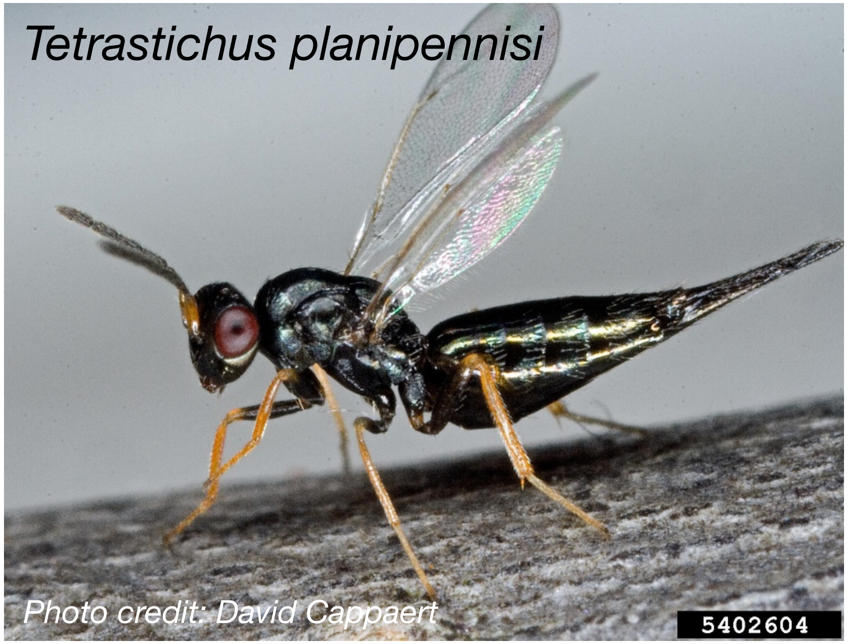
Life cycle of
Tetrastichus planipennisi
(Hymenoptera: Eulophidae),
a gregarious larval endoparasitoid of
EAB

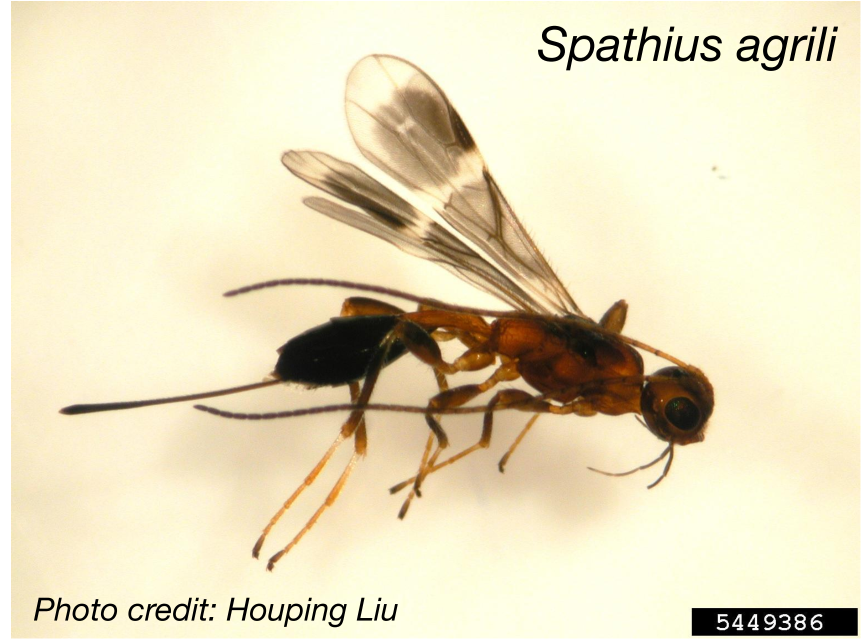
Parasitism reduced in ash with > 12 cm dbh

Life cycle of *Spathius agrili*
(Hymenoptera: Braconidae),
a gregarious larval ectoparasitoid
of EAB

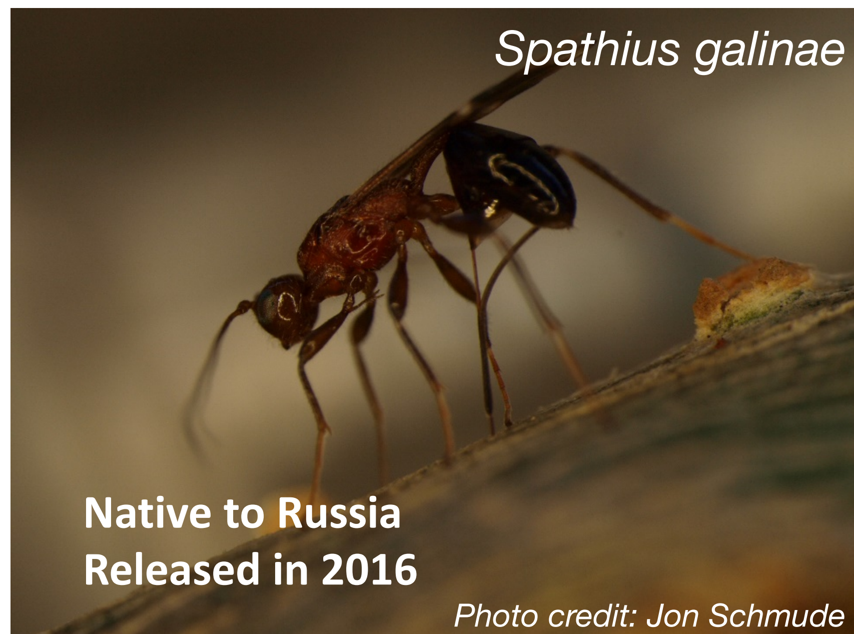


Does not establish in colder regions


Tetrastichus planipennisi
Photo credit: David Cappaert
5402604


Spathius agrili
Photo credit: Houping Liu
5449386


Oobius agrili
Photo credit: Jian Duan


Spathius galinae
Native to Russia
Released in 2016
Photo credit: Jon Schmude

Sampling:

“Harvest” trees to rear EAB and natural enemies from ash logs

De-bark trees to determine EAB fate


Killed by tree
Predation
Disease/Unknown
Parasitism
Alive

Sampling:

Visual survey and bark collection methods

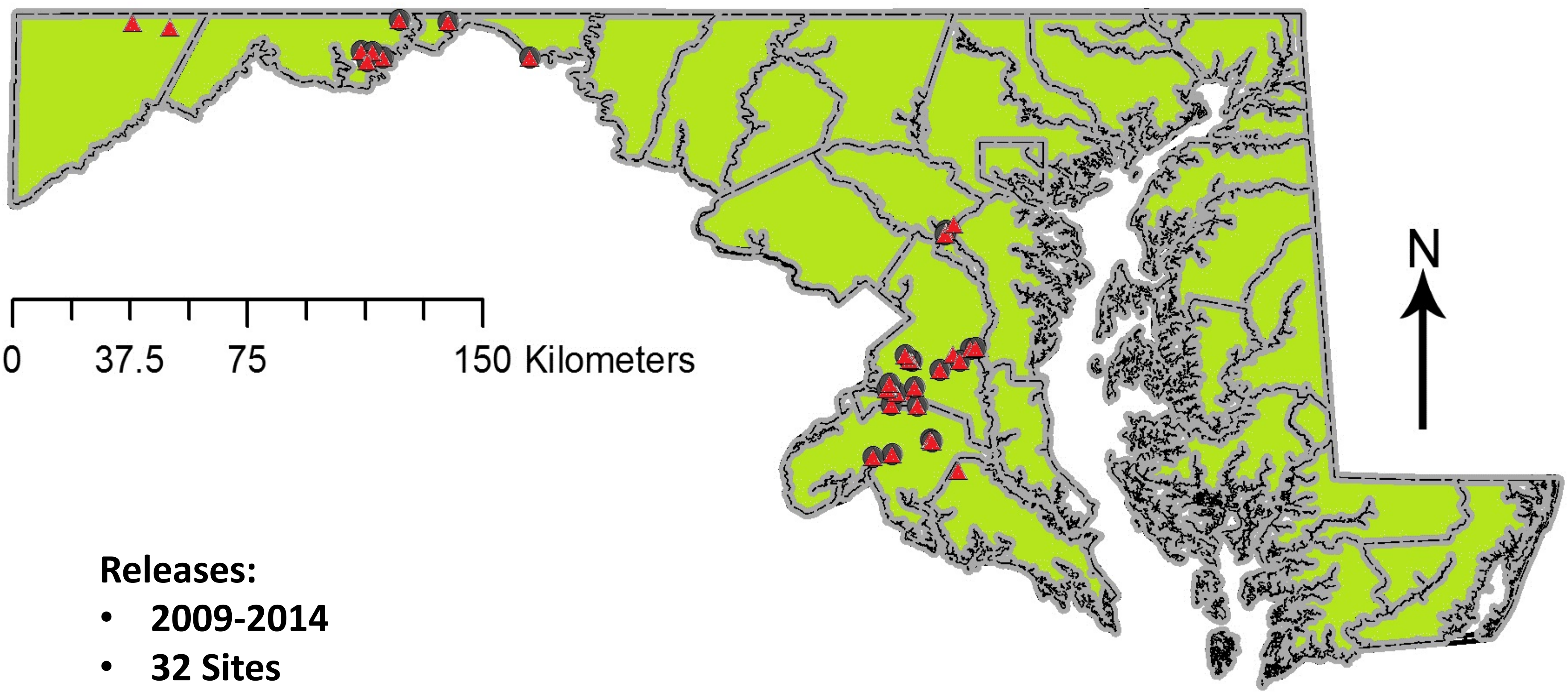
Parasitoid Sampling Methods for *Oobius*

Parasitized EAB eggs

Overview – Emerald ash borer

1. Emerald ash borer (EAB) distribution and impact
2. **Parasitoid release and recovery projects (MD and MI)**
3. **Impact of biological control (BC) on emerald ash borer populations (MD and MI)**
4. Ongoing projects

Release sites

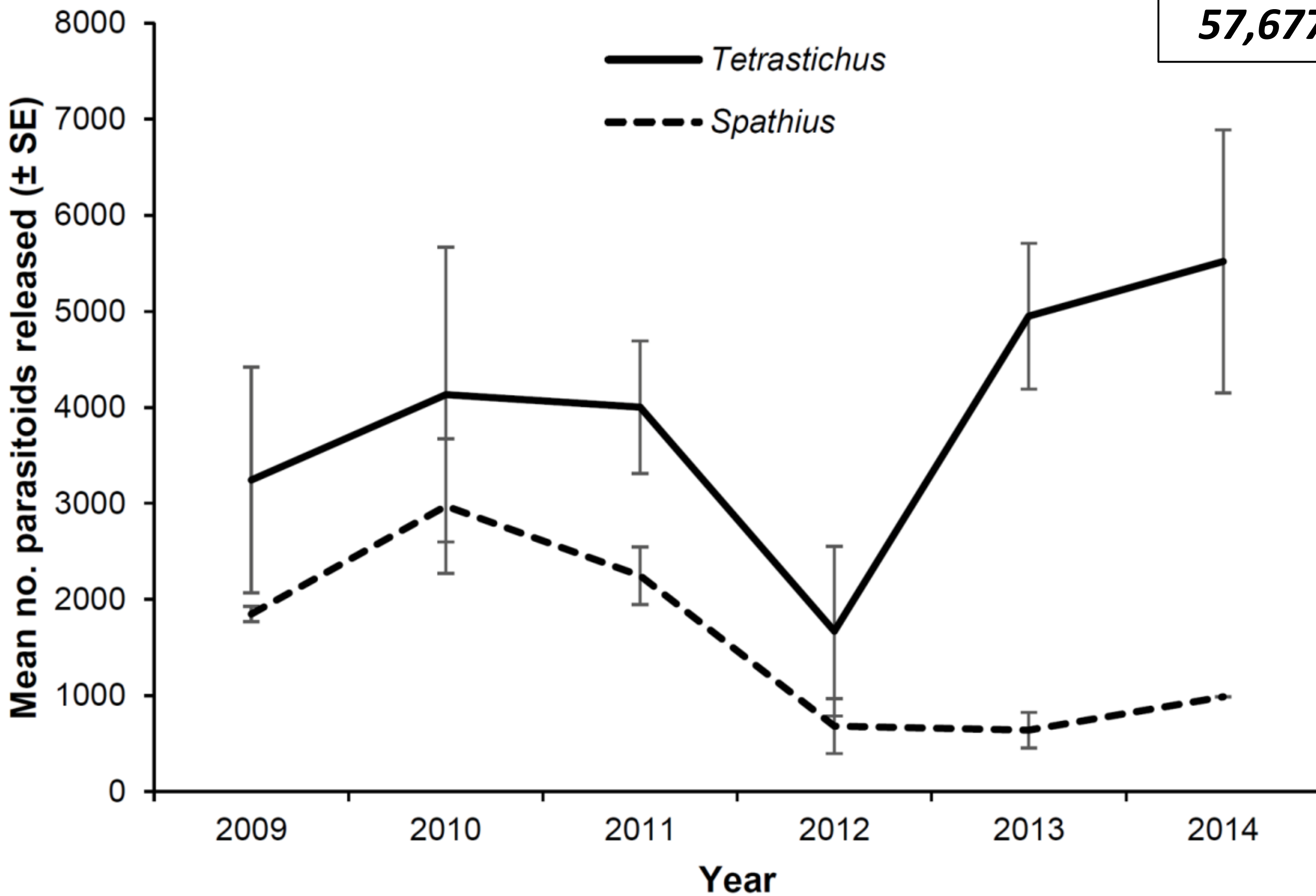


Releases:

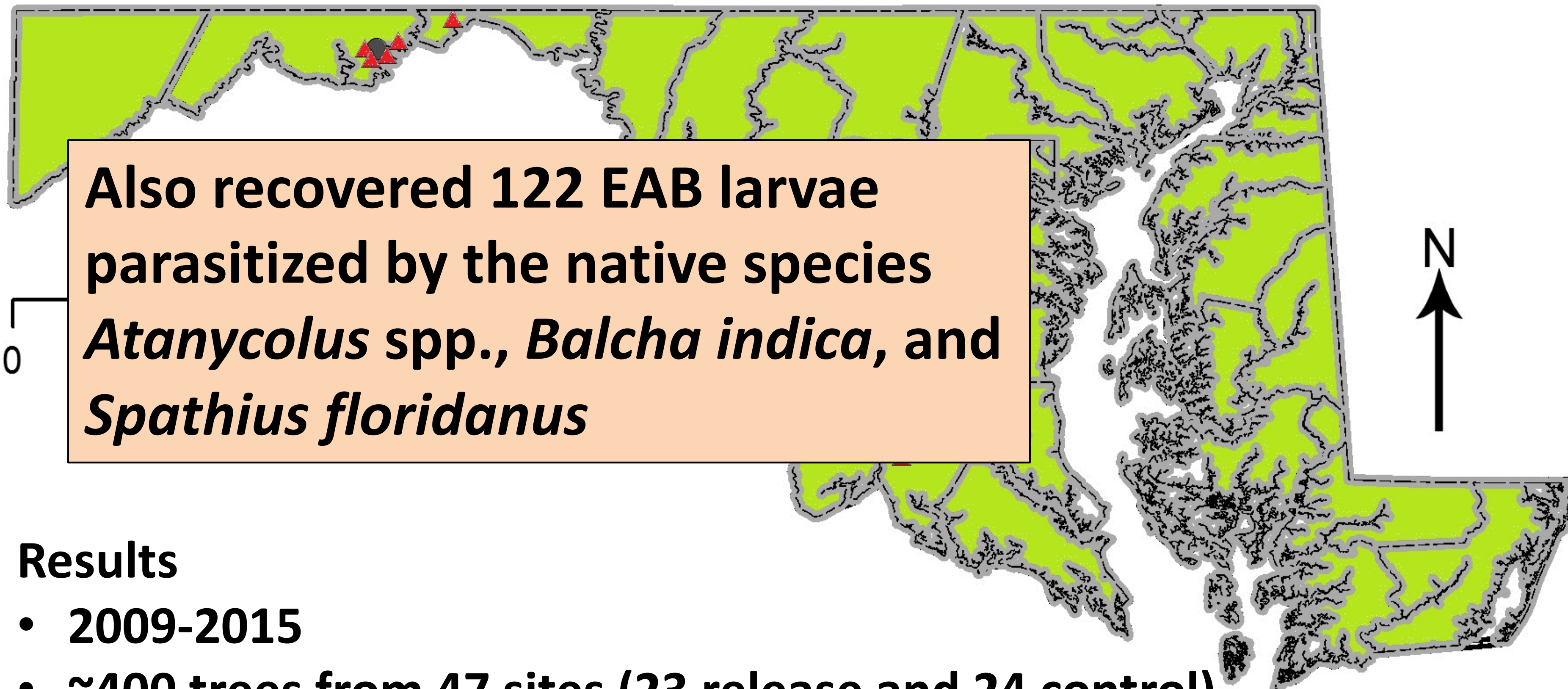
- **2009-2014**
- **32 Sites**
- ***Tetrastichus planipennisi* (32) (red)**
- ***Spathius agrili* (26) (gray)**

Numbers of parasitoids released

191,506 Tetrastichus
57,677 Spathius



Parasitoid recovery



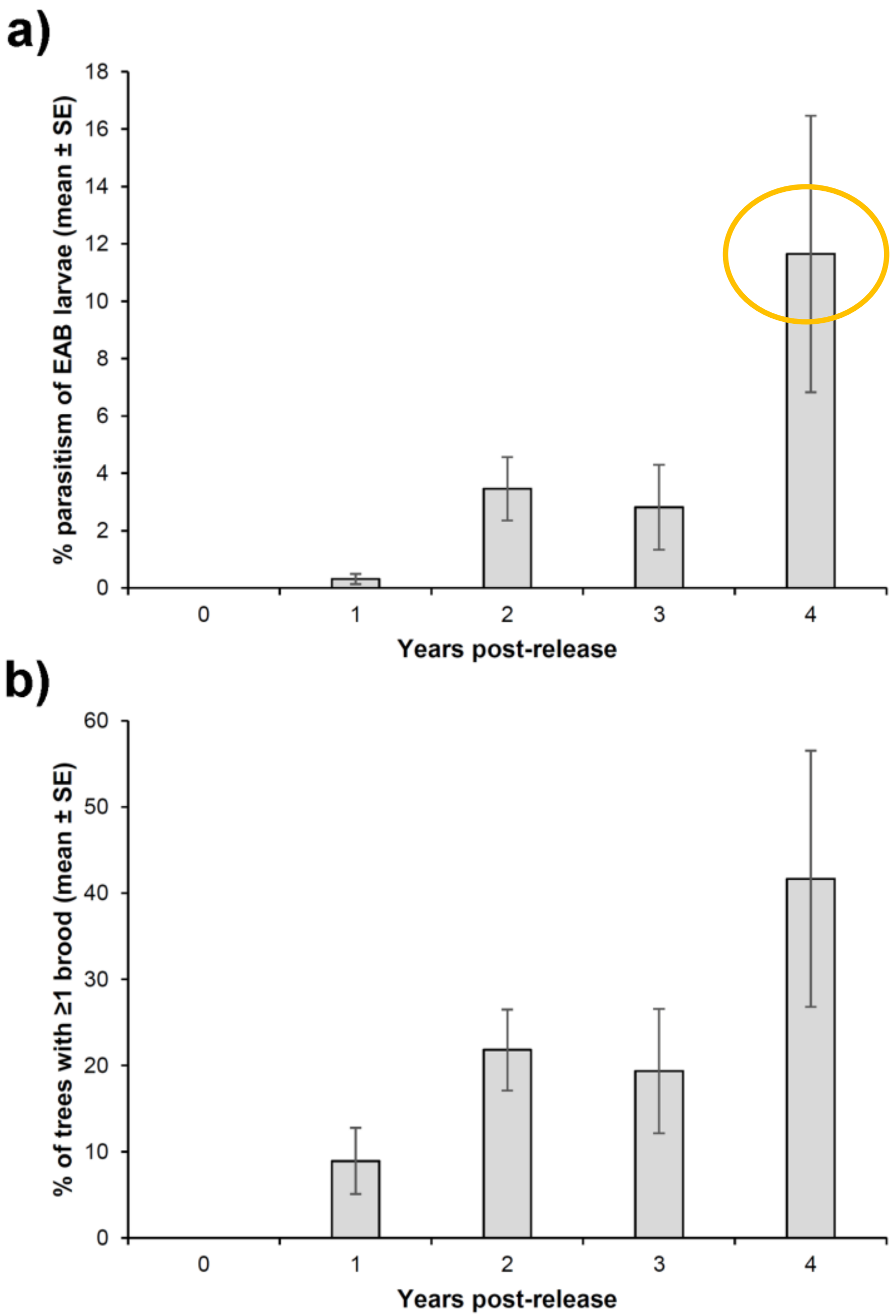
Also recovered 122 EAB larvae parasitized by the native species *Atanycolus* spp., *Balcha indica*, and *Spathius floridanus*

Results

- **2009-2015**
- **~400 trees from 47 sites (23 release and 24 control)**
- ***Spathius* (77 from 6 release sites)**
- ***Tetrastichus* (1,856 from 19 sites - 12 release sites, 7 control sites)**

Indicates establishment and dispersal

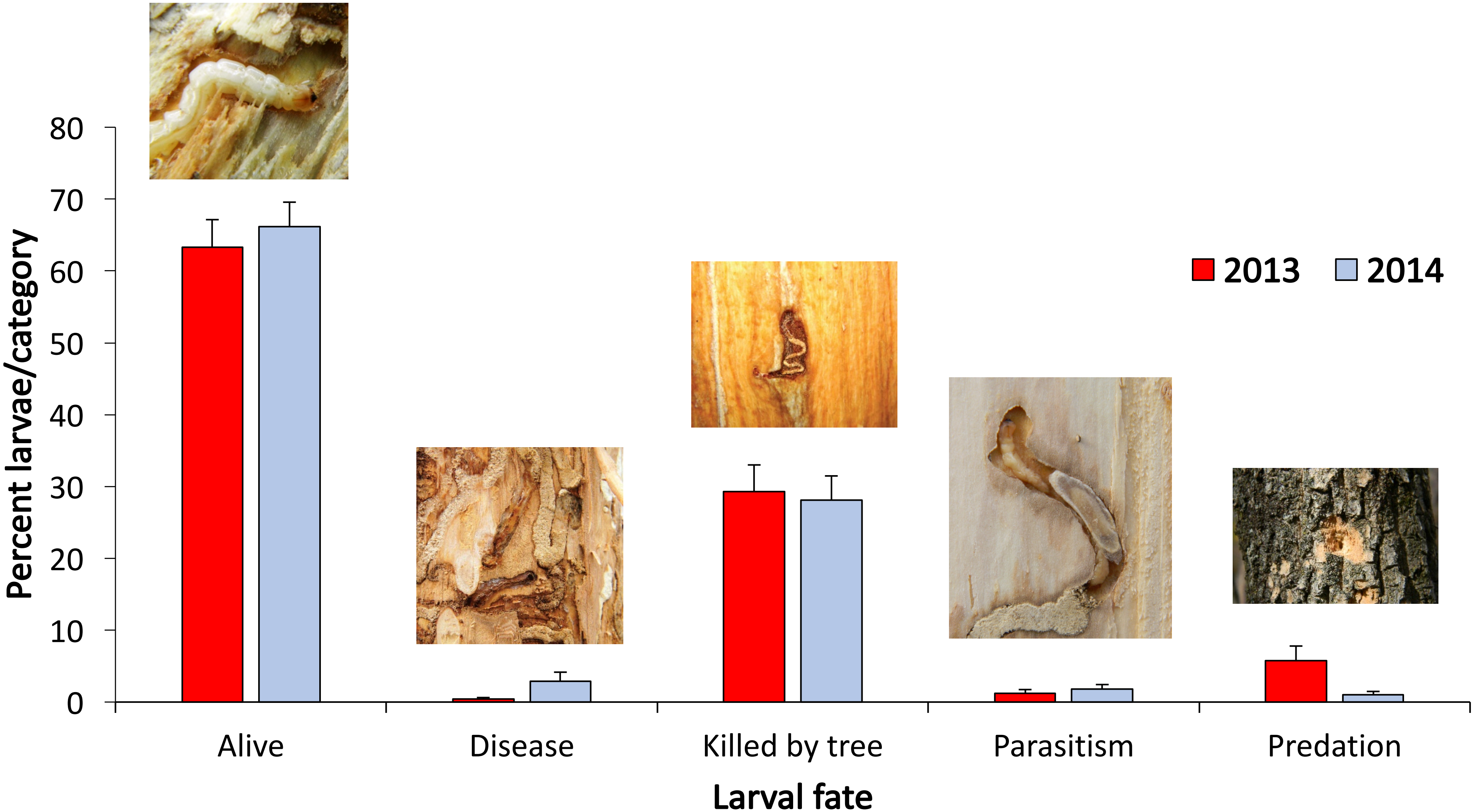
1. Parasitoid release and recovery



Establishment of *Tetrastichus planipennisi*

- **Significant increase in % of EAB larvae parasitized over time by *T. planipennisi***
- **Significantly more trees containing at least one brood of *T. planipennisi***
- **Establishment and dispersal (3-4 km away)**

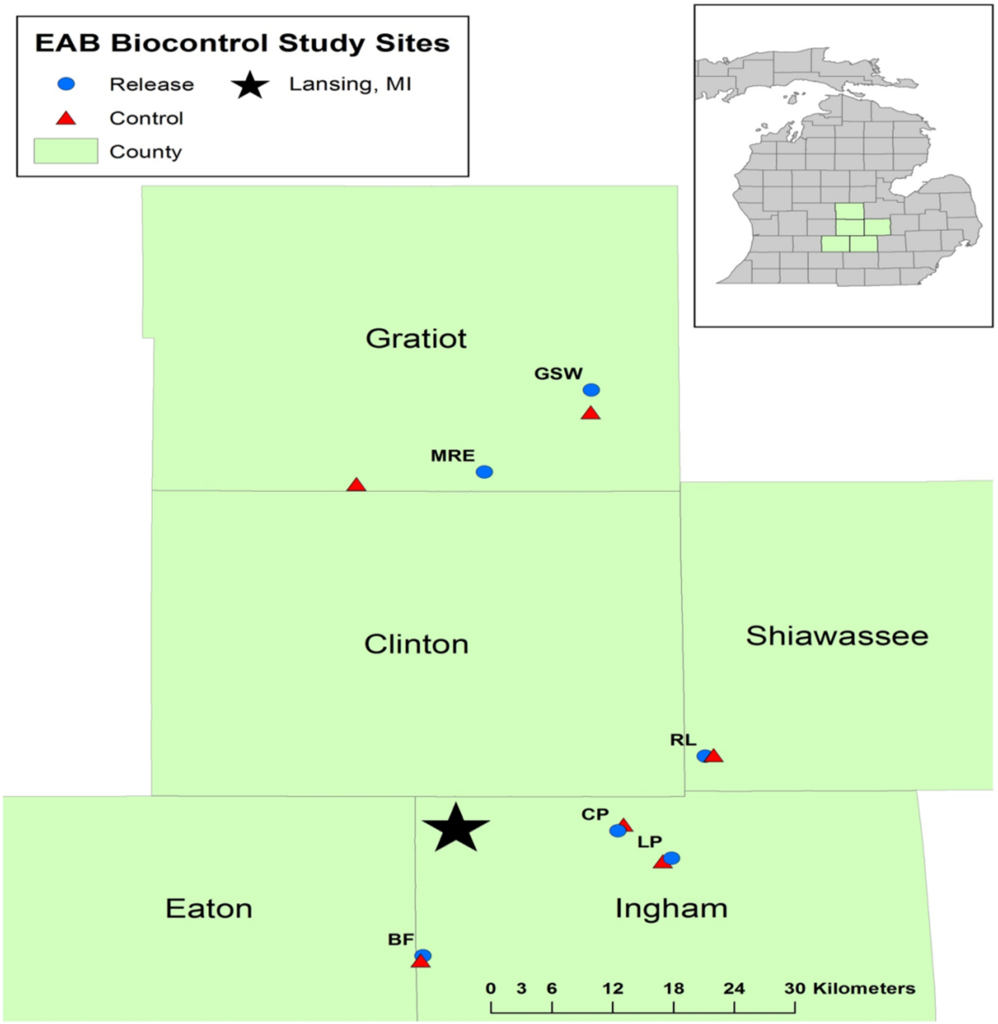
EAB mortality factors in Maryland



Summary (MD)

- *Tetrastichus planipennisi* successfully established and dispersed up to 4 km from release sites, averaging 1.7 km/year
- Parasitism rates of *T. planipennisi*, ranged from 4% to 12%
- Findings suggest that parasitism and other mortality factors remain too low to suppress EAB population growth in MD
- Other studies suggest more time may be needed

