Visit to Australia & New Zealand – February 2020

Status of Biocontrol and Management of *Halyomorpha halys*, *Drosophila suzukii* & *Lycorma delicatula* in the USA

Kim Hoelmer

USDA-ARS Beneficial Insects Introduction Research Unit, Newark DE, USA

H. halys - a severe agricultural & urban nuisance pest in USA

- ❖ Broad host plant range – fruit, nuts, vegetables, ornamentals
- ❖ Aggregates in the fall months to overwinter
- ❖ Enters buildings in large numbers - including homes
- ❖ Strong odor
- ❖ Staining secretions

History of BMSB in the USA

First suspected specimens collected in Allentown, PA — 1998

First properly identified specimen in the USA. Collected in Allentown, PA — 2001

First confirmed MD specimen — 2003

Continued spread and localized reports of injury in Allentown, PA area — 2004–2006

First widespread reports of late season injury in tree fruit in Mid-Atlantic — 2007–2008

Serious late season injury in tree fruit in Mid-Atlantic — 2008–2009

Severe crop injury and serious nuisance problems throughout the mid-Atlantic. — 2009–2011

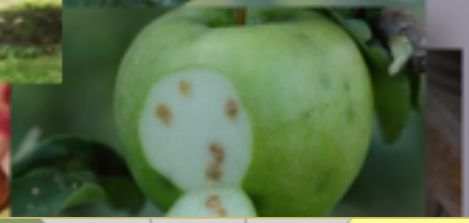
Aggressive chemically-based management. Late-season populations down in most locations, higher than others. — 2010–2011

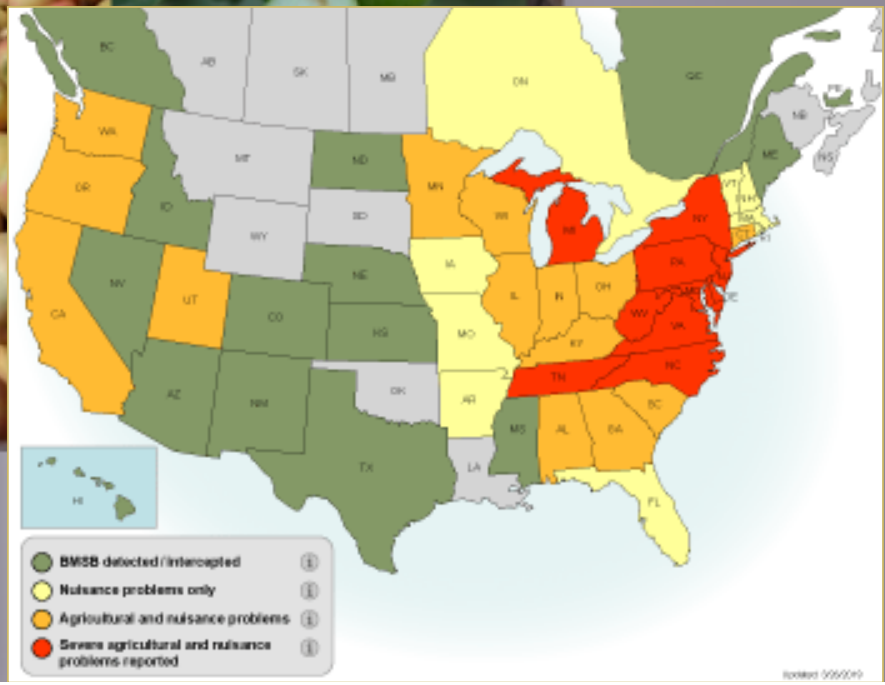
Secondary pest problems become common in east and increasing populations in west and southeast — 2011–2012

Rebuilding IPM and mitigating risk — 2012–2013 - Present

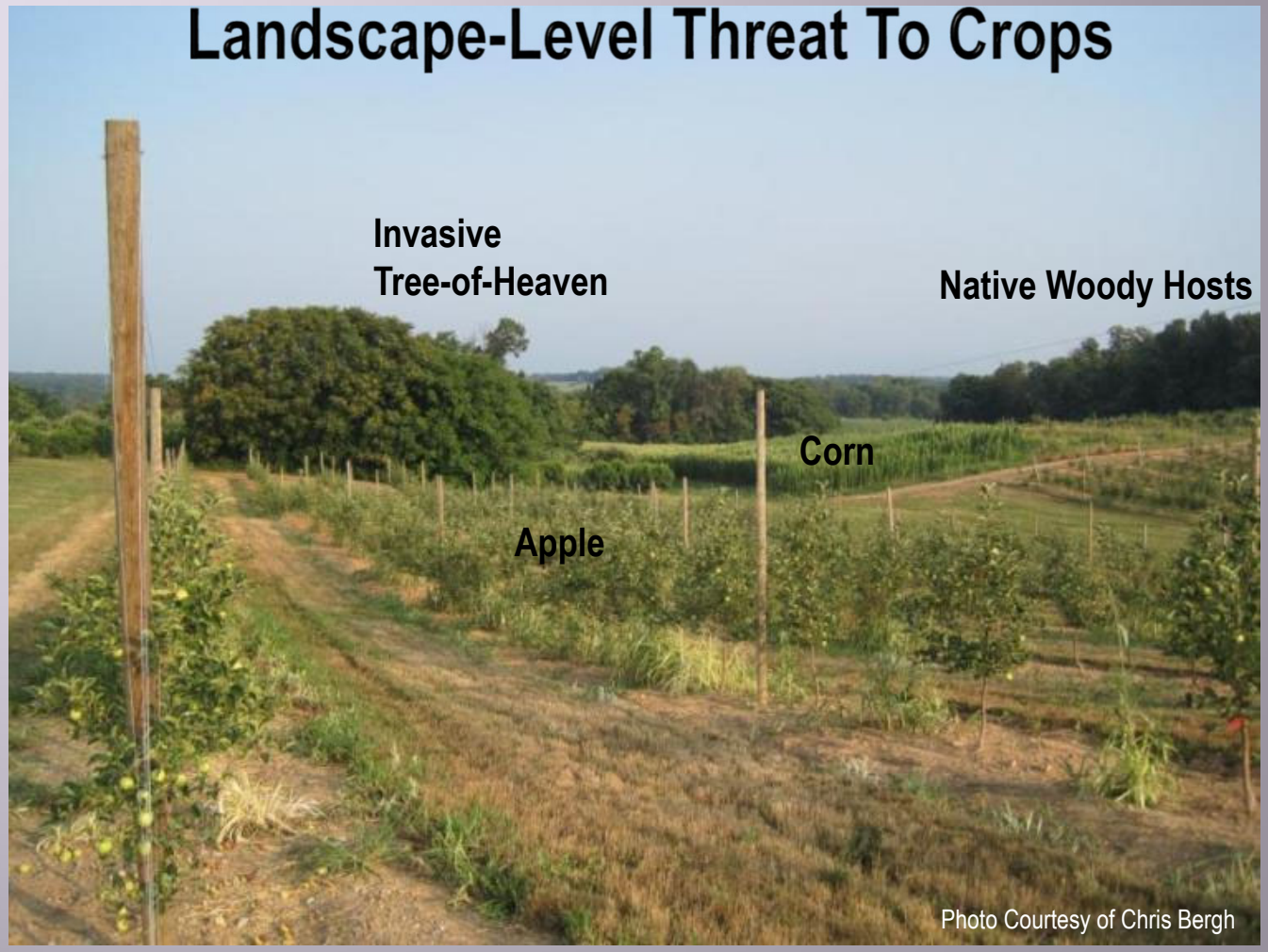
1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 - Present