EAB Biocontrol Project in Southern Michigan (2008 – 2015)



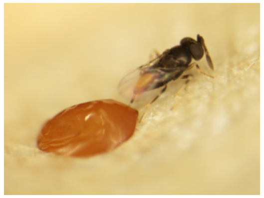
6 hardwood forest sites
Each divided into 2
- release and control (no release) plots

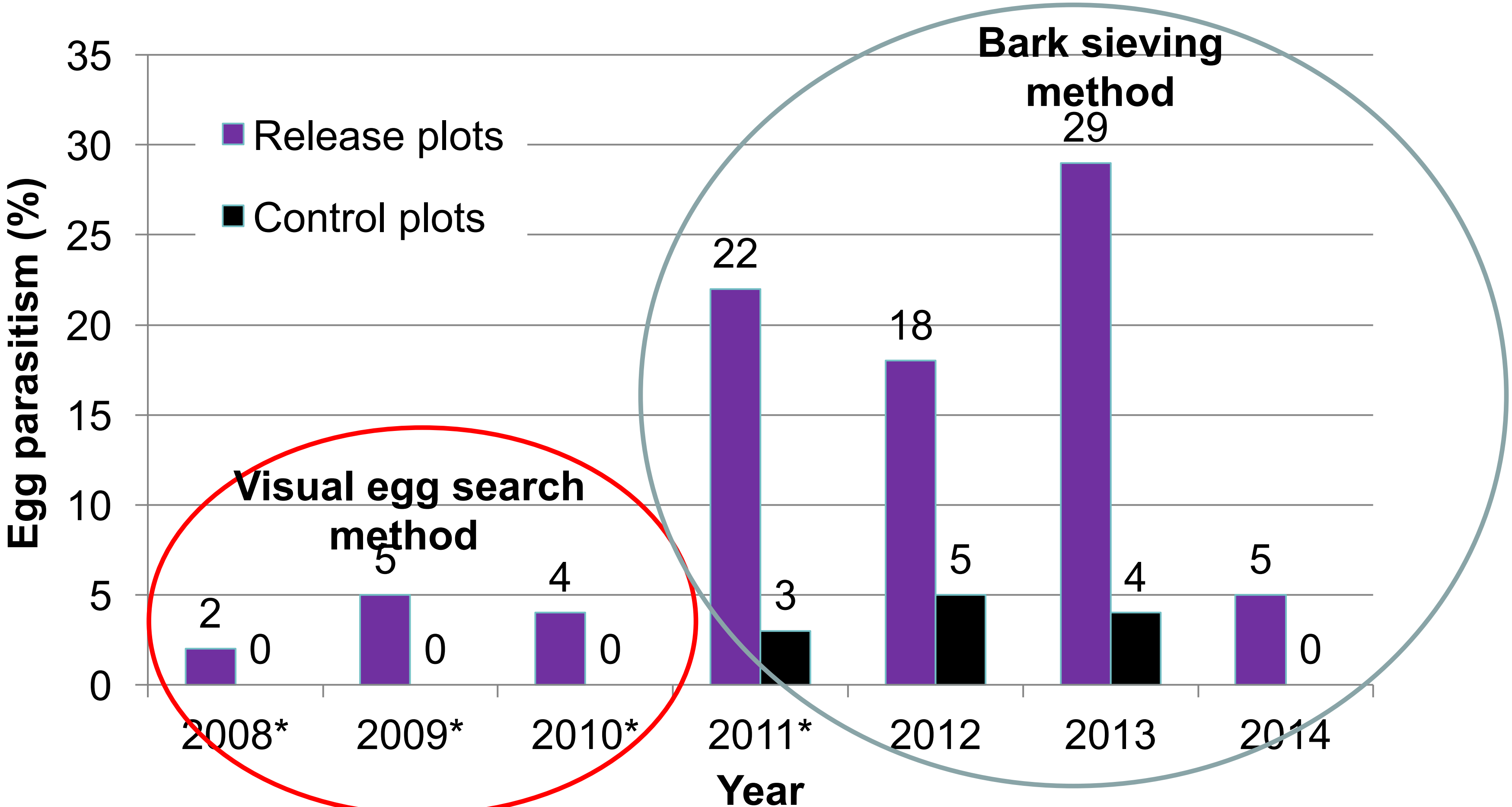
Research by: Duan, Bauer, Abell, Ulyshen and Van Driesche, Publ. in Journal of Applied Ecology, 2015.

Parasitoid Releases

Species	2008 - 2010 Per Site (Females)
Oobius agrili 	700 - 1150
Spathius agrili 	680 - 1100
Tetrastichus planipennisi 	3300- 3680

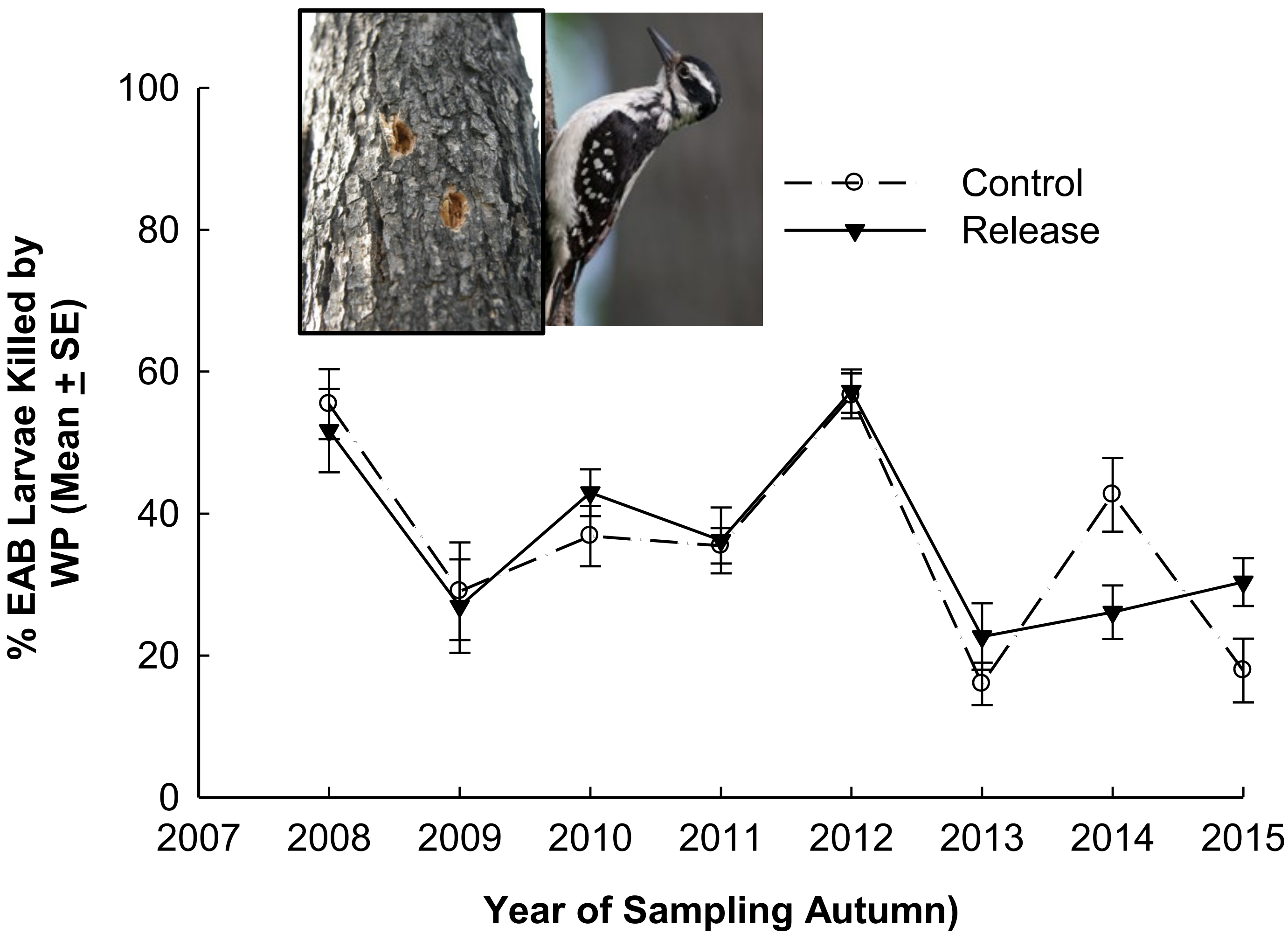
Egg Parasitism by *Oobius agrili* at the Six Michigan Study Sites





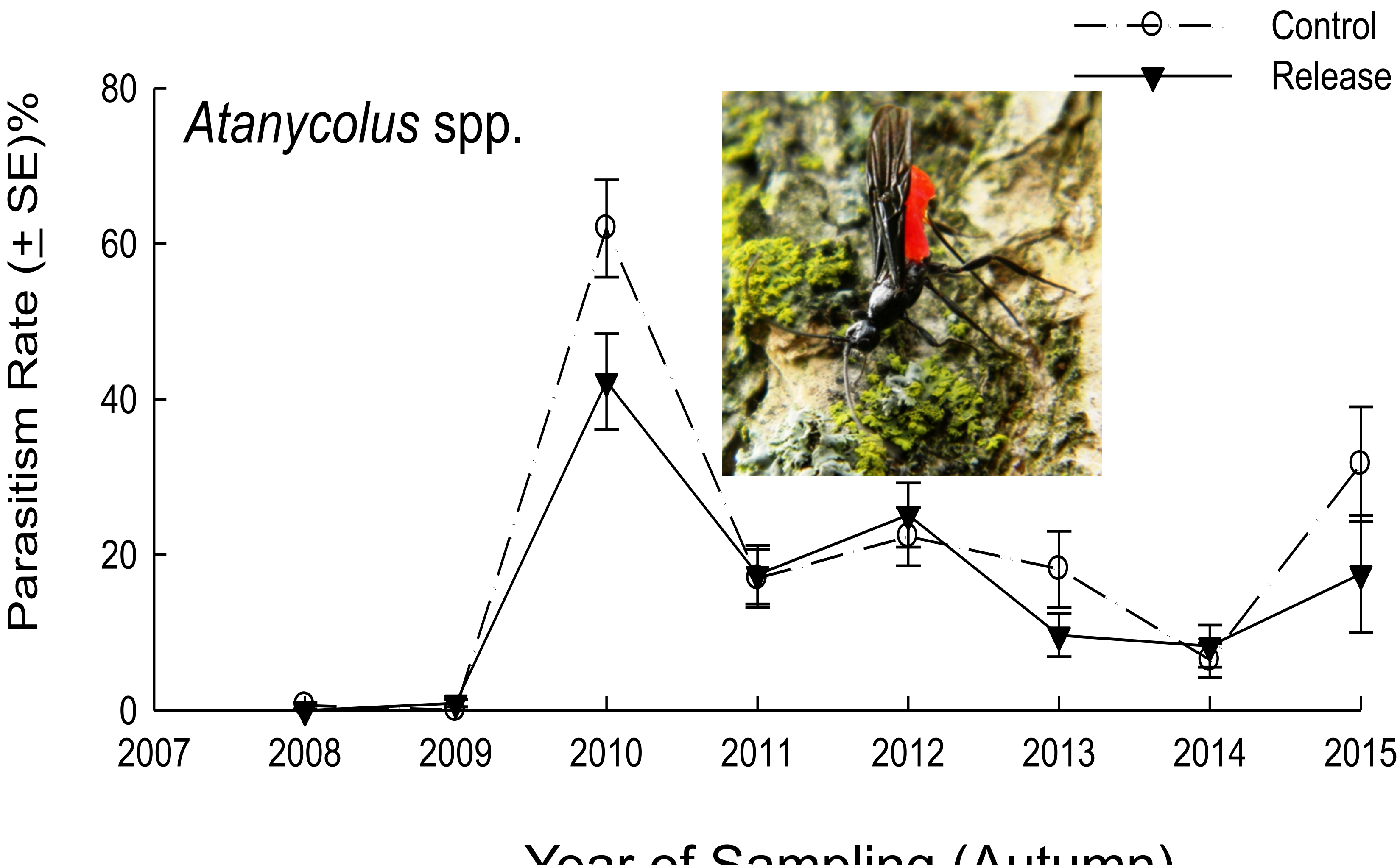
***Abell, Bauer, Duan, Van Driesche. 2014. Biol. Cont. 79: 36-42.**

Predation Rate by Birds on Larger Ash Trees (DBH = 7 – 21 cm)



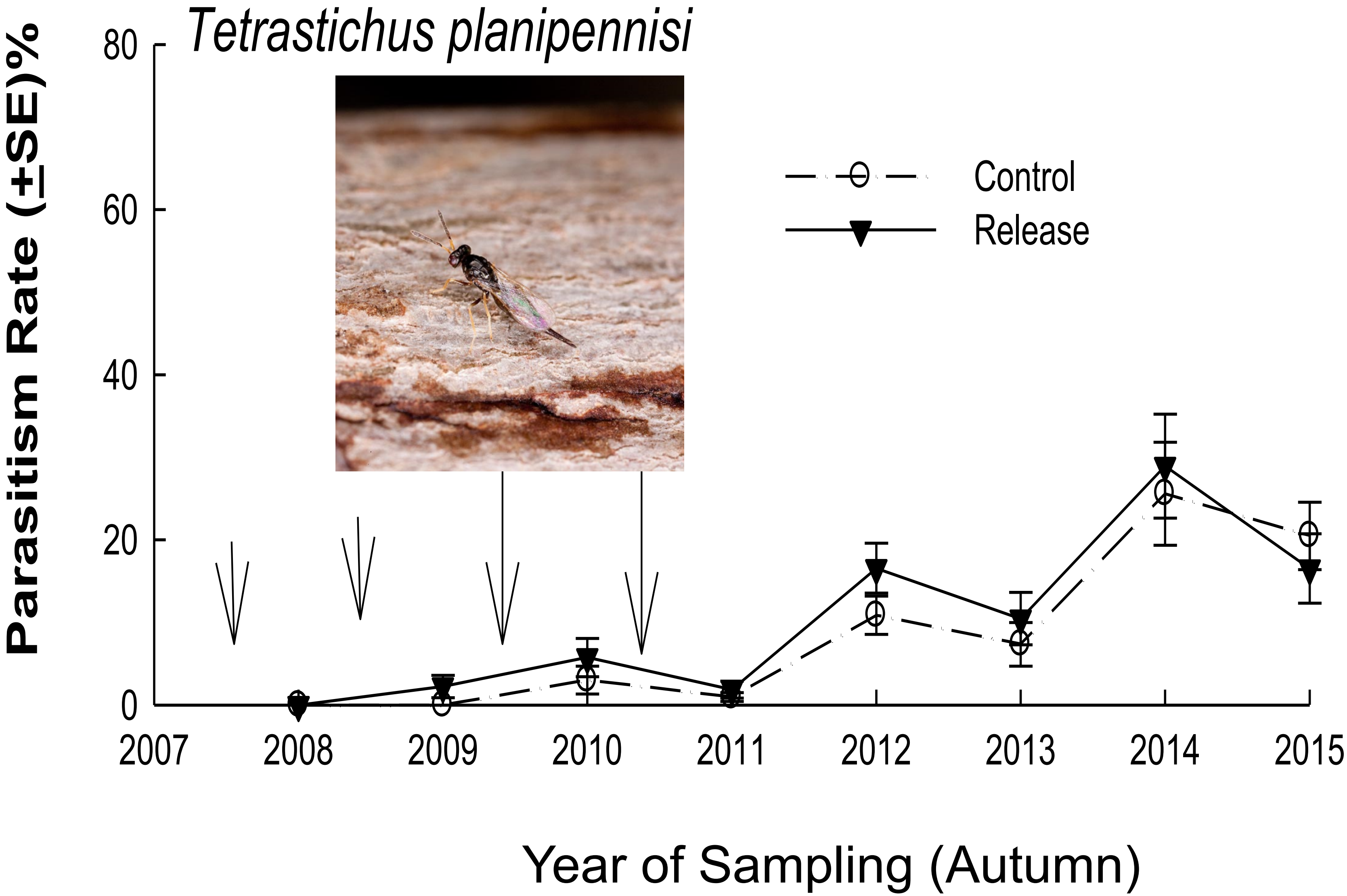
Duan et al. 2015 (J. Appl. Ecol. 1246 - 54)