BMSB IS STILL A SERIOUS PEST OF FRUIT

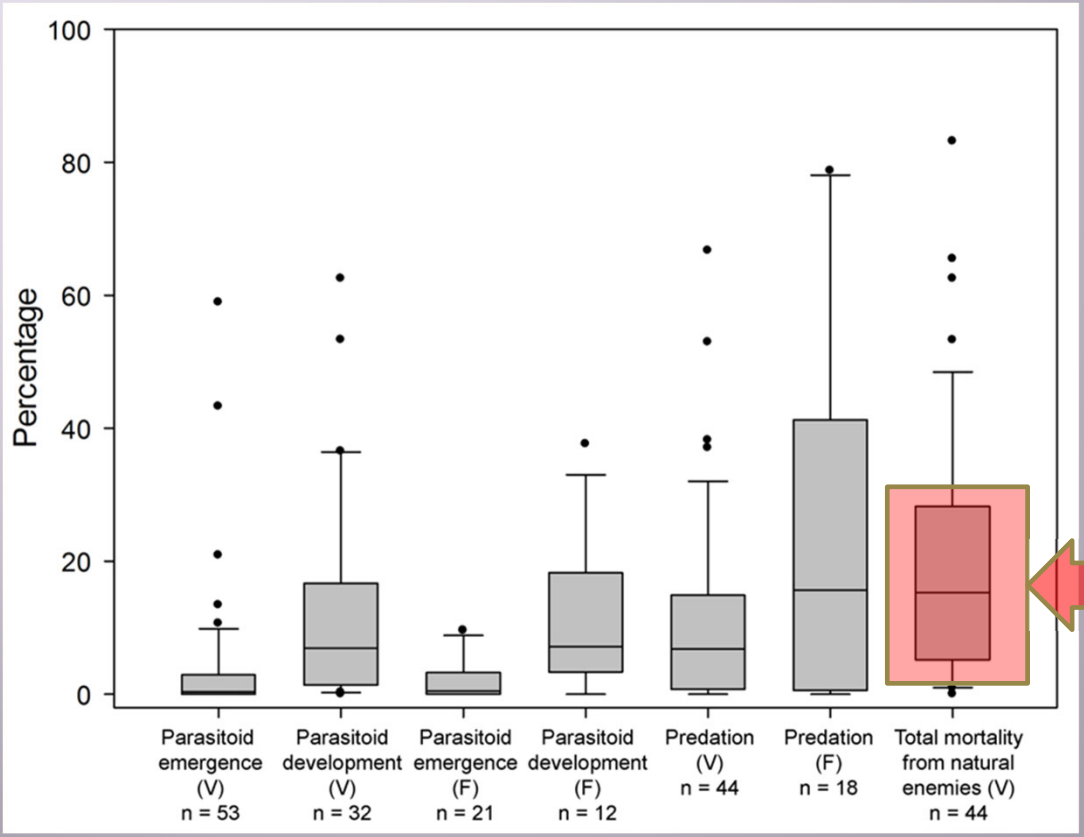




Landscape-Level Threat To Crops



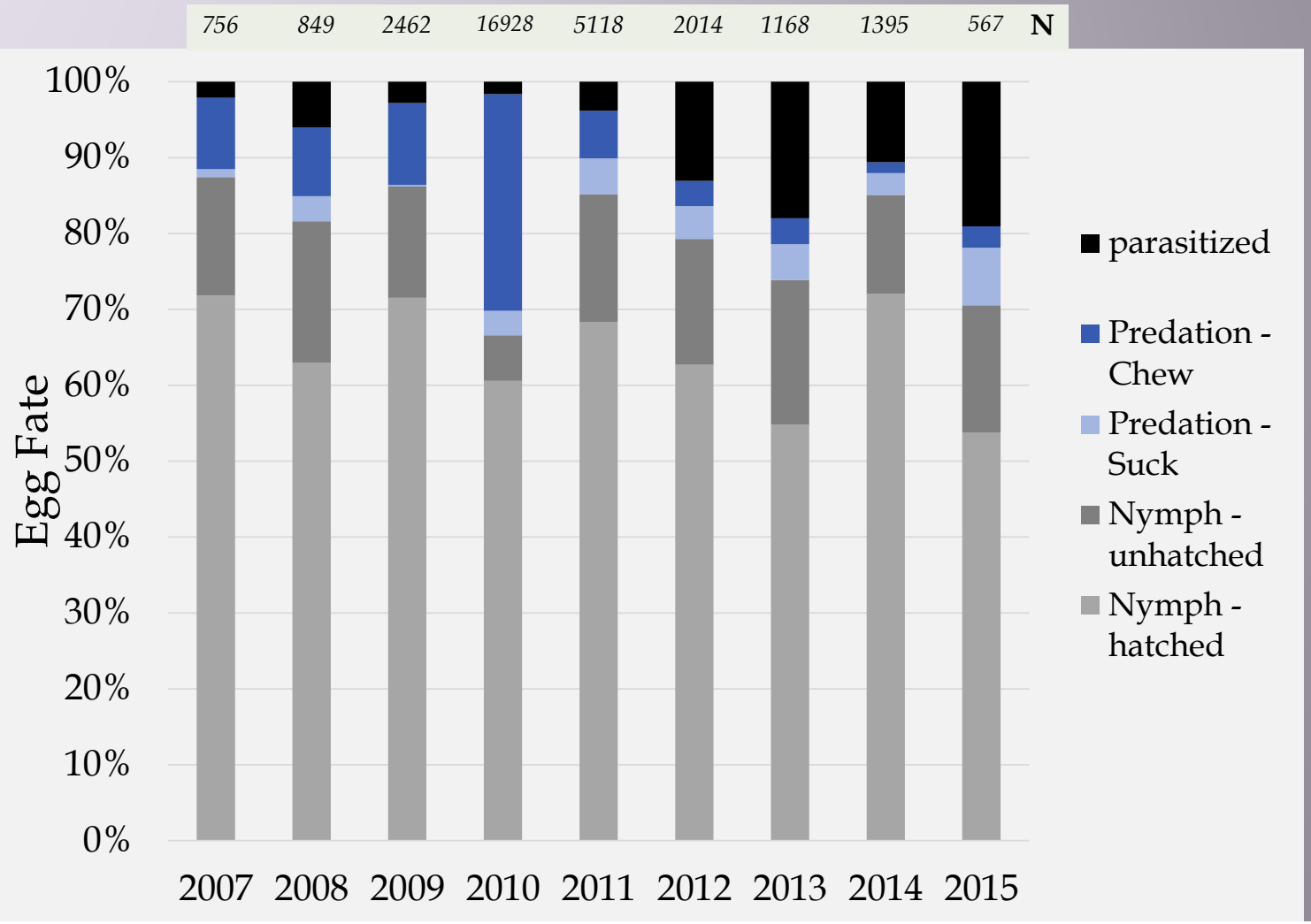
Indigenous predators & parasitoids have limited impact on BMSB



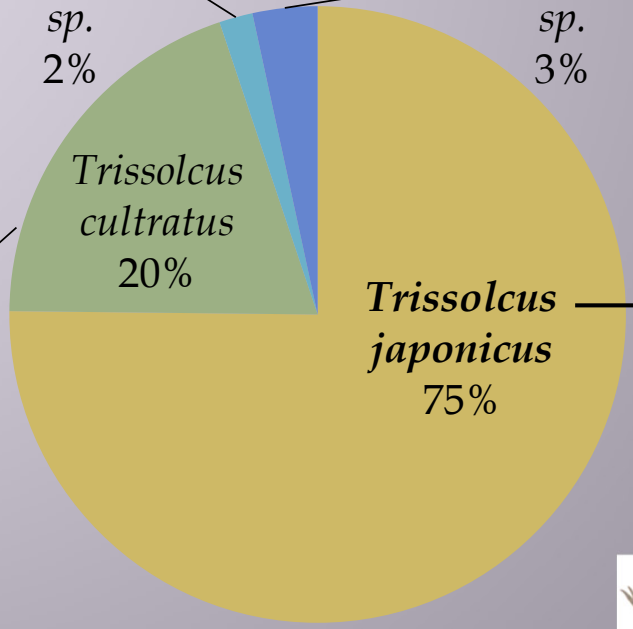
Mean parasitism & predation of BMSB by "native" enemies in invaded range

(Abram et al., BMSB Special Issue of J. Pest Science, 2017)

Fate of naturally laid BMSB eggs (NE USA)



BMSB egg parasitism : species composition in N. China



(CABI survey data – T. Haye)

Ooencyrtus sp.

Acroclisoides sp. (hyperparasitoid)

rarely

Trissolcus japonicus attacks some (but not all) species of Pentatomidae in Asia

Halyomorpha halys

Glaucias subpunctatus

Plautia crossota

Dolycoris baccarum

Erthesino fullo

JHR 43: 45–110 (2015)
doi: 10.3897/JHR.43.8560
http://jhr.pensoft.net

MONOGRAPH

JOURNAL OF Hymenoptera RESEARCH

Key to Nearctic species of *Trissolcus* Ashmead (Hymenoptera, Scelionidae), natural enemies of native and invasive stink bugs (Hemiptera, Pentatomidae)

Elijah J. Talamas[1], Norman F. Johnson[2], Matthew Buffington[1]

JHR 56: 3–185 (2017)
doi: 10.3897/jhr.56.10158
http://jhr.pensoft.net

MONOGRAPH

JOURNAL OF Hymenoptera RESEARCH

Revision of Palearctic *Trissolcus* Ashmead (Hymenoptera, Scelionidae)

Elijah J. Talamas[1], Matthew L. Buffington[1], Kim Hoelmer[2]

Taxonomic revisions facilitate the accurate identification of species in native & invaded ranges

JHR 33: 113–117 (2013)
doi: 10.3897/JHR.33.5627
www.pensoft.net/journals/jhr

RESEARCH ARTICLE

JOURNAL OF Hymenoptera RESEARCH

New synonymy of *Trissolcus halyomorphae* Yang

Elijah J. Talamas[1], Matthew Buffington[1], Kim Hoelmer[2]

JHR 65: 111–130 (2018)
doi: 10.3897/jhr.65.25620
http://jhr.pensoft.net

RESEARCH ARTICLE

JOURNAL OF Hymenoptera RESEARCH

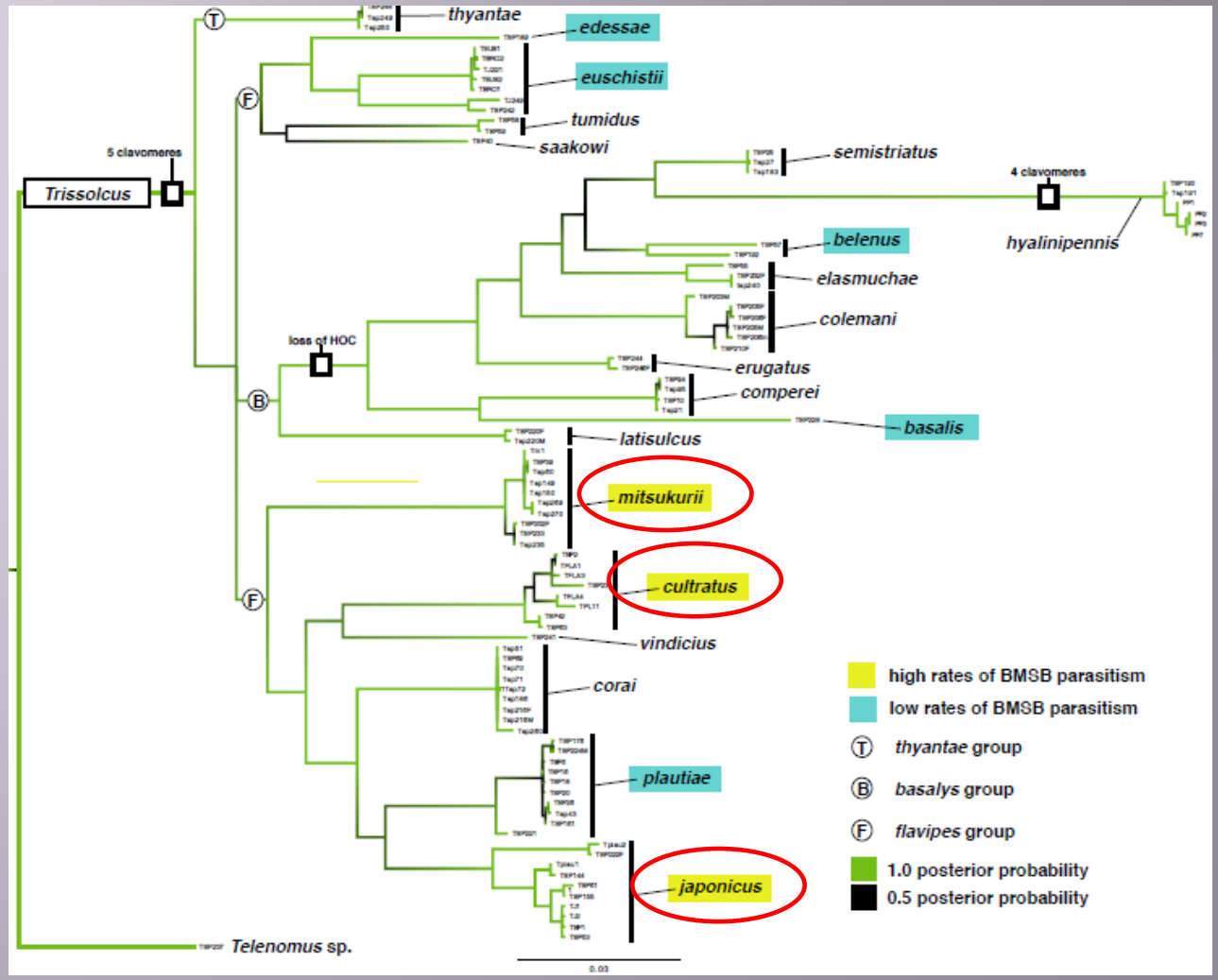
Trissolcus hyalinipennis Rajmohana & Narendran (Hymenoptera, Scelionidae), a parasitoid of *Bagrada hilaris* (Burmeister) (Hemiptera, Pentatomidae), emerges in North America