Dynamics of EAB Larval Parasitism by Native Natural Enemies on Larger Ash Trees (DBH = 7 – 21 cm)



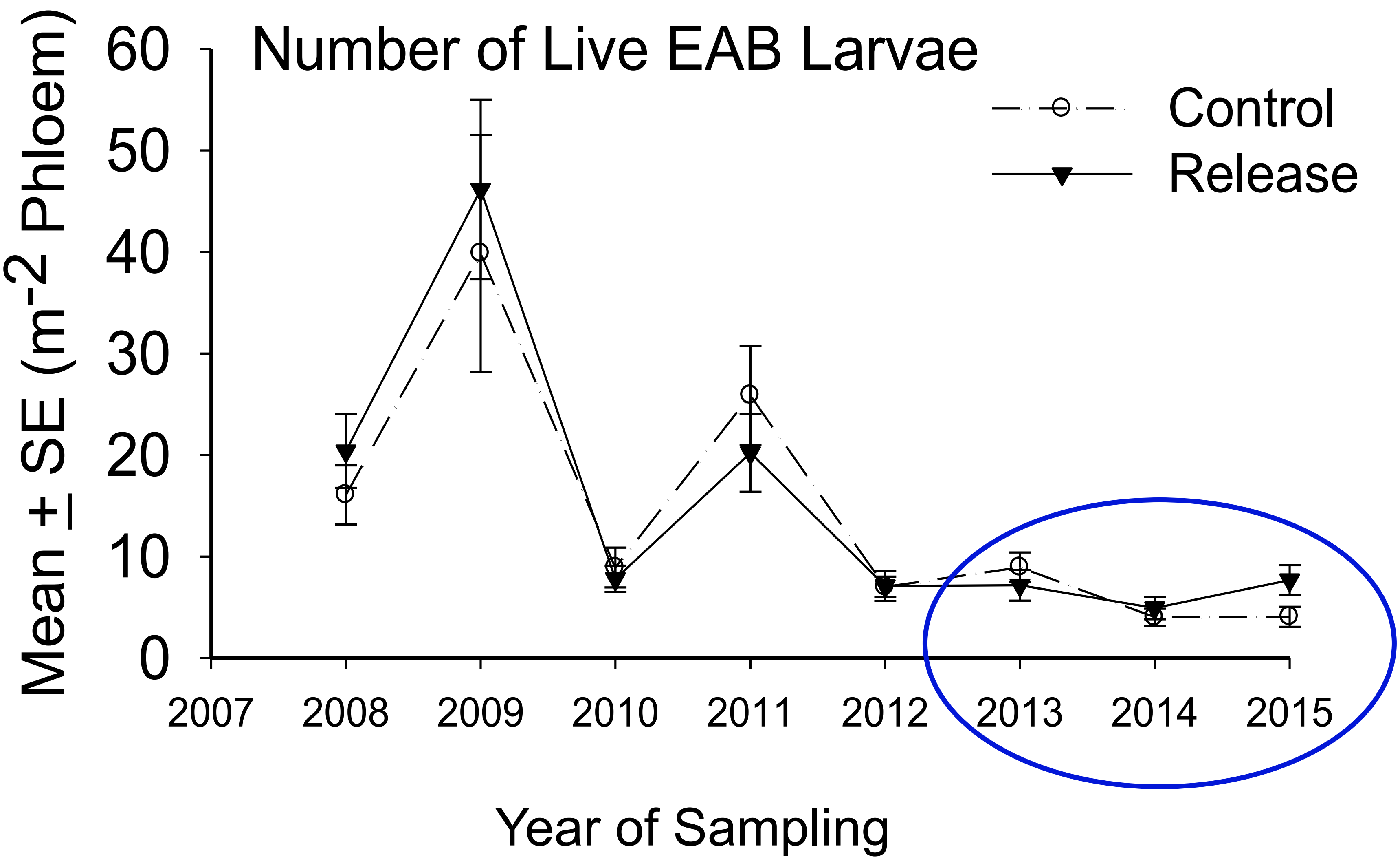
Duan et al. 2015 (J. Appl. Ecol. 52: 1246 - 54

Dynamics of EAB Larval Parasitism by Biocontrol Agents on Larger Ash Trees (DBH = 7 – 21 cm)



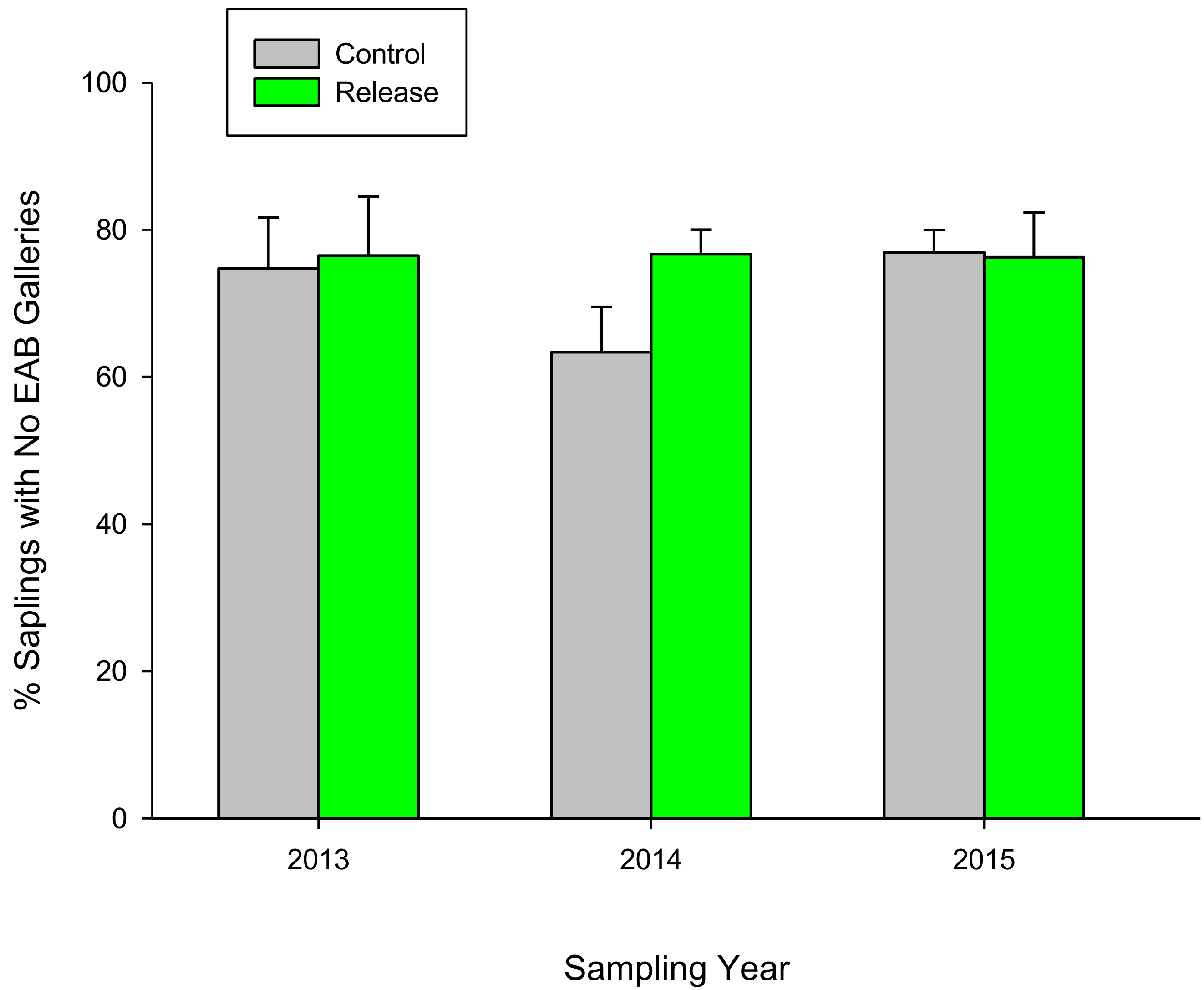
Duan et al. 2015 (J. Appl. Ecol. 52: 1246-54)

EAB Density Adjusted for Live Phloem Area on Larger Ash Trees (DBH 7 – 21 cm)

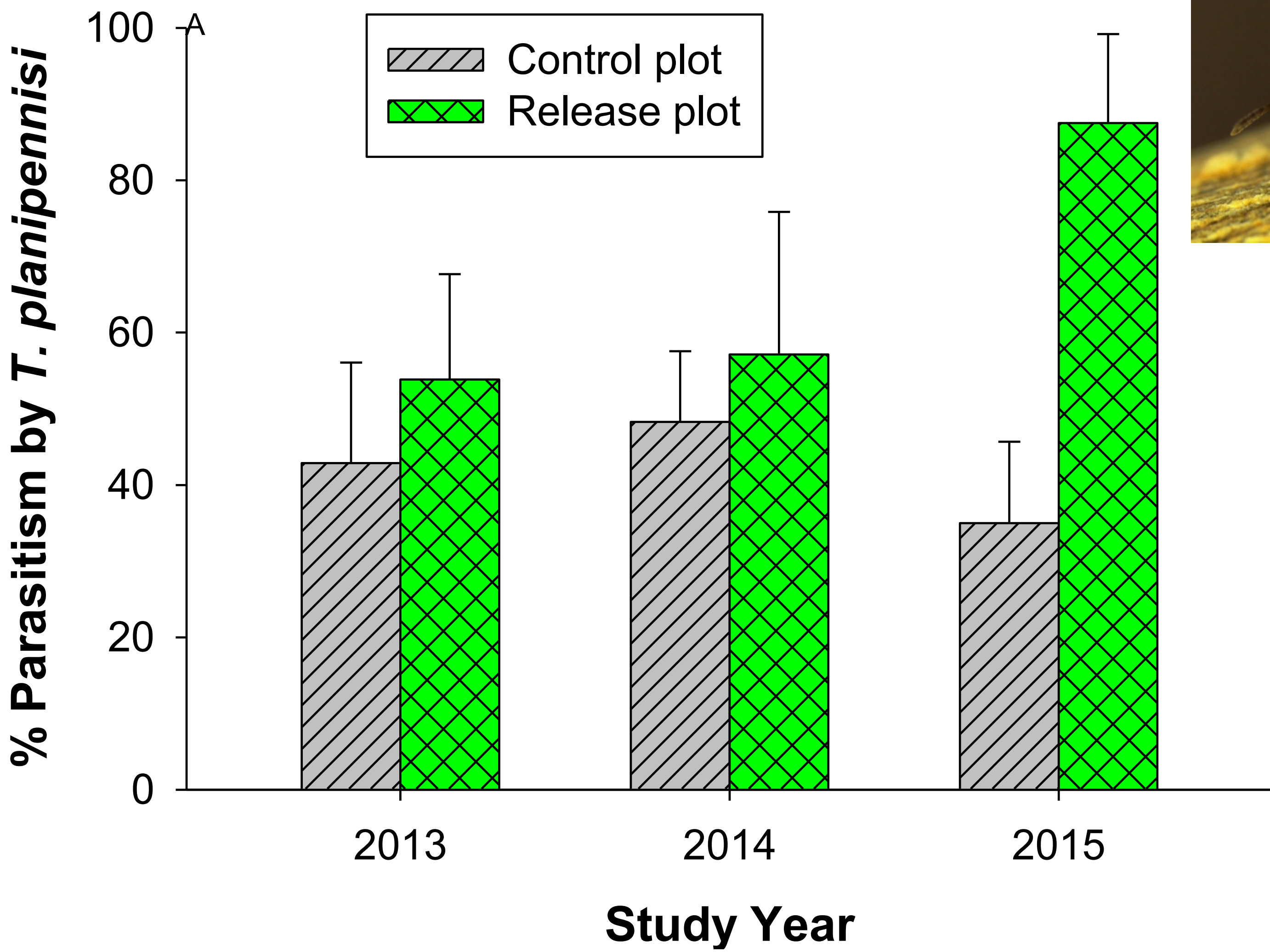


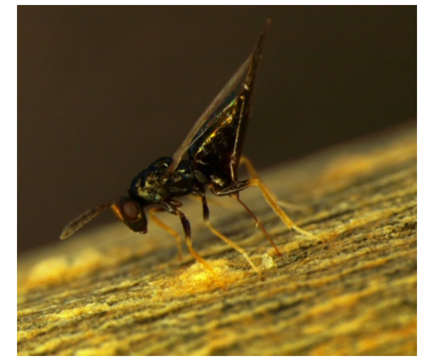
Duan et al. 2015 (J. Appl. Ecol. 1246 - 54)

EAB Infestation of Ash Saplings (DBH = 2.5 – 5.8 cm)



Parasitism of EAB Larvae in Saplings by T. planipennisi (36 – 85%): the Sole Dominant Mortality Factor





Summary (MI)

- **The native natural enemies (*Atanycolus spp*. and avian predator) played a key role in suppressing EAB population growth during the outbreak phase (2008-2010)**

- **The introduced biocontrol agent (*Tetrastichus planipennisi*) became a dominant mortality factor and significantly reduced EAB population growth on saplings and small trees in the aftermath of EAB invasion (2012 – 2015)**

- **Over 75% ash saplings survived the initial EAB invasion wave and now appear to be protected by *Tetrastichus planipennisi* (2013 – 2015)**

As ash trees grow out of size range protected by *Tetrastichus* will they survive?