Fatemeh Ganjisaffar[1], Elijah J. Talamas[2], Marie Claude Bon[3], Lisa Gonzalez[4], Brian V. Brown[4], Thomas M. Perring[1]

Molecular phylogeny of *Trissolcus* confirms patterns in host use among species in native & invaded ranges

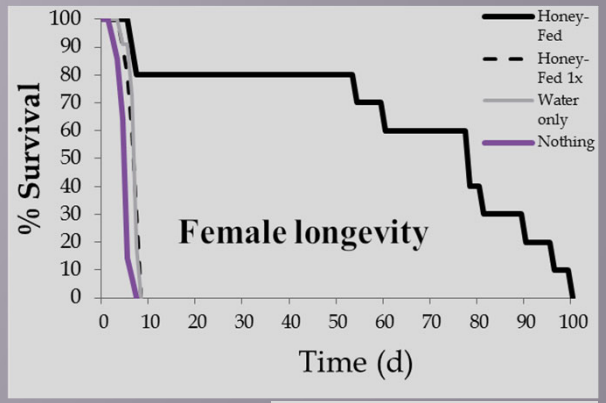
(Talamas et al. 2019
J. Hymenoptera Res. 73:201-217)

Note that certain Asian spp. have high parasitism rates on BMSB; but European and Nearctic spp. are less successful



Characteristics of *Trissolcus japonicus* that contribute to its success as an adventive parasitoid

- Attacks high % of eggs in host egg mass
- 65 - 90% parasitism of BMSB in Asia
- Sib-mating: mate upon emergence
- Female-biased sex ratio (65-85% ♀)
- Parent females aggressively guard egg masses
- Multiple generations per year (2 - 3 weeks/generation)
- Females capable of long life (2-3 months during summer)
- Overwinter as adults in/under tree bark
- Attacks several other Asian pentatomids with wide host ranges

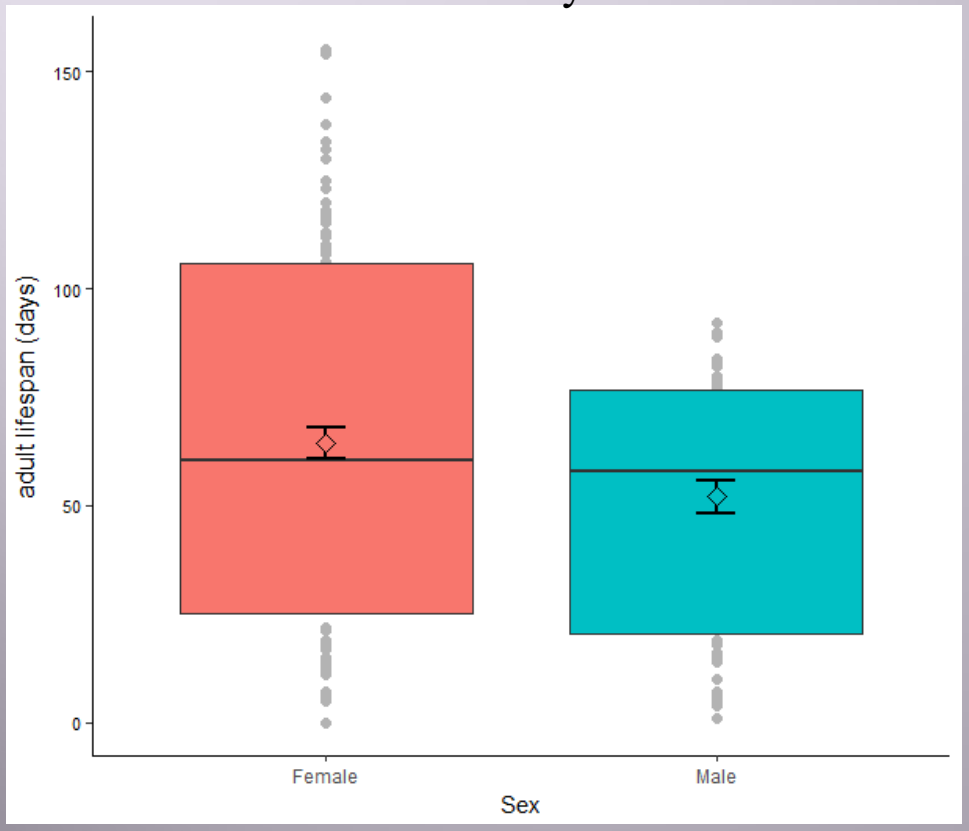


C. Dieckhoff/ARS

Maximum adult lifespan: 155 d

Mean males: 52 d **Mean females:** 64 d

Mean difference in lifespan:
female > male = 12.4 days

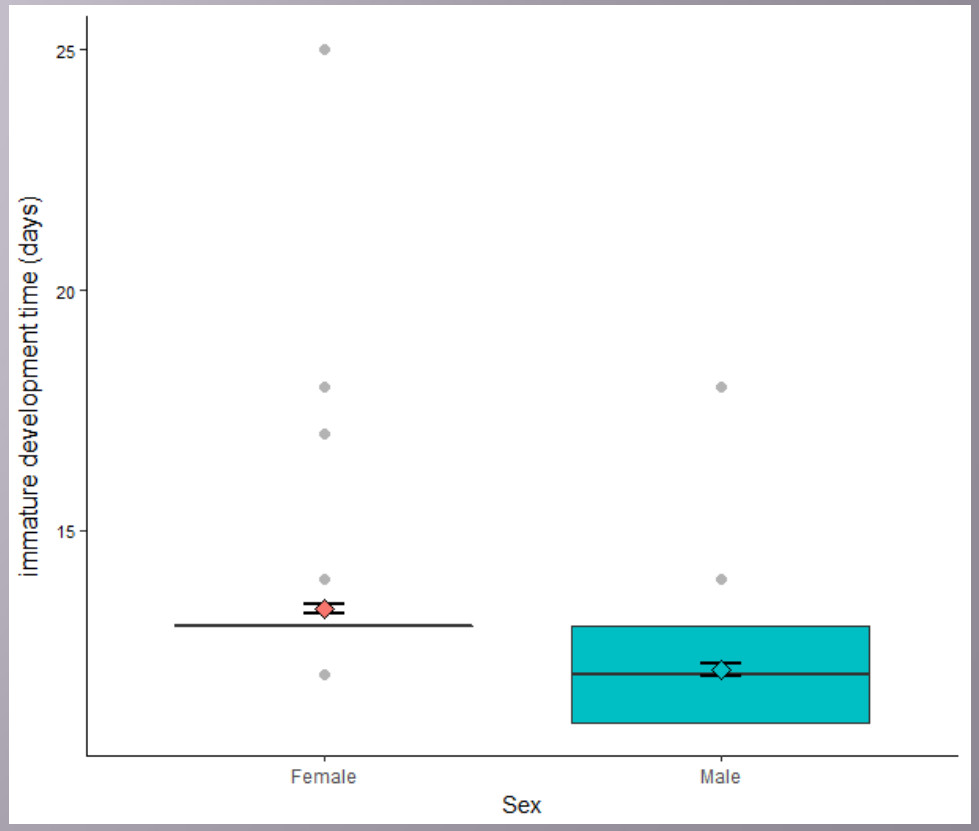


Mean immature development time: 13 d

Mean males: 12.10 **Mean females:** 13.37

Mean difference: 1.27

Min: 11 days (male) **Max:** 25 days (female)



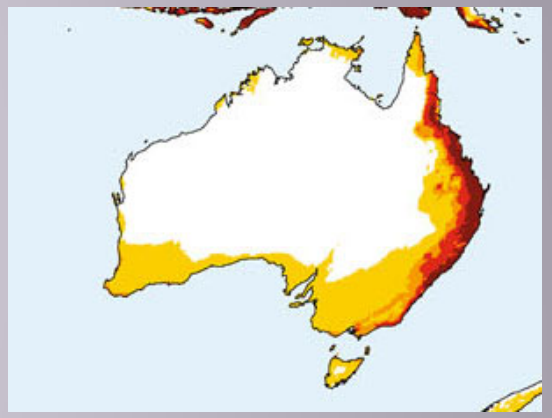
In Korea & Japan
T. japonicus
overwinters in
aggregations under
bark of trees

BioControl (2018) 63:505–518
https://doi.org/10.1007/s10526-018-9866-8

CrossMark

Modelling the potential geographic distribution of *Trissolcus japonicus*: a biological control agent of the brown marmorated stink bug, *Halyomorpha halys*

G. A. Avila · J. G. Charles



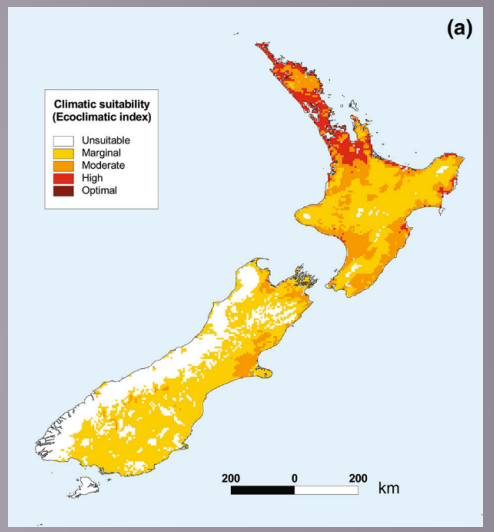
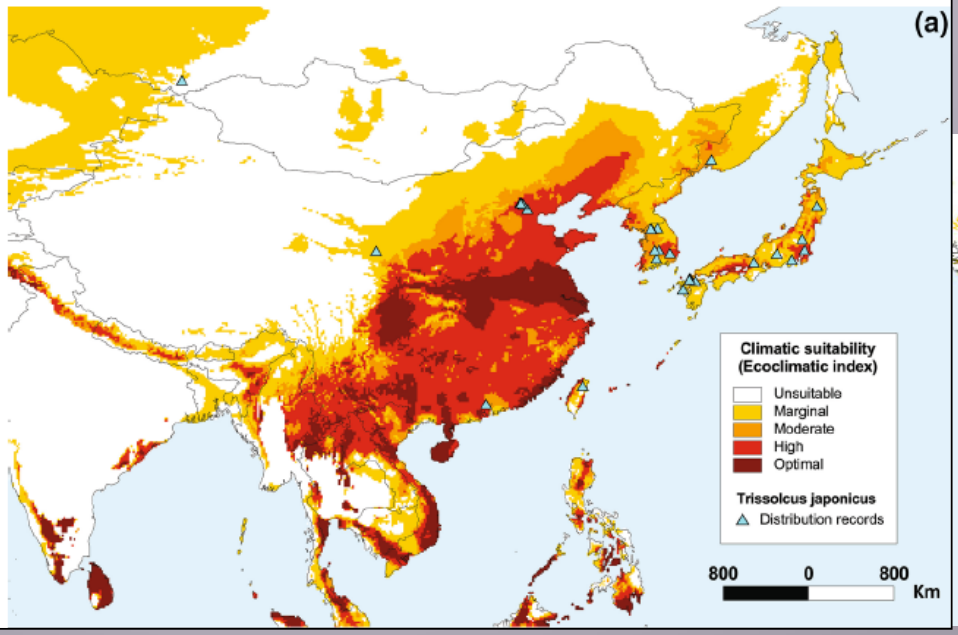
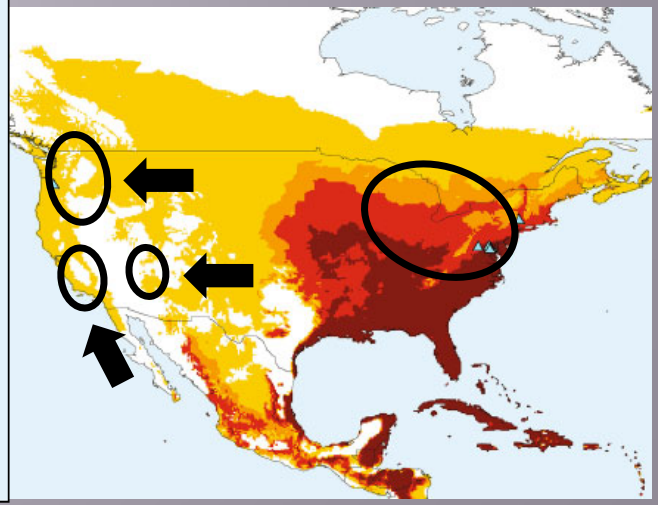


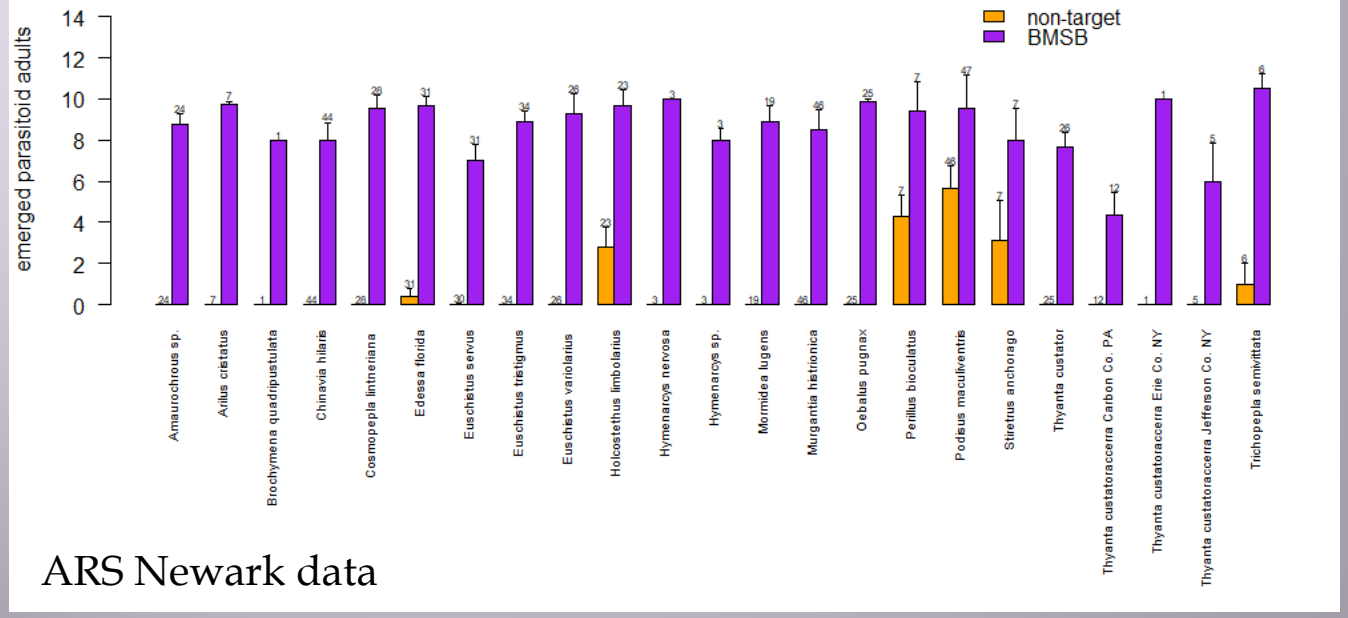
Fig. 2 Modelled climate suitability (CLIMEX Ecoclimatic Index) for *T. japonicus* to persist as a permanent population in **a** its native range in Asia (China, Taiwan, South Korea and Japan) and adventive range in Russia, and in **b** its adventive range in the USA. Known current distribution is shown as point locations (triangles)





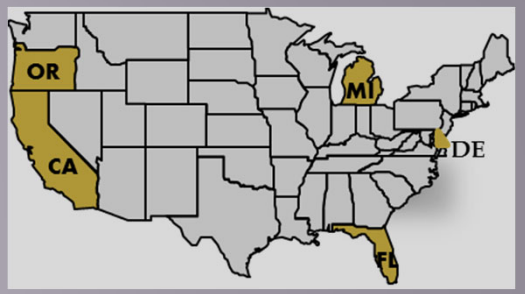
No-Choice Host Range Evaluations of North American Pentatomidae:

- **Evaluations of ca. 60 spp. in 5 U.S. states**

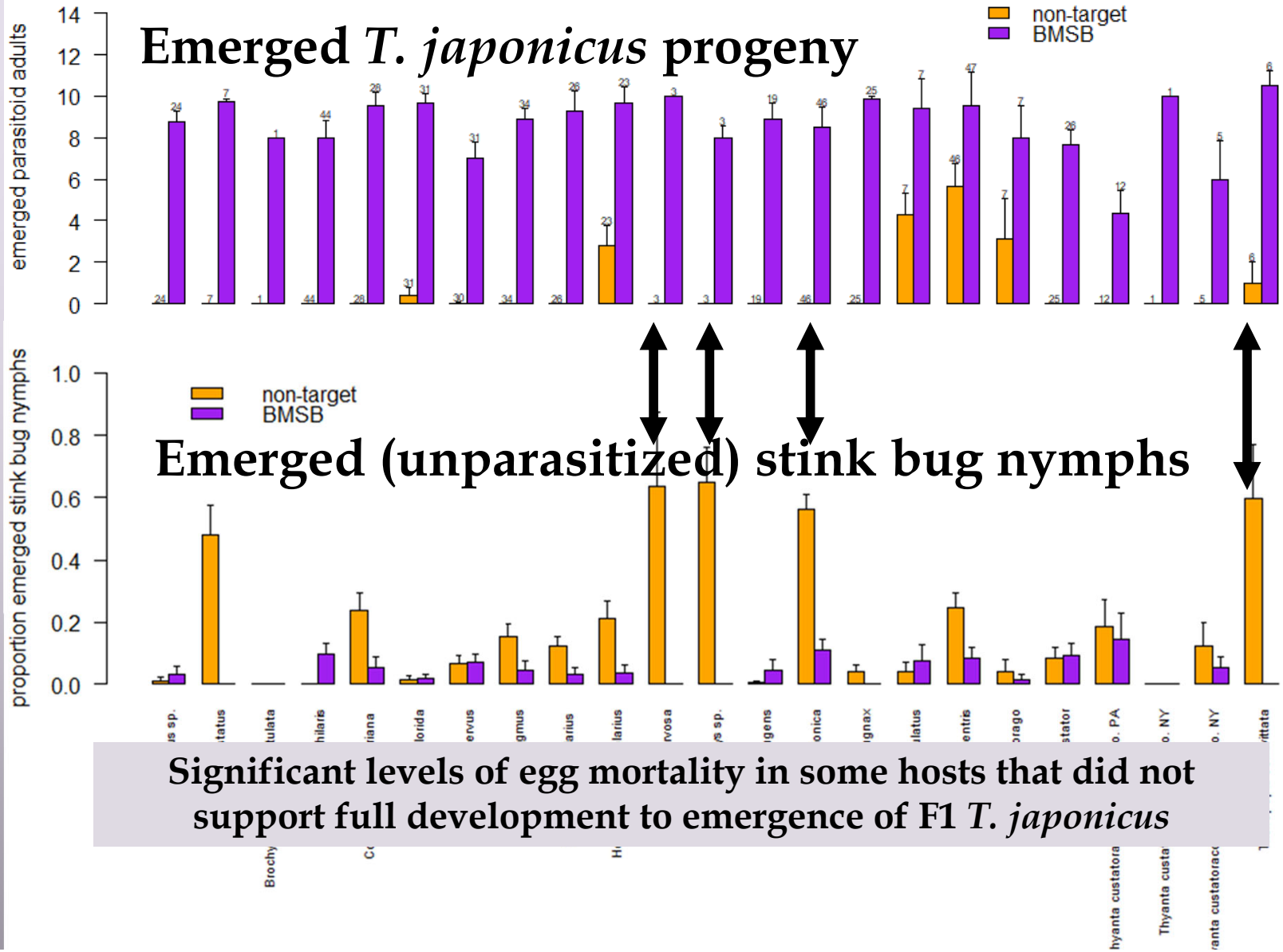


ARS Newark data

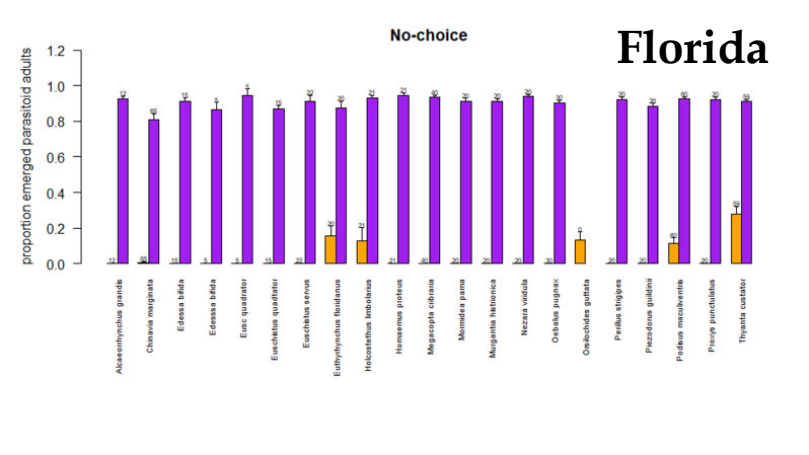
T. japonicus females tested were exposed to BMSB egg mass as "competency" controls following non-target exposure

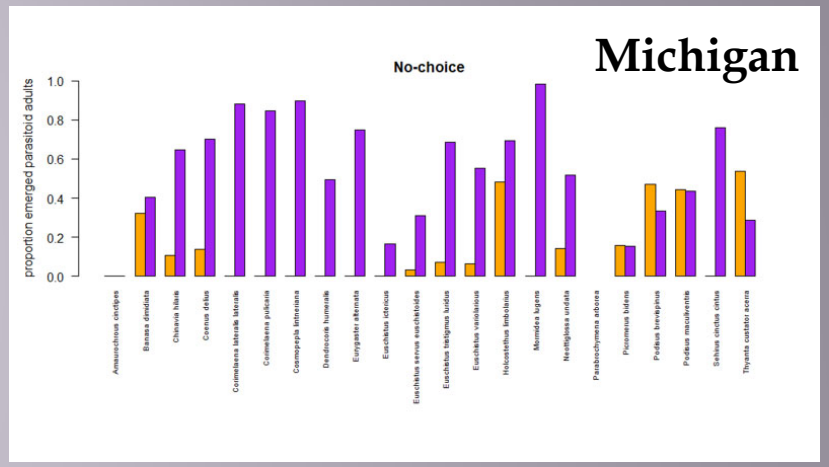


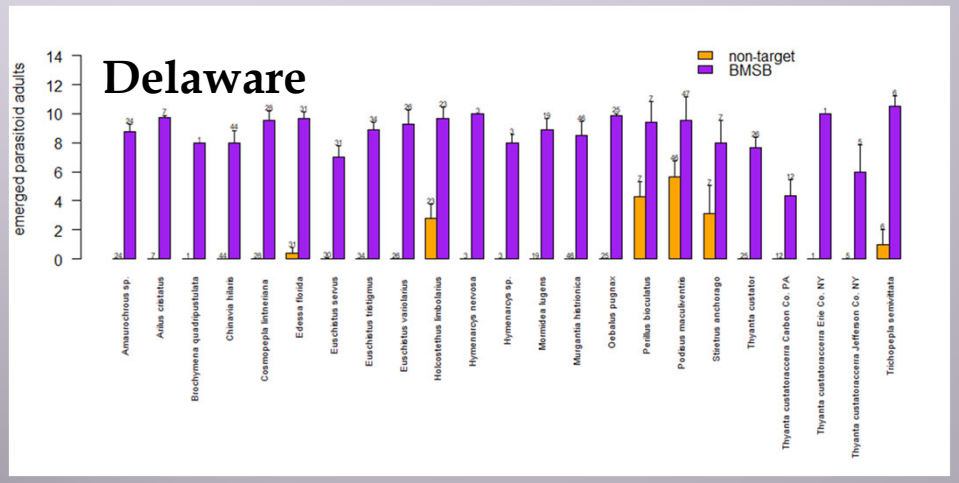
- **Successful development to emergence of F1 generation in only 6 of 21 species tested in Delaware**
- **BMSB is a more suitable host (higher level of successful development)**

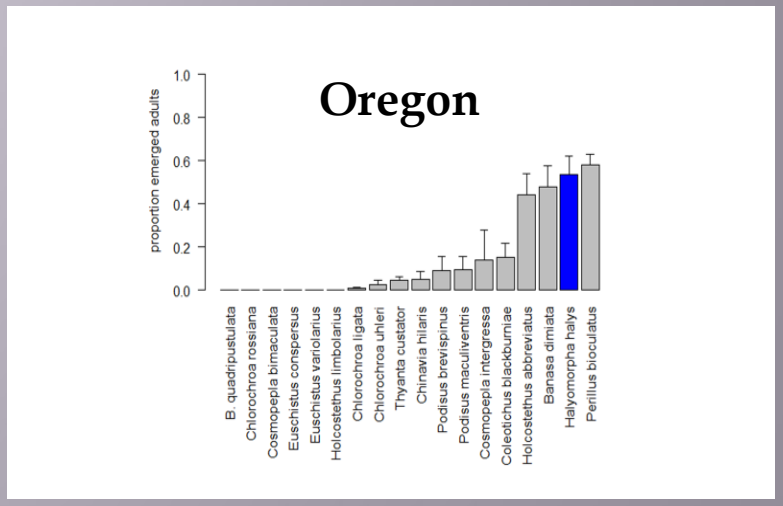


Significant levels of egg mortality in some hosts that did not support full development to emergence of F1 *T. japonicus*









Similar results in evaluations of pentatomids in other U.S. regions

J Pest Sci
DOI 10.1007/s10340-017-0863-y

ORIGINAL PAPER

Seasonal parasitism and host specificity of *Trissolcus japonicus* in northern China

Jinping Zhang[1] · Feng Zhang[1] · Tara Gariepy[2] · Peter Mason[3] · Dave Gillespie[4] · Elijah Talamas[5,7] · Tim Haye[1,6]