Spathius galinae

Tetrastichus planipennisi

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IPM for EAB (MD)

1. Will a combination of systemic insecticide applications and biological control (release of parasitic wasps from EAB's native range) effectively suppress EAB populations and protect high value ash trees more so than biological control only?

2. Does biological control using parasitoids work better or worse for ash trees in built compared to natural forests?

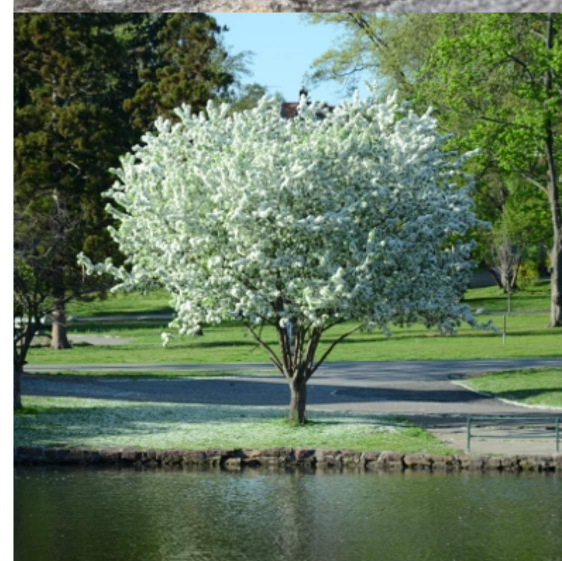
3. Novel Host Plant – White Fringetree

EAB moved to another Oleaceae!

Chionanthus virginicus D. Cipollini 2014

How Does *Tetrastichus planipennisi* Respond to EAB in White Fringetree, *Chionanthus virginicus*?

- **Evaluate the effect of EAB host plant, white fringetree compared to green ash, on the preference, performance and fitness of an introduced parastioid parasitoid, *T. planipennisi*.**



What should the U.K. be thinking about?

- Be prepared and have a plan
- Read literature, learn from U.S. and Canada
- Catch EAB early
  - Active monitoring and survey program
  - Train arborists, practitioners, citizens

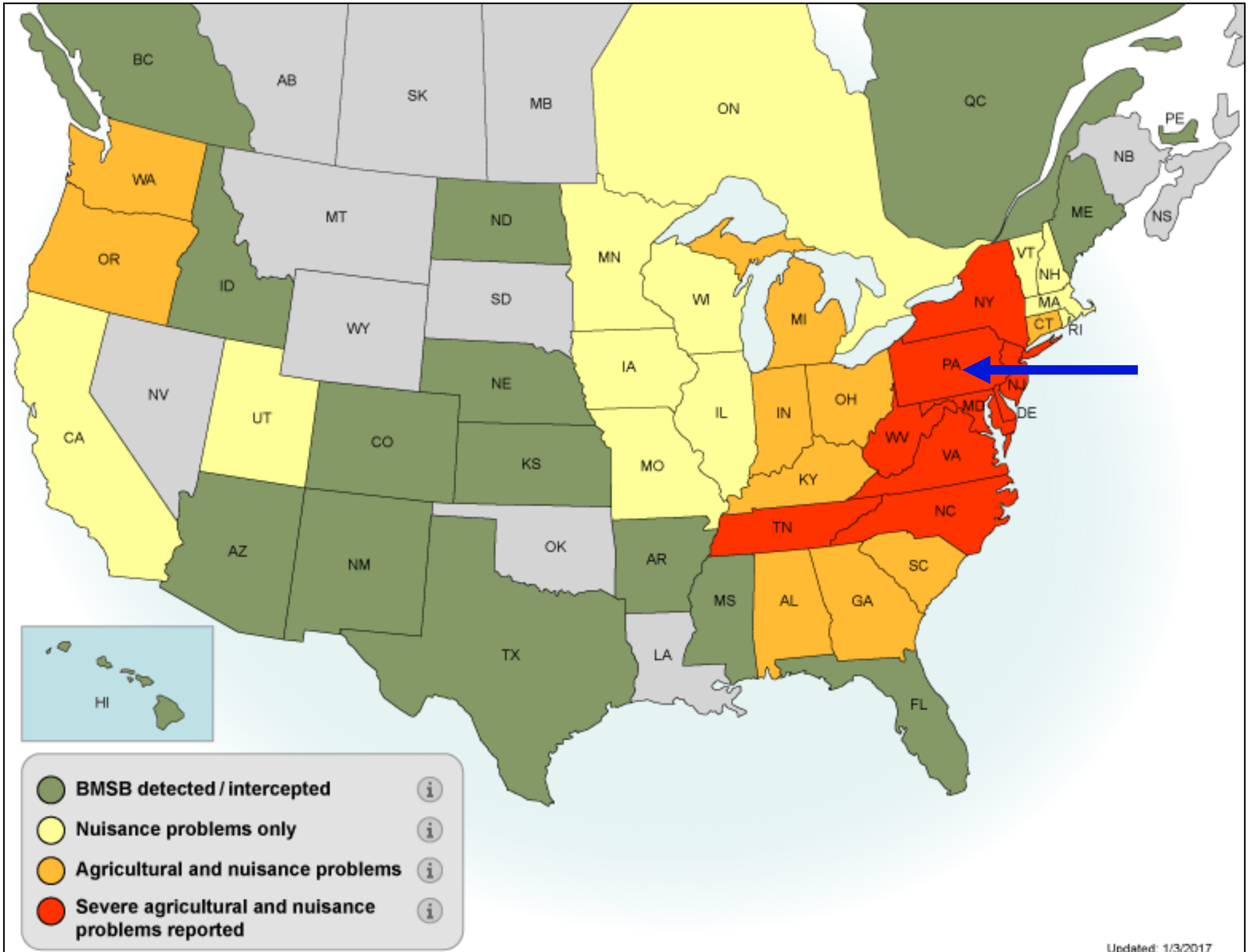
- When / if EAB arrives…
  - Treat "keeper" trees with systemic insecticide
  - Implement biocontrol program
  - Be prepared to remove lots of ash trees

- Remember… Biological control gives us HOPE!

Survey and impact of native and exotic natural enemies of the invasive brown marmorated stink bug, *Halyomorpha halys*, in the eastern U.S.

Paula Shrewsbury,
Ashley Jones, Cerruti Hooks,
Michael Raupp, David Jennings
Department of Entomology,
University of Maryland, USA

Brown marmorated stink bug detected in U.S. in mid 1990's, now spread to 43 states and 3 Canadian provinces; first reported in Europe in 2007 in Switzerland



Reported and Predicted Distribution of BMSB in Europe (climate model)

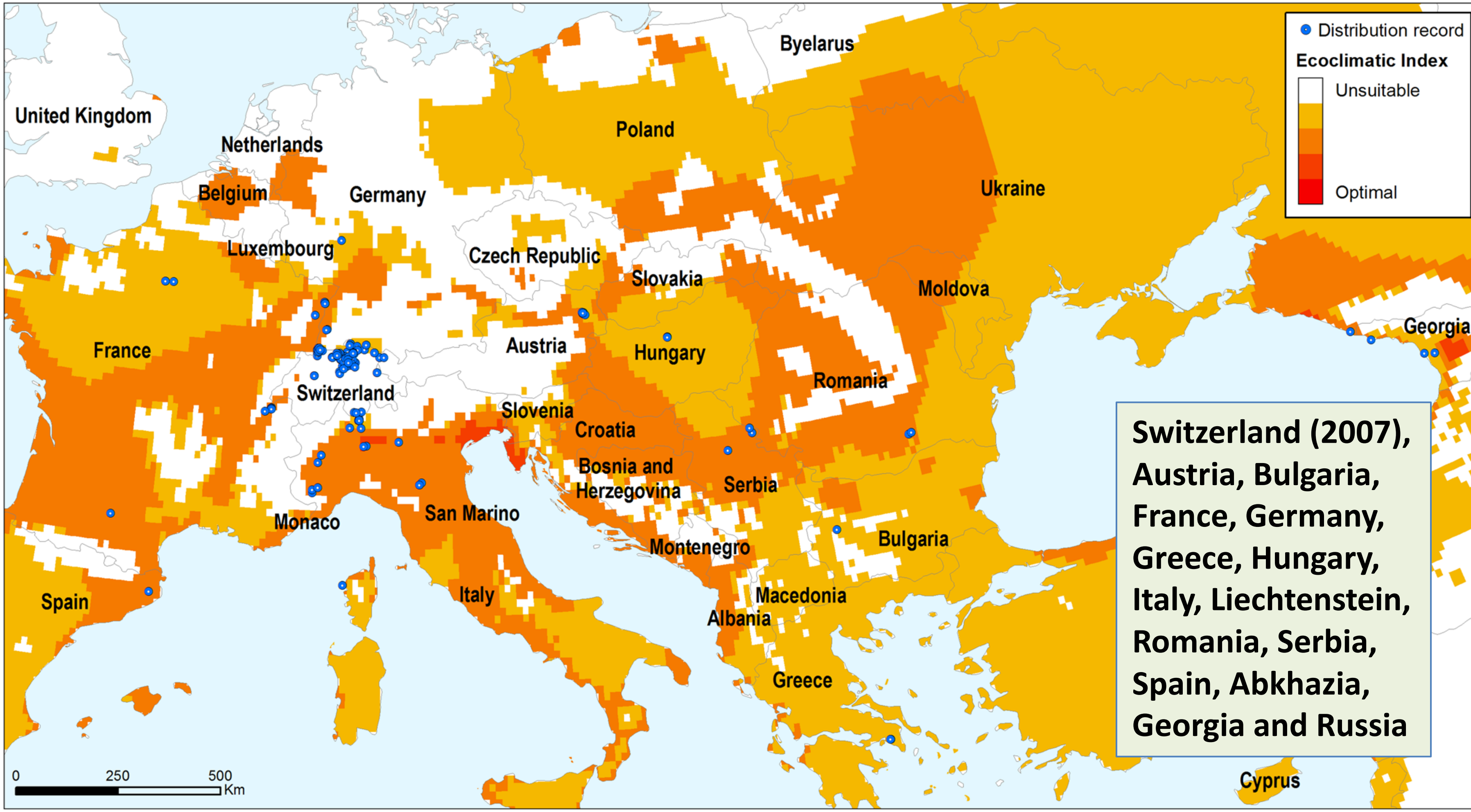


Fig. 3 Modelled climate suitability (CLIMEX Ecoclimatic Index) for *Halyomorpha halys* in Europe, including reported distribution locations

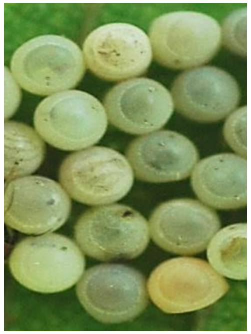
From: Kriticos et al. 2017. The potential global distribution of the brown marmorated stink bug, Halyomorpha halys, a critical threat to plant biosecurity. Journal of Pest Science.

BMSB Damage

- Nuisance pest in structures, buildings
- Economic pest in many cropping systems (tree fruits, small fruits, vegetables, legumes, corn)
- Feed on a wide variety of ornamental plant hosts (managed and natural habitats)

Biological Control of BMSB in Nurseries

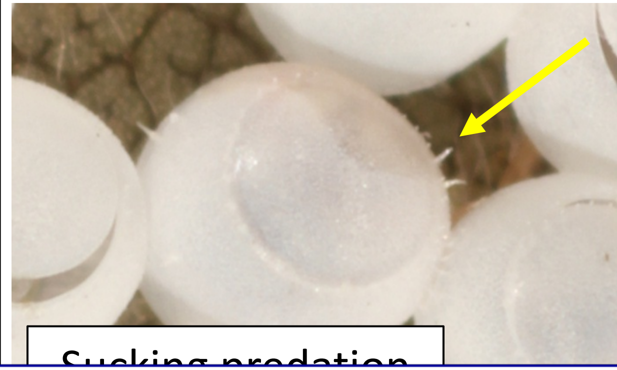
- **Obj. - Survey and identify native natural enemy activity in ornamental nurseries**
  - **BMSB egg mortality factors**
  - **Parasitoid complex and parasitism rates**
  - **Predator complex and impact**