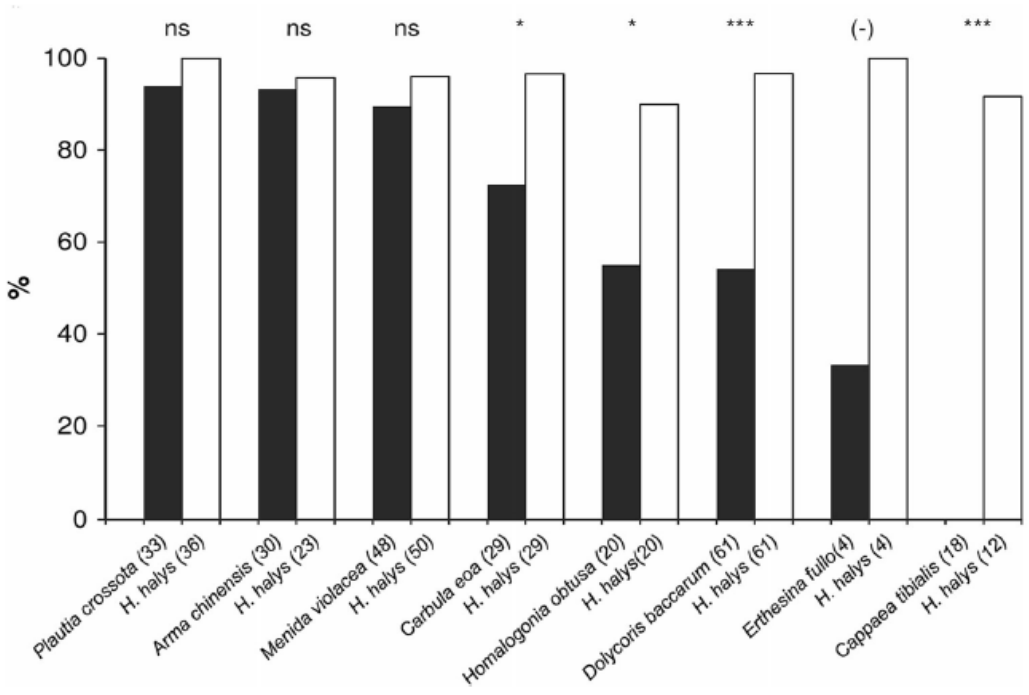
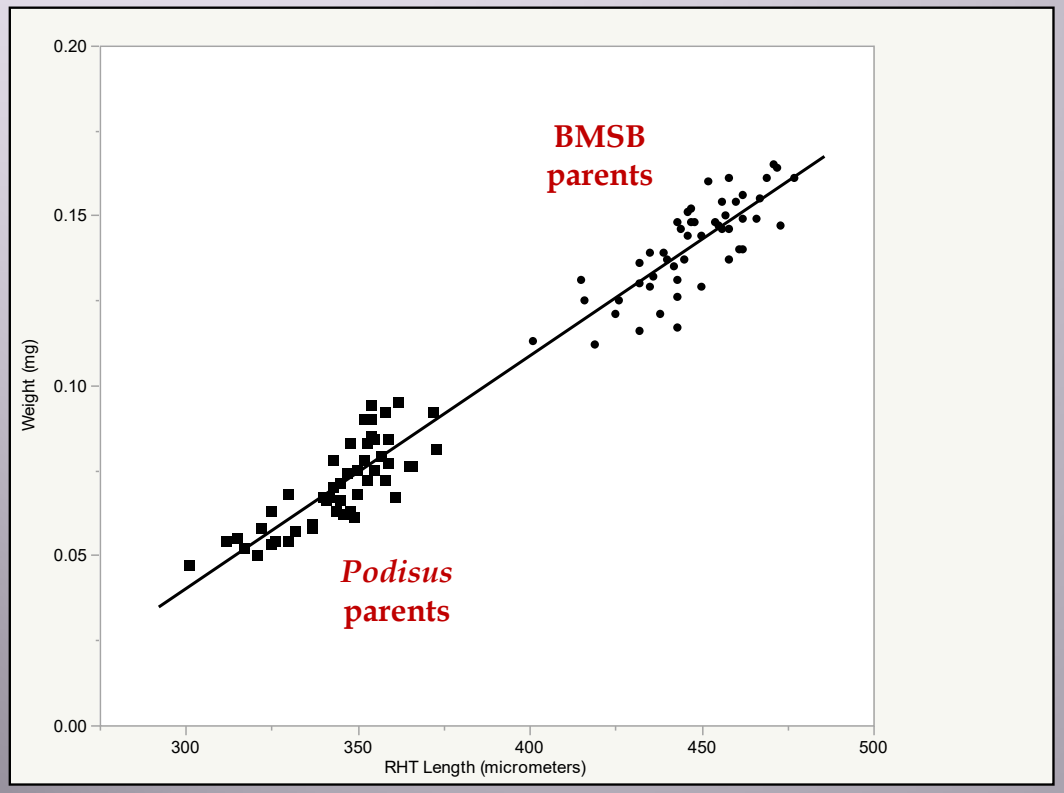
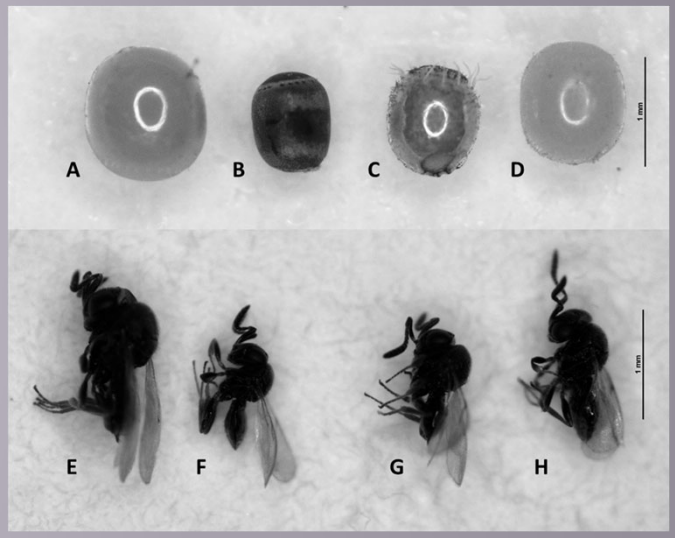


Fig. 1 Percentage of *T. japonicus* females successfully parasitizing egg masses of *Halyomorpha halys* (*white bars*) and non-target hosts (*black bars*) in small arena no-choice tests. The number of tested females is given in *brackets* for each species. *Bars* marked with *asterisks* indicate a significant difference between groups (Pearson Chi-Square test: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$; *ns* not significantly different). Due to the low number of replicates, *E. fullo* was not included in the analysis (–)

Variation in size & weight of female *T. japonicus* (right hind tibia length measured as indicator)





T. japonicus females that emerged from eggs of different host species: *H. halys* (A, E), *T.c. accerra* (B, F), *P. maculiventris* (C, G), and *E. variolarius* (D, H). (Botch & Delfosse, *2018, Env.Entomol.*)

BioControl
https://doi.org/10.1007/s10526-019-09949-x

Experimental assessment of the biosafety of *Trissolcus japonicus* in New Zealand, prior to the anticipated arrival of the invasive pest *Halyomorpha halys*

J. G. Charles · G. A. Avila · Kim A. Hoelmer · Sophie Hunt · Robin Gardner-Gee · Frances MacDonald · Vicky Davis

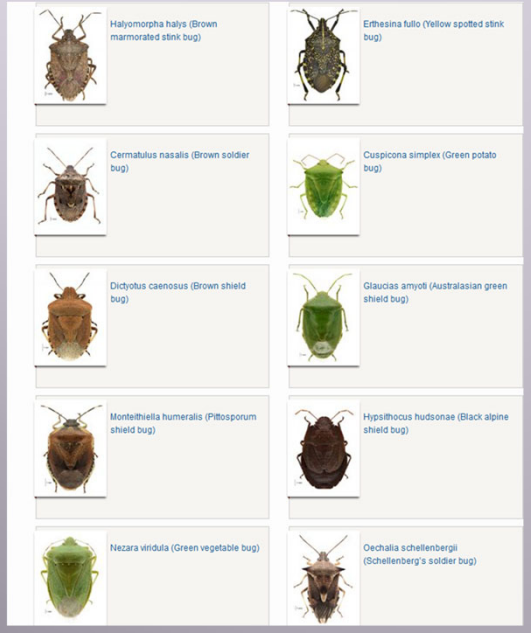


Table 3 Parasitism rates and development of parasitoids and nymphs from non-target pentatomid egg masses exposed to a single female *T. japonicus* in no-choice tests

Host	Total egg masses parasitised				Mean % (95% CI) per egg mass of parasitoids and nymph development		
	No. of masses tested	Mean no. of eggs per mass	No. of masses parasitised	% egg masses parasitized (95% CI)	Developed parasitoids	Developed nymphs	Undeveloped parasitized eggs
H. halys	46	27	46	100 (8[illegible]8–99.9)a	52.5 (44.9–59.7)a	18.9 (14.4–24.9)c	28.6 (23.4–34.5)c
C. n. hudsoni	11	21	2	18.2 (5.8–52.9)cd	97.8 (24.4–99.9)abcd	0 (0.24–50.9)abc	2.2 (0.04–57.8)abc
C. n. nasalis	42	28	40	95.2 (81.6–98.3)a	82.7 (75.4–87.7)bc	7.9 (5.2–13.4)b	9.4 (6.3–14.2)b
C. simplex	71	11	23	32.4 (22.8–44.3)c	88 (78.6–93.7)c	0.9 (0.2–7.6)a	11.1 (6.3–18.8)b
D. caenosus	26	13	19	73.1 (52.4–85.9)b	71.1 (59.2–81.2)b	4.7 (2.2–13.7)ab	24.2 (15.7–33.5)c
G. amyoti	70	14	67	95.7 (86.7–98.3)a	94.8 (91.3–97.2)d	0.6 (0.2–2.9)a	4.6 (2.5–7.2)a
M. humeralis	19	11	15	78.9 (53.[illegible]–90.9)b	83.7 (71.2–92)bc	0 (0.05–12.5)ab	16.3 (8.6–26.4)b
N. viridula	34	60	0	0 (0–[illegible]9.7)d	nd	nd	nd
O. schellenbergii	36	26	8	22.2 (1[illegible].1–39.3)c	74.1 (55.5–96.4)b	8.5 (3.6–24.5)bc	17.4 (8.8–31.7)bc

Within column means for percent egg masses parasitized, as well as for mean percentage of developmental effects, not sharing a letter are significantly different (pair-wise comparisons of fitted means; $p < 0.05$). No data collected are indicated with 'nd'

JHR 43: 119–128 (2015)
doi: 10.3897/JHR.43.4661
http://jhr.pensoft.net

SHORT COMMUNICATION

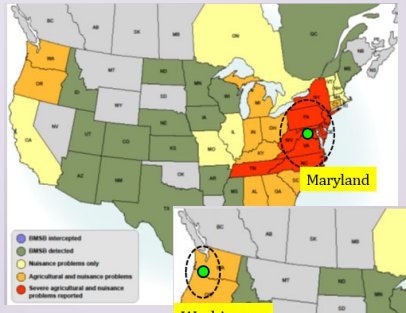
JOURNAL OF Hymenoptera RESEARCH

Trissolcus japonicus (Ashmead) (Hymenoptera, Scelionidae) emerges in North America

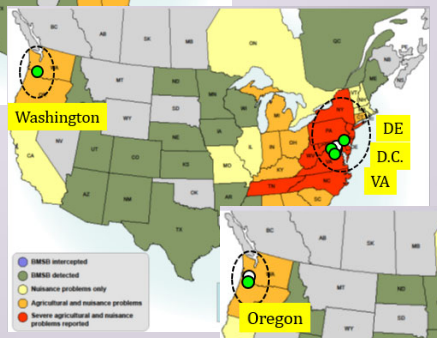
Elijah J. Talamas[1], Megan V. Herlihy[2], Christine Dieckhoff[3,4], Kim A. Hoelmer[4], Matthew L. Buffington[1], Marie-Claude Bon[5], Donald C. Weber[2]

Unexpected recovery in 2014 of adventive *Trissolcus japonicus* in the U.S.