No mortality


Newly laid

Mortality factors

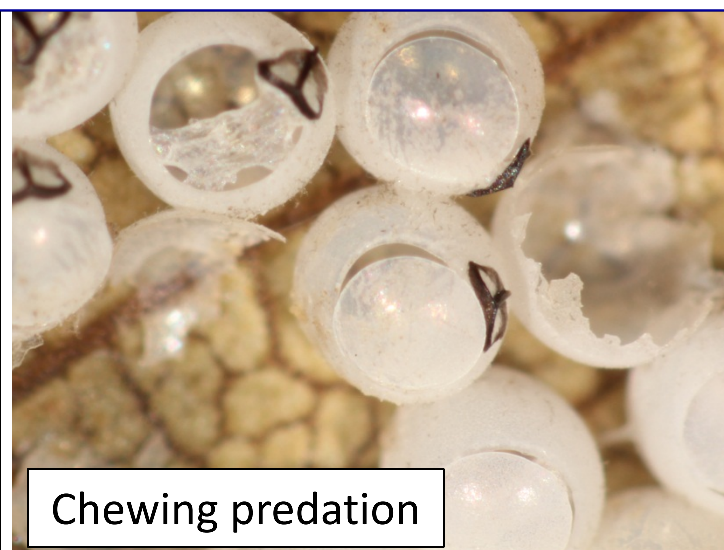

Sucking predation


Unascribed

2012: 897 egg masses > 24,124 eggs

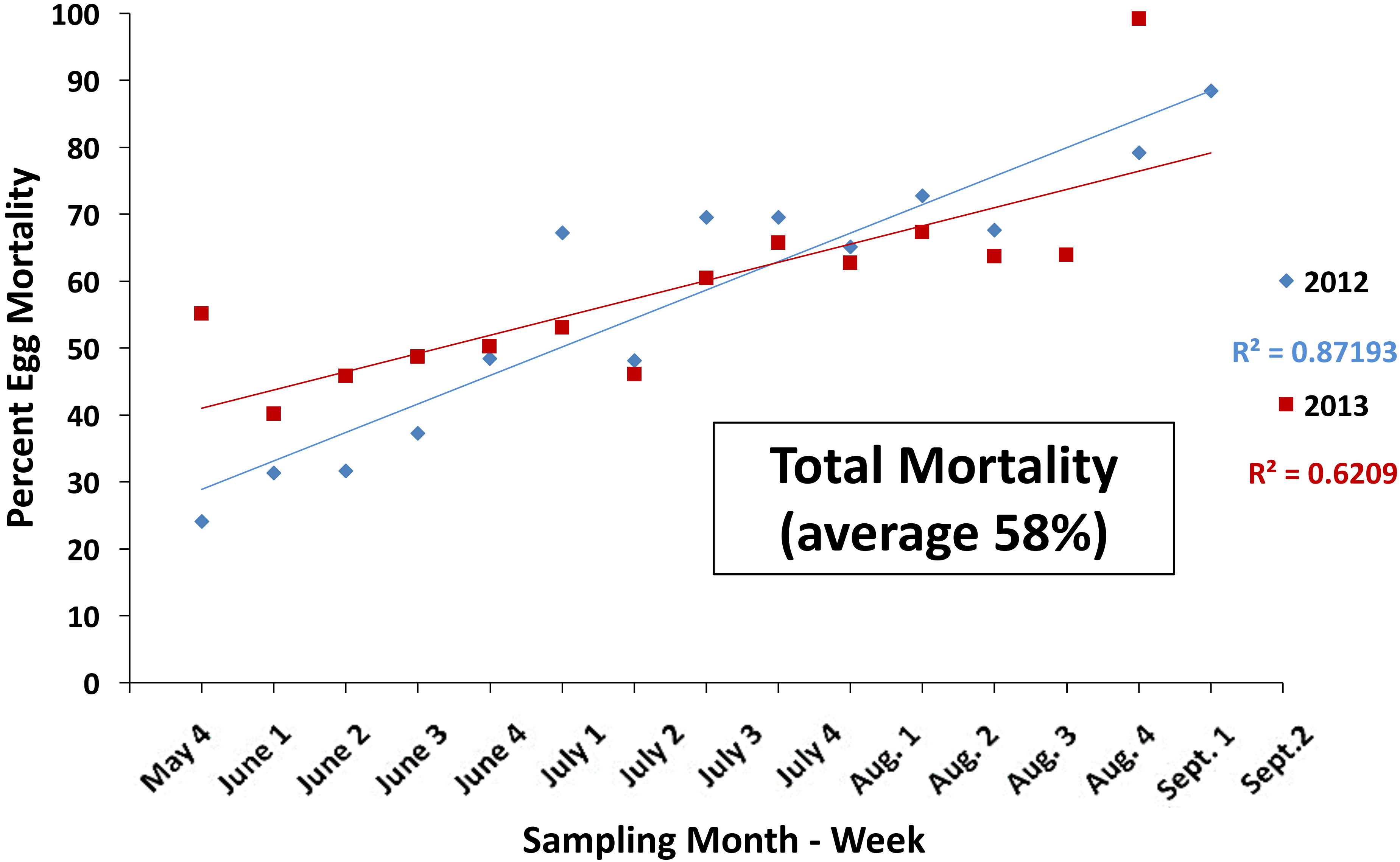
2013: 1,208 egg masses > 32,076 eggs


Hatched

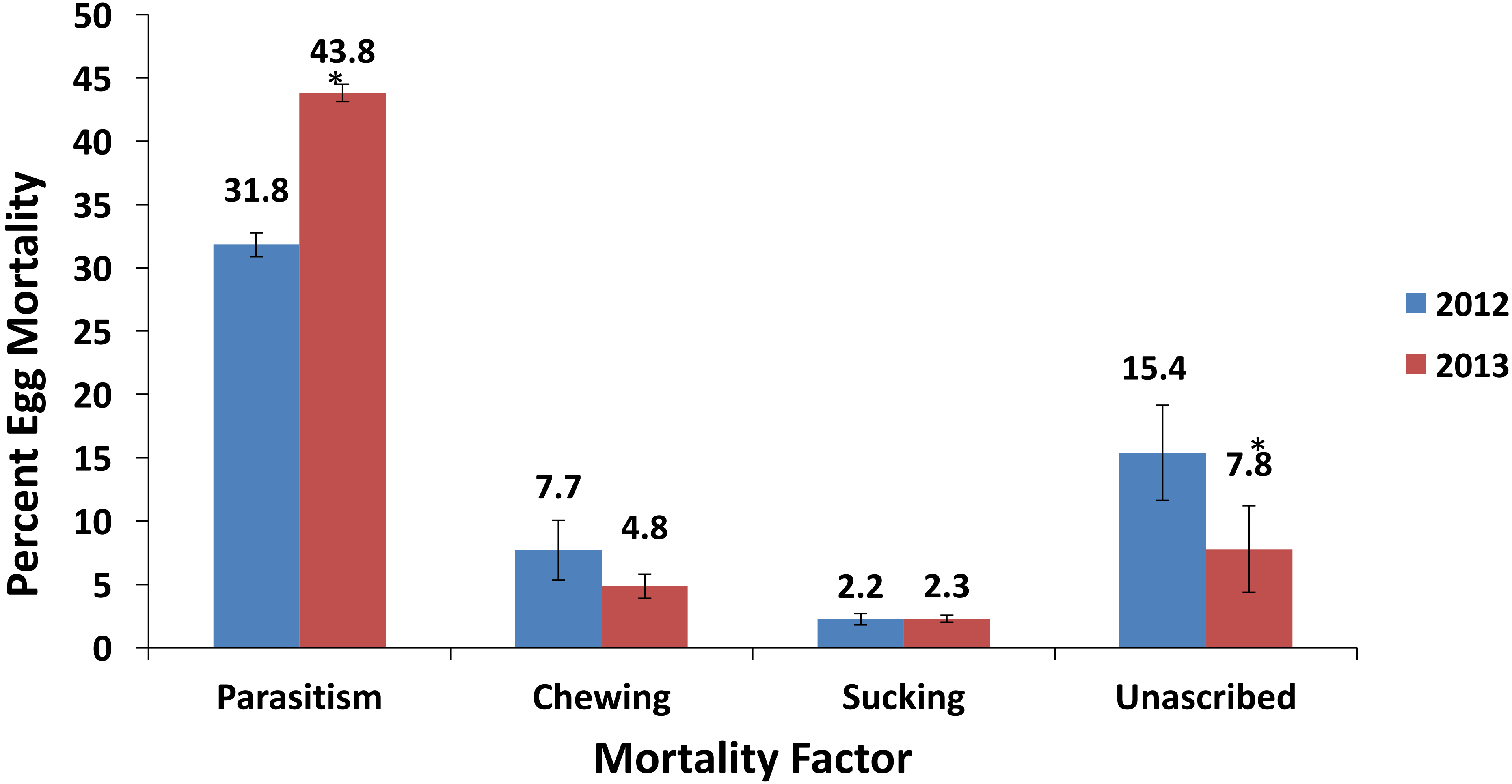

Chewing predation


Parasitized

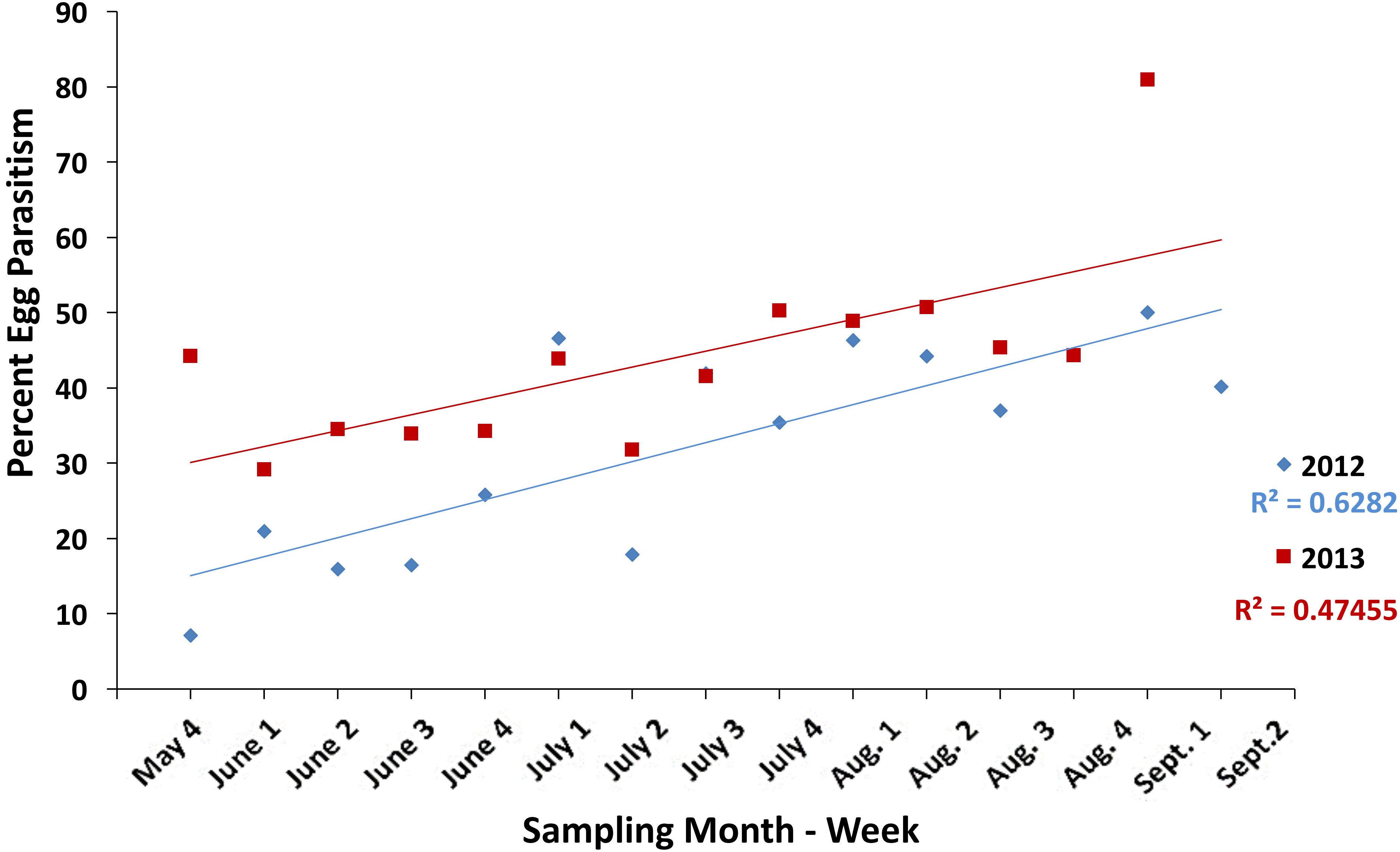
Percent BMSB Egg Mortality



BMSB Egg Mortality Factors

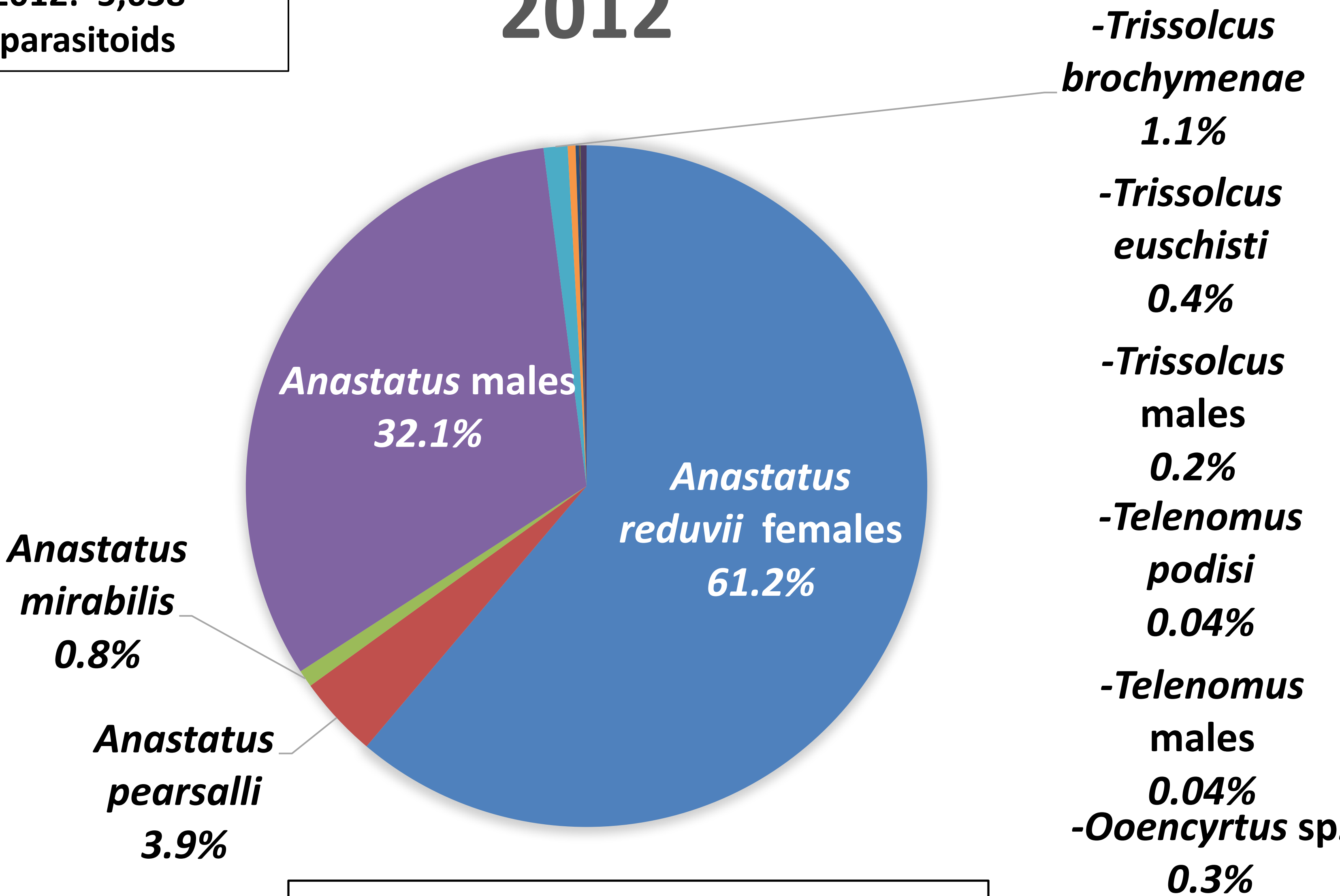


Percent BMSB Egg Parasitism



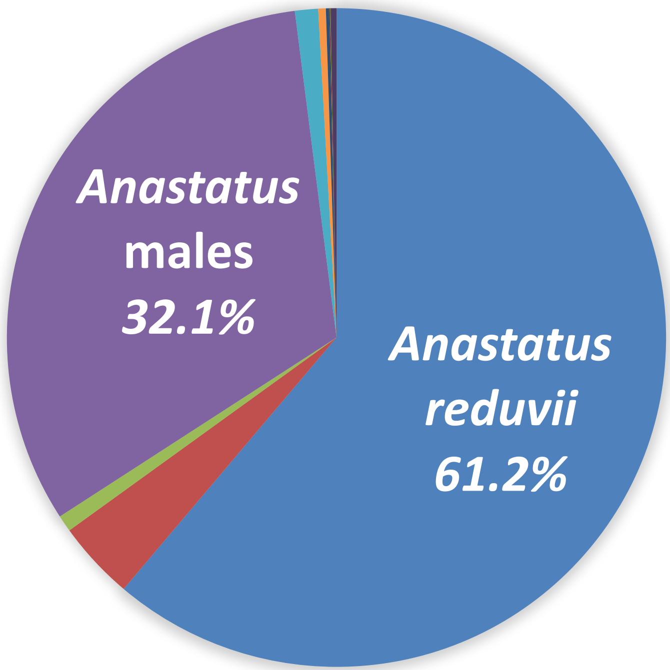
2012: 5,638 parasitoids

2012



***Anastatus* total: 98%**

2012

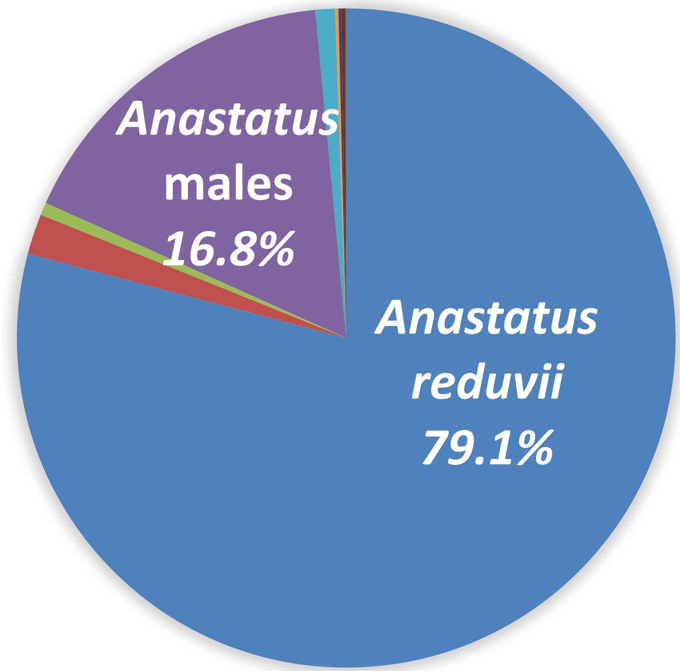


5,638 parasitoids

24,124 eggs

1 : 2.05 M:F ratio

2013

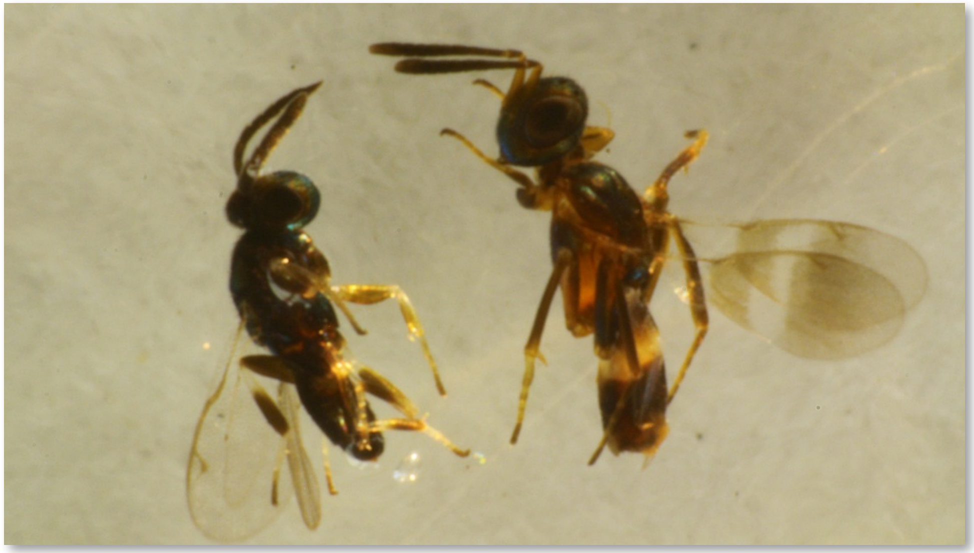


9,719 parasitoids

32,073 eggs

1 : 4.86 M:F ratio

Anastatus reduvii (Eupelmidae)



Anastatus pearsalli

Anastatus mirabilis

Summary

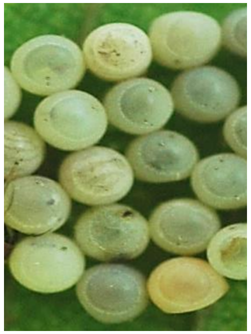
- Egg mortality from all sources averaged 58%
- Mortality increased throughout the season

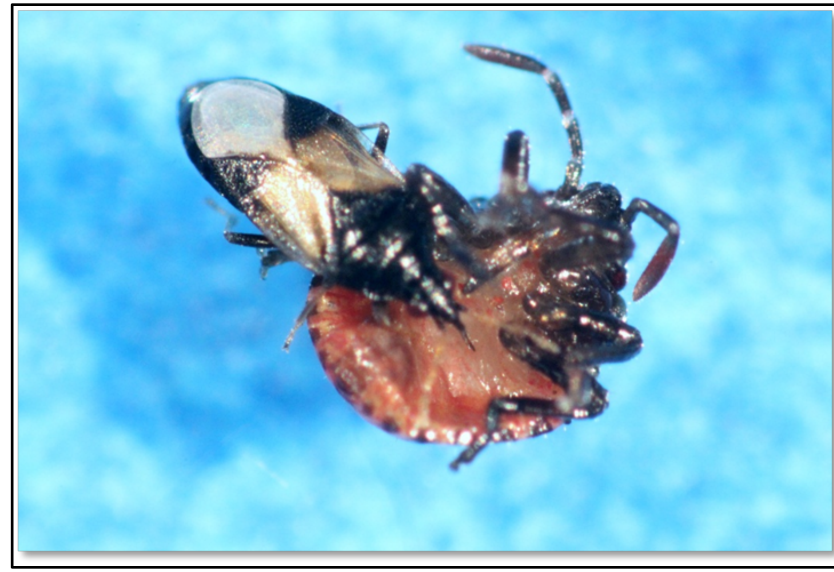
- Native parasitoids are attacking BMSB eggs
- Greatest cause of egg mortality
- Higher rates of parasitism in year 2 (~32% - 44%)
- Increased proportion of females = expanding population

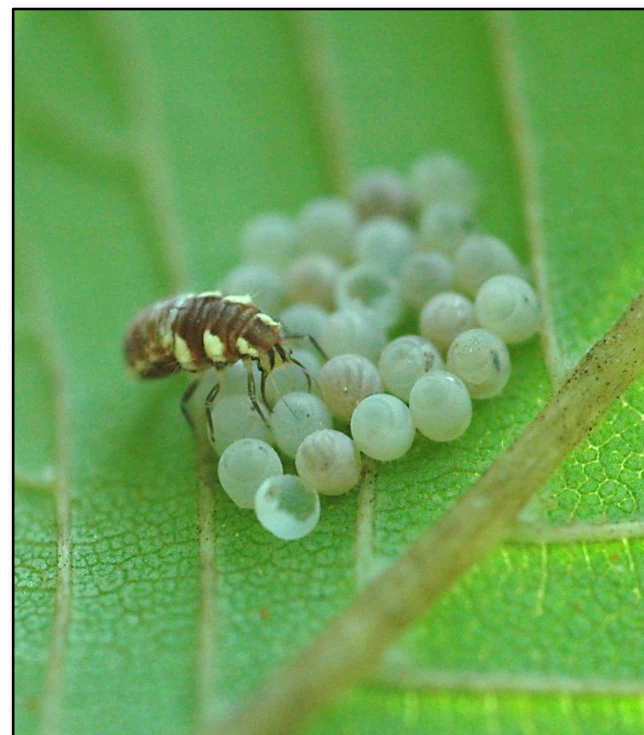
- *Anastatus reduvii* was the most abundant parasitoid
  - Generalist across orders
    - Hemiptera, Lepidoptera, Mantidae, Orthoptera, Neuroptera
  - Appear to be a habitat specialist (arboreal)

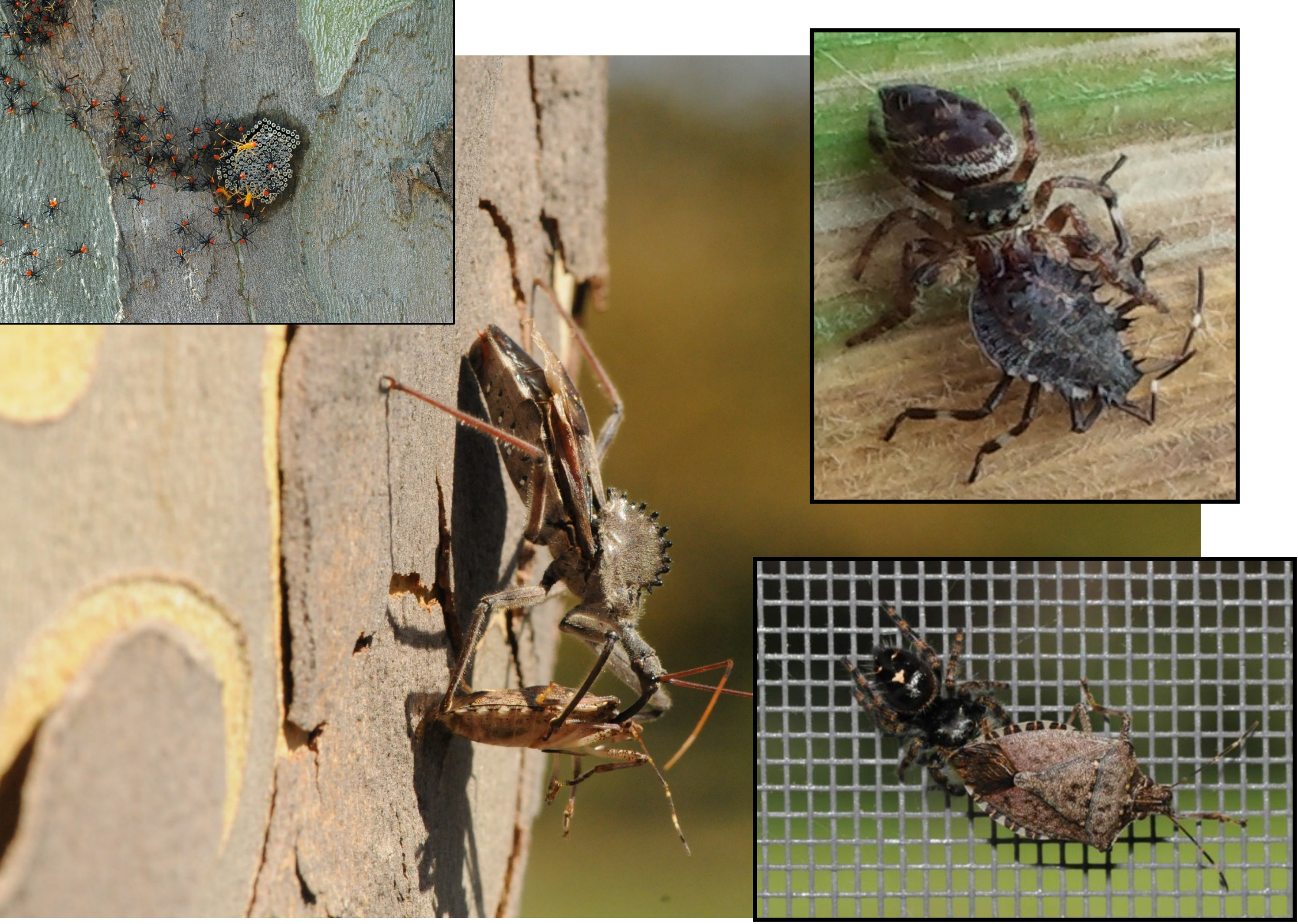
Biological Control of BMSB in Nurseries

- **Obj. - Survey and identify native natural enemy activity in ornamental nurseries**
  - BMSB egg mortality factors
  - Parasitoid complex and parasitism rates
  - **Predator complex and impact**
    - **Field observations**
    - **Lab feeding trials**





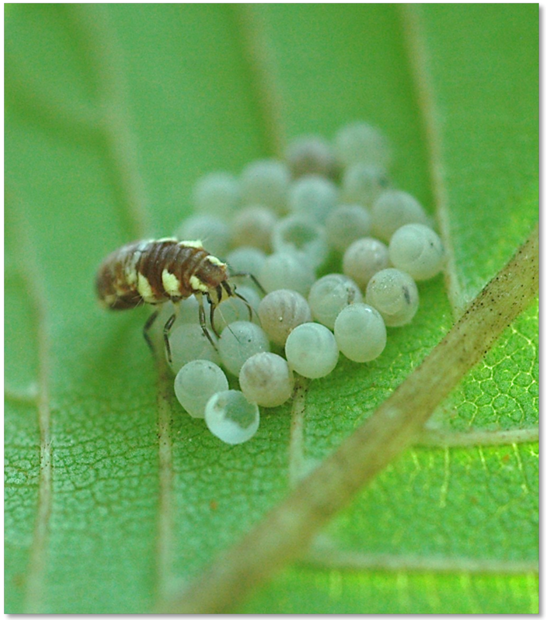




Predator complex and impact

Summary

- Several predator species attacked active stages of BMSB (field)
- Wheel bugs (*Arilus cristatus*) the most voracious predators (lab)
  - Consumed both nymphs and adult stages
- Egg predation was low
  - No predators consumed eggs (lab)
  - Egg field survey; egg predation only 7-10%



Conclusions – Ornamental trees in MD (U.S.)