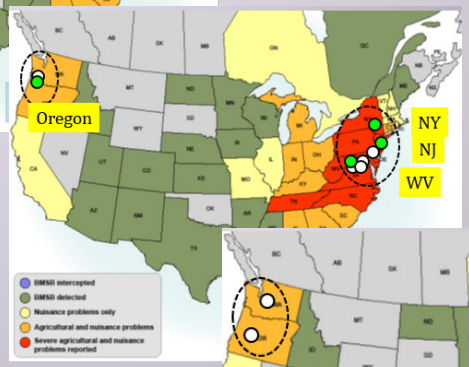
Science **361** (6402), 542-545.



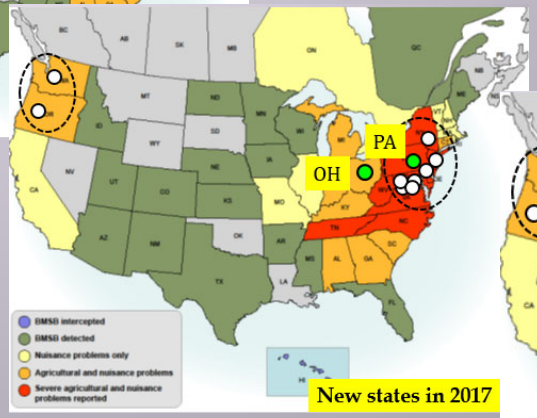
2014



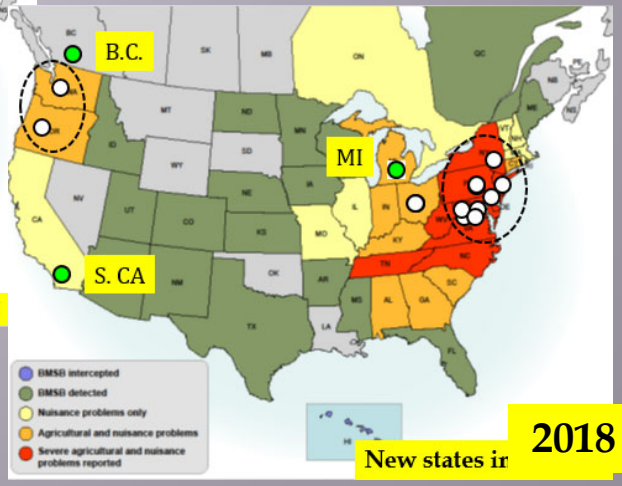
2015



2016



2017



2018

… its range continues to expand…

Utah in 2019

JHR 43: 119–128 (2015)
doi: 10.3897/JHR.43.4661
http://jhr.pensoft.net

SHORT COMMUNICATION

JOURNAL OF Hymenoptera RESEARCH

Trissolcus japonicus (Ashmead) (Hymenoptera, Scelionidae) emerges in North America

Elijah J. Talamas[1], Megan V. Herlihy[2], Christine Dieckhoff[3,4], Kim A. Hoelmer[4], Matthew L. Buffington[1], Marie-Claude Bon[5], Donald C. Weber[2]

JHR 68: 29–36 (2019)
doi: 10.3897/jhr.68.32203
http://jhr.pensoft.net

SHORT COMMUNICATION

JOURNAL OF Hymenoptera RESEARCH

First detection of the samurai wasp, *Trissolcus japonicus* (Ashmead) (Hymenoptera, Scelionidae), in Canada

Paul K. Abram[1], Elijah J. Talamas[2], Susanna Acheampong[3], Peter G. Mason[4], Tara D. Gariepy[5]

Journal of Pest Science
https://doi.org/10.1007/s10340-018-1061-2

RAPID COMMUNICATION

First discovery of adventive populations of *Trissolcus japonicus* in Europe

Judith Stahl[1,2] · Francesco Tortorici[3] · Marianna Pontini[3] · Marie-Claude Bon[4] · Kim Hoelmer[5] · Cristina Marazzi[6] · Luciana Tavella[3] · Tim Haye[1]

Received: 26 September 2018 / Revised: 23 October 2018 / Accepted: 27 October 2018
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Journal of Pest Science
https://doi.org/10.1007/s10340-018-1061-2

RAPID COMMUNICATION

First discovery of adventive populations of *Trissolcus japonicus* in Europe

Judith Stahl[1,2] · Frances
Luciana Tavella[3] · Tim H

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http://jhr.pensoft.net

SHORT COMMUNICATION

JOURNAL OF Hymenoptera RESEARCH

First detection of the samurai wasp, *Trissolcus japonicus* (Ashmead) (Hymenoptera, Scelionidae), in Canada

Paul K. Abram[1], Elijah J. Talamas[2], Susanna Acheampong[3], Peter G. Mason[4], Tara D. Gariepy[5]

Journal of Pest Science
https://doi.org/10.1007/s10340-018-1061-2

RAPID COMMUNICATION

First discovery of adventi
in Europe

Judith Stahl[1,2] · Francesco Tort
Luciana Tavella[3] · Tim Haye[1]

Received: 26 September 2018 / Revised:
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T. mitsukurii

T. japonicus

JHR 67: 37–53 (2018)
doi: 10.3897/jhr.67.30883
http://jhr.pensoft.net

DATA PAPER

JOURNAL OF Hymenoptera RESEARCH

Two Asian egg parasitoids of *Halyomorpha halys* (Stål) (Hemiptera, Pentatomidae) emerge in northern Italy: *Trissolcus mitsukurii* (Ashmead) and *Trissolcus japonicus* (Ashmead) (Hymenoptera, Scelionidae)

Giuseppino Sabbatini Peverieri[1], Elijah Talamas[2], Marie Claude Bon[3], Leonardo Marianelli[1], Iris Bernardinelli[4], Giorgio Malossini[4], Luca Benvenuto[4], Pio Federico Roversi[1], Kim Hoelmer[5]

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RAPID COMMUNICATION

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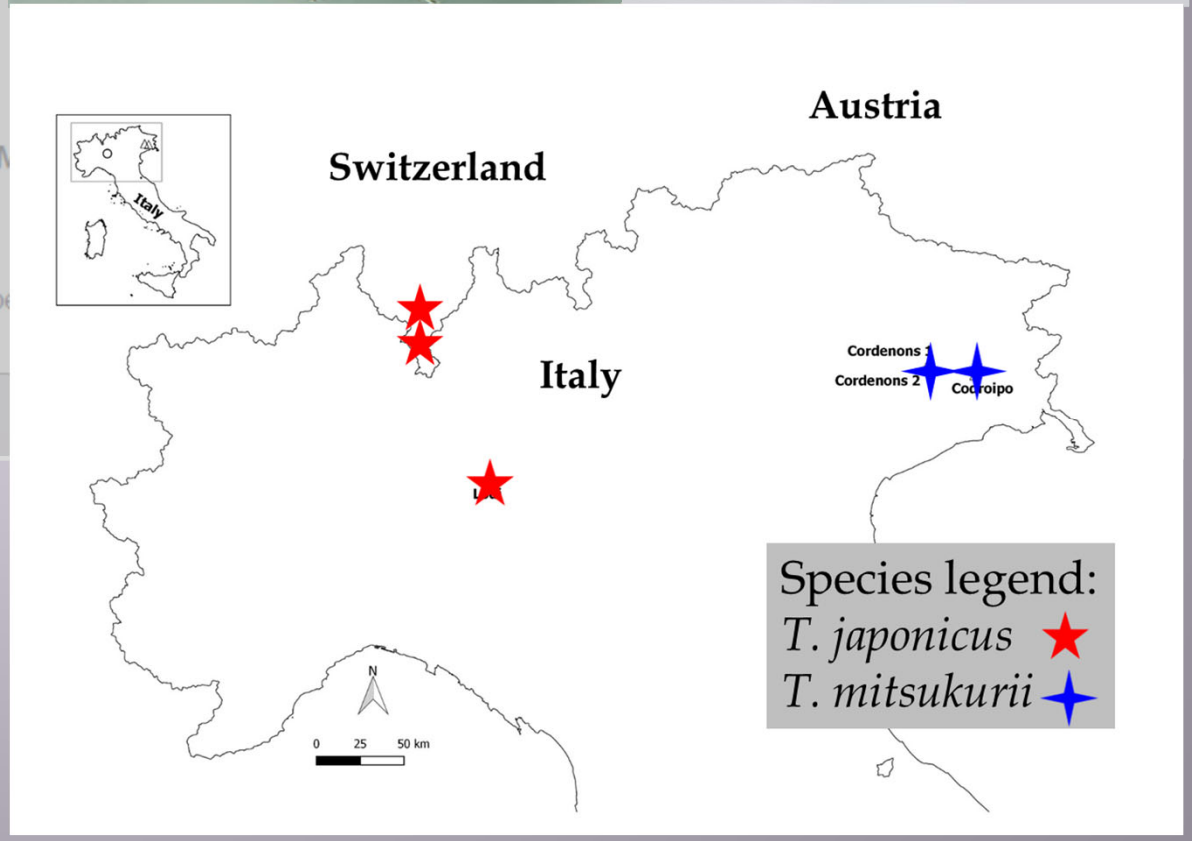
T. mitsukurii

T. japonicus



How does *Trissolcus* disperse so readily?

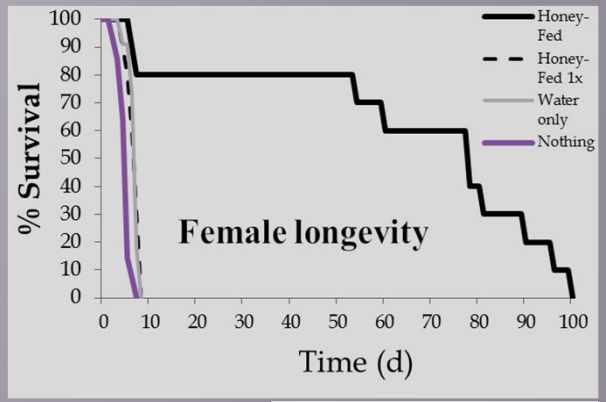
In parasitized egg masses on imported plant hosts?