- **Native natural enemies are attacking BMSB (~58% egg mortality)**

- **Egg parasitism rates range 7-80%, average ~40%**
- **Parasitoids may be responding to new host resource**

- **Predators attack BMSB eggs but at low rates**
- **Predators attack active stages of BMSB**
- **Wheel bugs (*Arilus cristatus*) the most voracious predators (lab)**

Native natural enemies vary between habitats and location – diversity and impact

New studies of native and exotic natural enemies

1. Conservation strips
   -Nurseries

2. Survey and monitor for natural enemies that attack the egg stage
   a. Sentinel eggs
   b. Citizen science

Project Stink-be-Gone

Dr. Rebeccah Waterworth, UMD

1. Management of BMSB

- Conservation strips of floral resources in nurseries
- Select plants

- Conservation strips attract natural enemies and pollinators

Questions:

1. Is the abundance and diversity of natural enemies enhanced with conservation strips?
2. Is there increased biological control of BMSB? Of other pests?

2. Survey and Monitor Natural Enemies

a. Sentinel Eggs - Identify natural enemies associated with BMSB in different crops

b. Citizen Science - Expand area to survey for native and exotic natural enemies of stink bugs

Project Stink-be-Gone

From a pool of Master Gardeners:

1. Recruit
2. Train
3. Process and identify samples as they were sent to campus

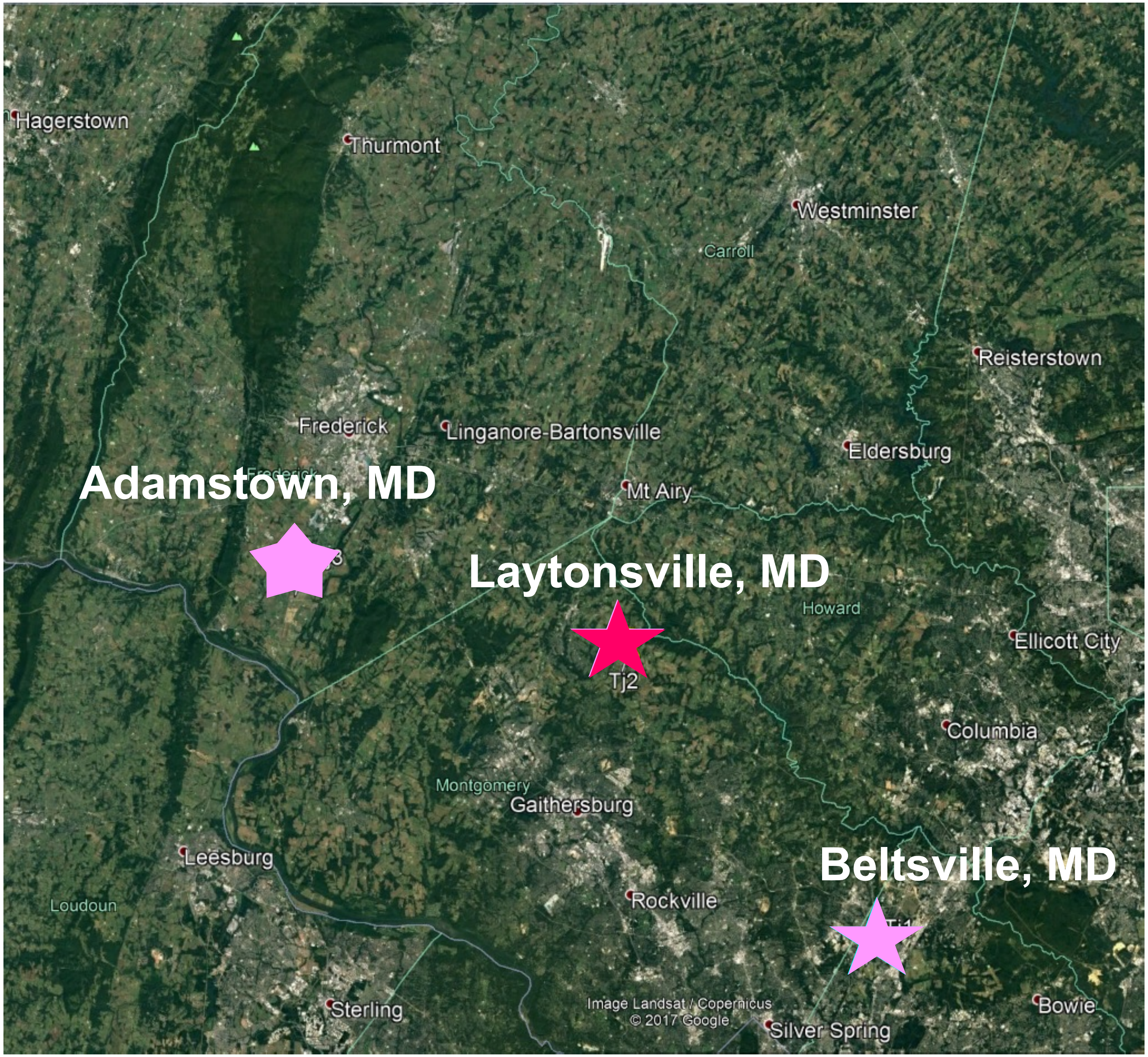
Results from sentinel eggs and sticky cards

*Trissolcus** Species	Zelkova	Peaches	Apples	Corn	Soybean	Wooded Edge
T. brochymenae	30	12	24	7	3	55
T. euschisti	19	4	2	1	0	33
T. edessae	0	4	1	0	2	2
T. japonicus	0	2	0	0	0	10
T. thyantae	10	6	9	0	1	18

Wasp Genus	Zelkova	Peaches	Apples	Corn	Soybean	Wooded Edge
Trissolcus	X		X	X		X
Telenomus		X		X		
Ooencyrtus				X		
Anastatus	X	X		X		X

*** Not standardized for sampling effort**

Where did we find the exotic species *T. japonicus*?



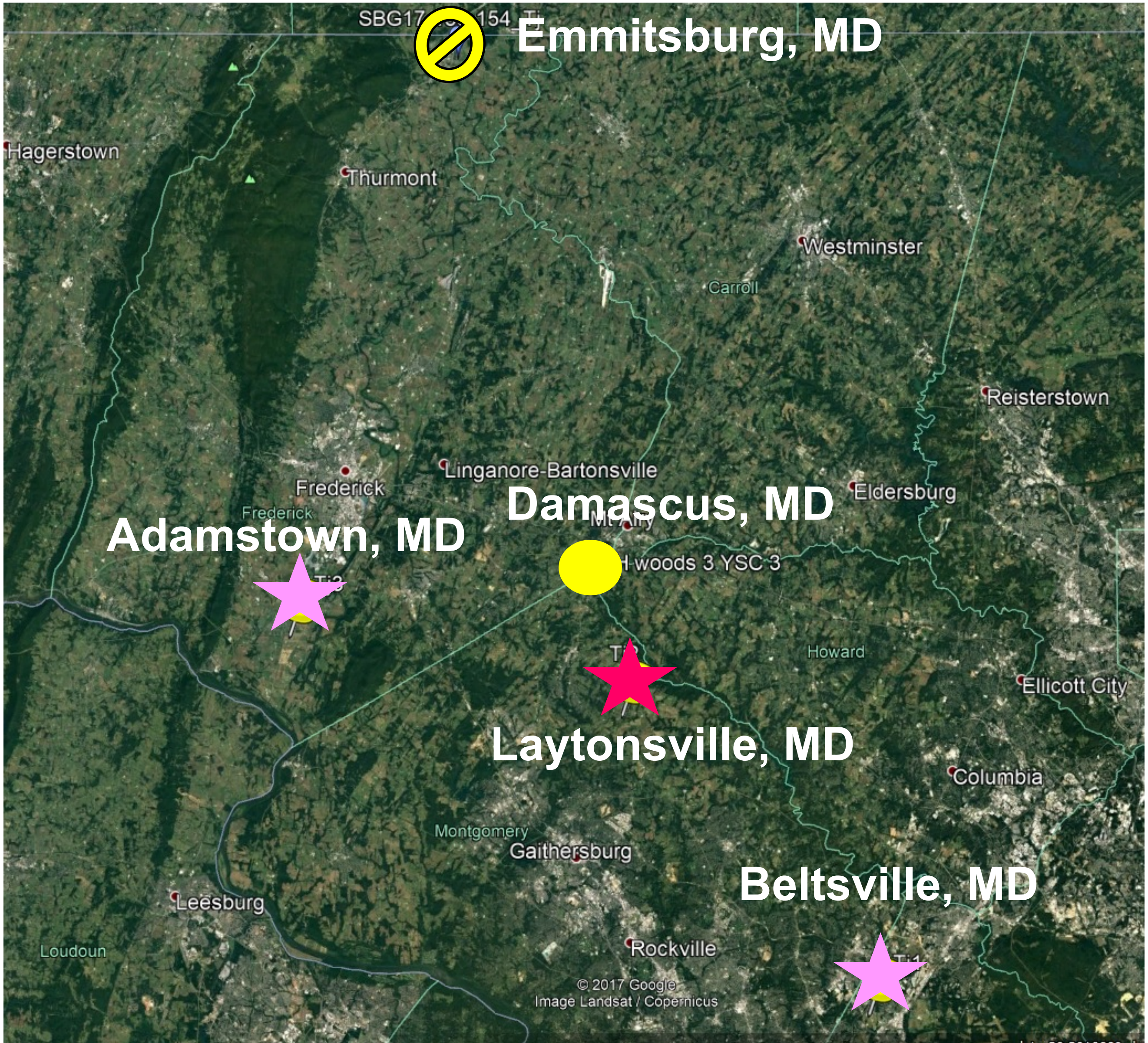
Recoveries from sentinel egg masses:

★ **2014**

★ **2015**

★ **2016**

Where did we find the exotic species *T. japonicus*?



2017 Recovery (yellow sticky cards)

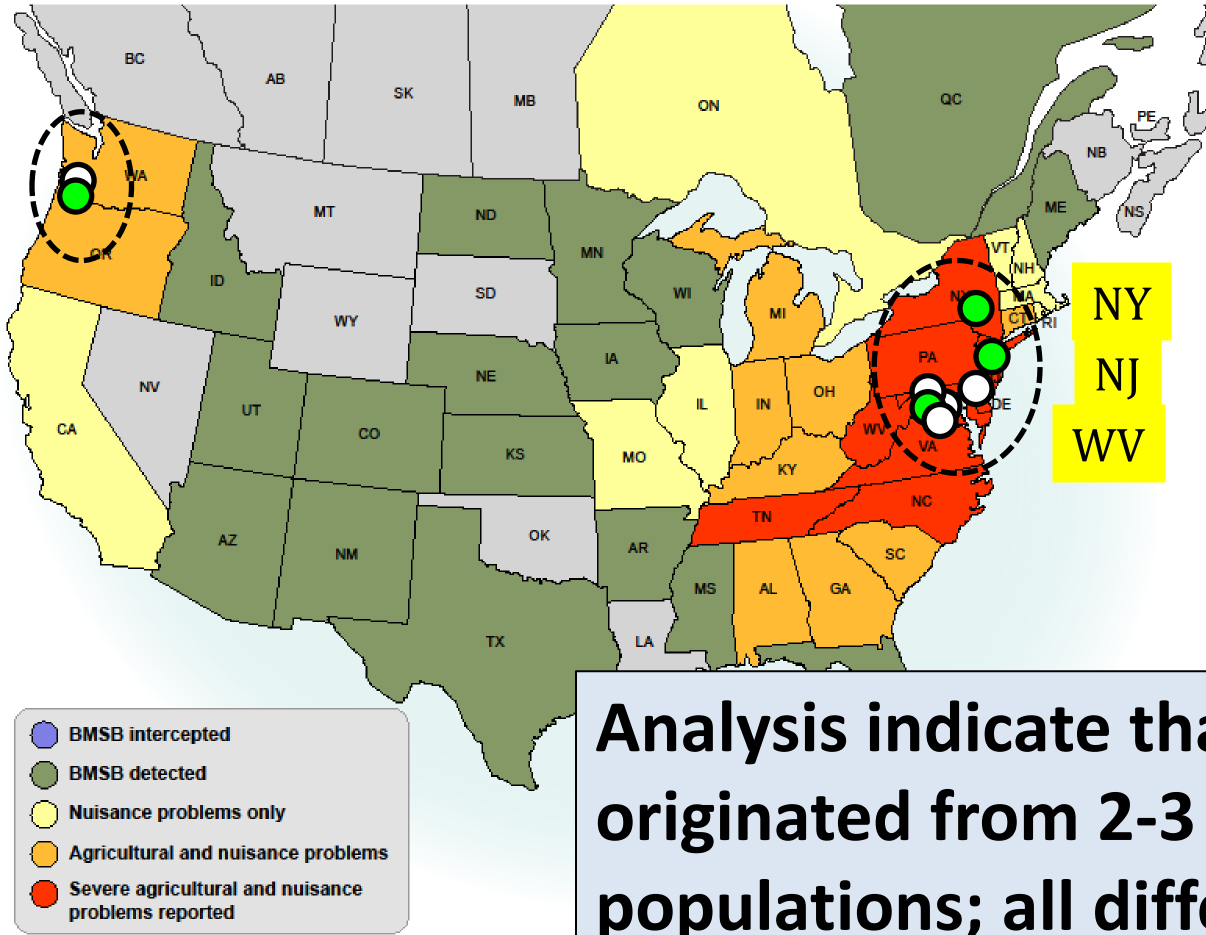
2017 Recovery (Citizen Science)

Project Stink-be-Gone

U.S. Field recoveries of *Trissolcus japonicus*

(as of Nov. 2016)

Oregon



NY

NJ

WV

New states

Analysis indicate that Tj originated from 2-3 distinct populations; all differ from populations in quarantine

Conclusions

1. EAB - Biological control shows promise in Michigan where parasitism rates are increasing and in Maryland where establishment was successful
2. BMSB – Indigenous natural enemies now attack and kill significant numbers of BMSB in nurseries and landscapes – damage to crops and home invasions have declined dramatically
3. Surveys by citizen scientists help scientist understand the distribution of natural enemies
4. Tiny wasps (and their allies) are helping mitigate the impact of exotic invaders like EAB and BMSB

Project Stink-be-Gone

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