As hitchhiking adult wasps?

… or are they associated with different host species on different commodities…?

Characteristics of *Trissolcus japonicus* that contribute to success as an adventive parasitoid

- Attacks high % of eggs in host egg mass
- 65 - 90% parasitism of BMSB in Asia
- Sib-mating: mate upon emergence
- Female-biased sex ratio (65-85% ♀)
- Parent females aggressively guard egg masses
- Multiple generations per year (2 - 3 weeks/generation)
- Females capable of long life (2-3 months during summer)
- Overwinter as adults in/under tree bark
- Attacks several other Asian pentatomids with wide host ranges

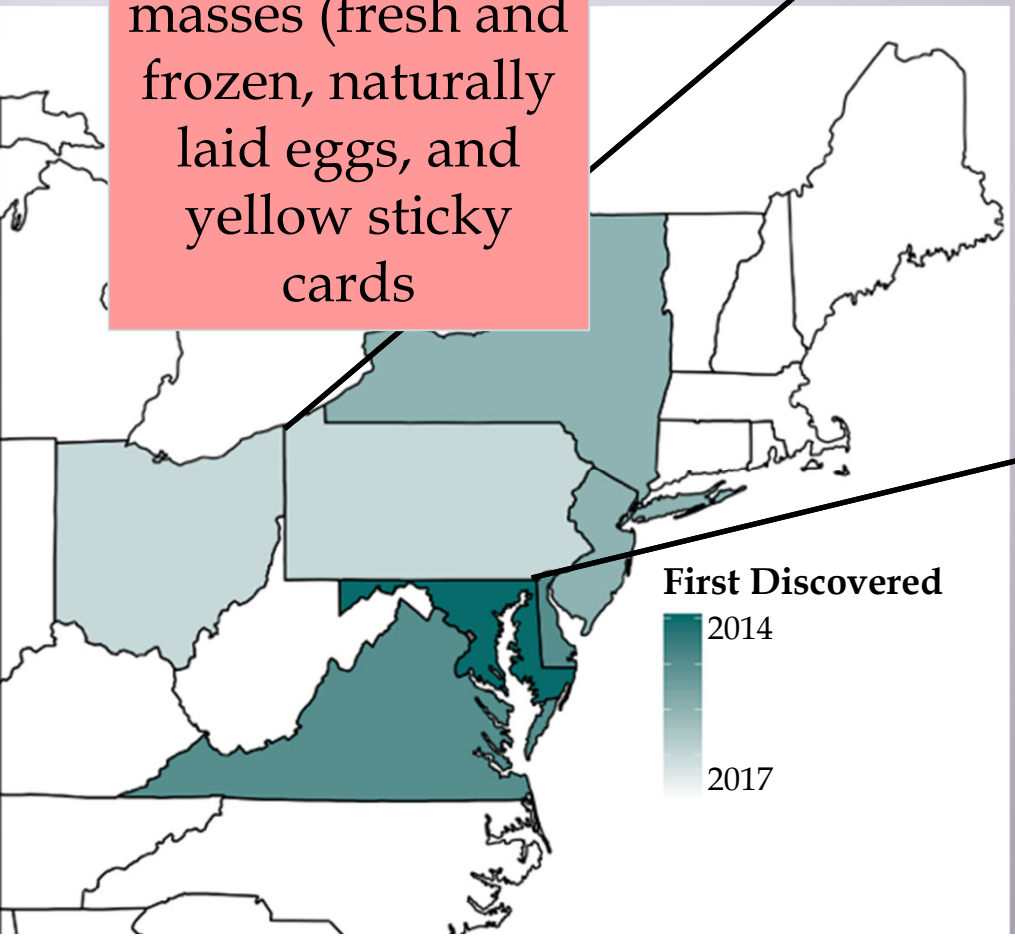


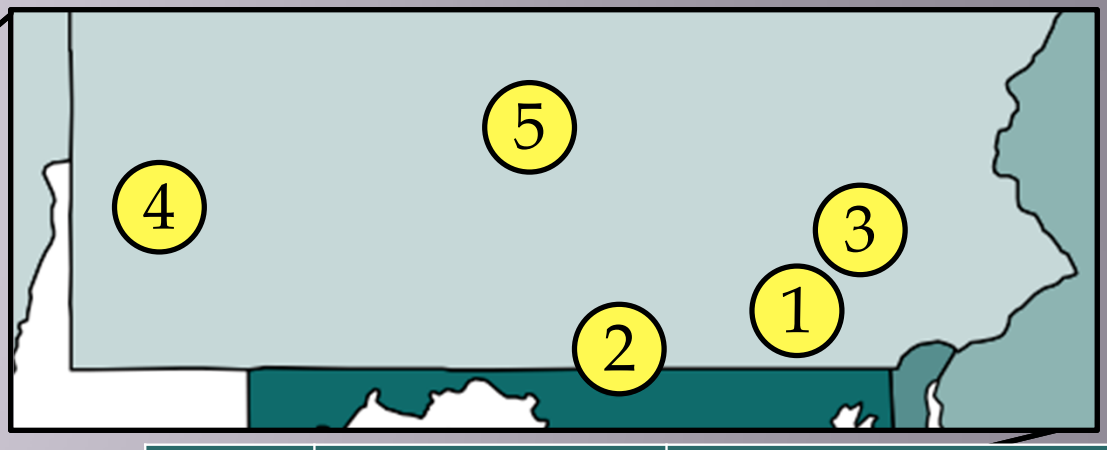
C. Dieckhoff/ARS

Samurai wasp detections in Pennsylvania (data / Hilary Peterson)

PennState College of Agricultural Sciences

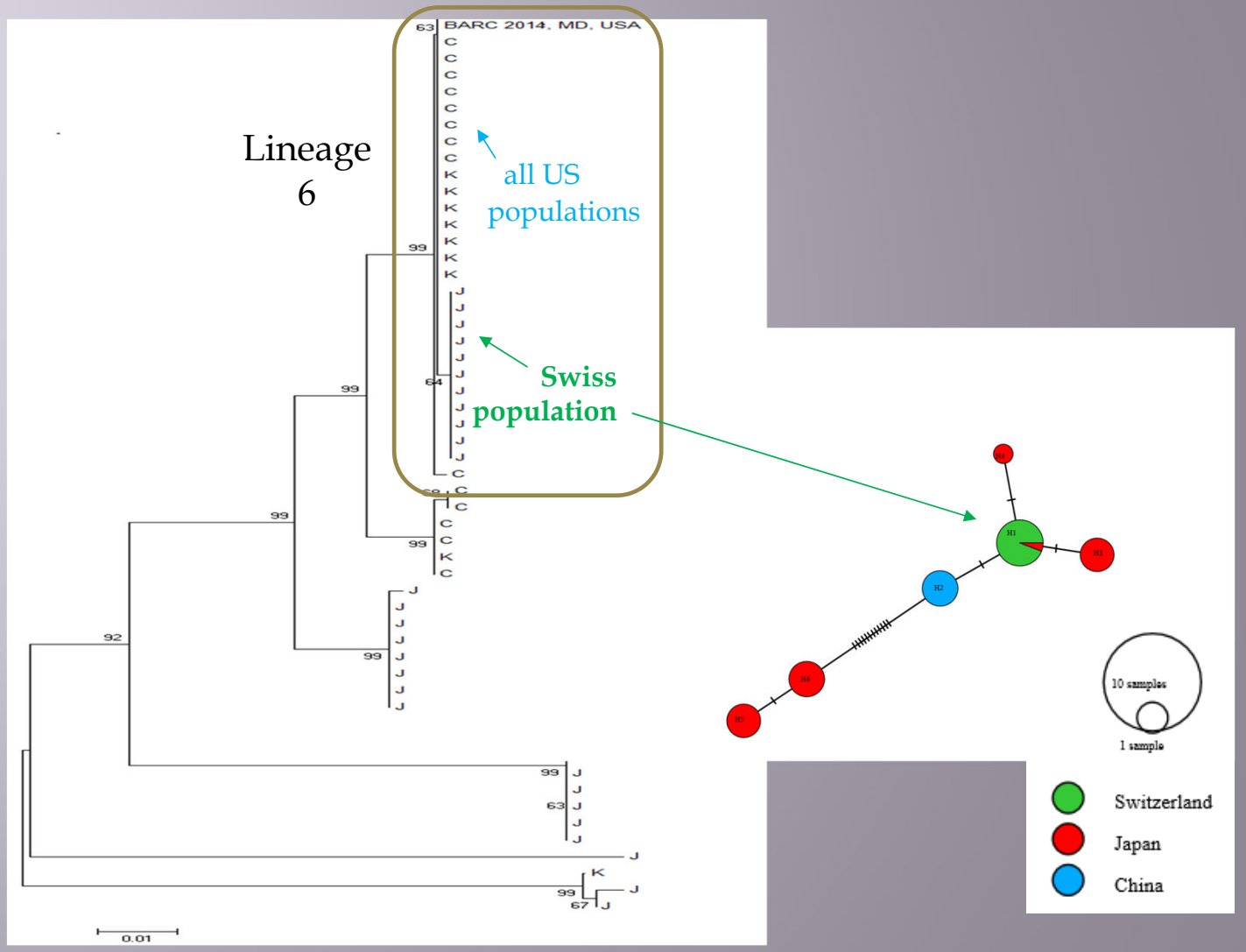
Surveys use a combination of sentinel egg masses (fresh and frozen, naturally laid eggs, and yellow sticky cards



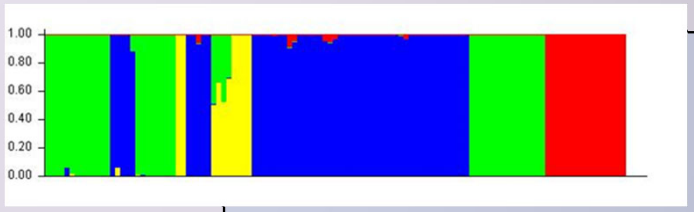


Year	Site Numbers	Method of Discovery
2017	1-2	
2018	1-2	
2018	1-5	

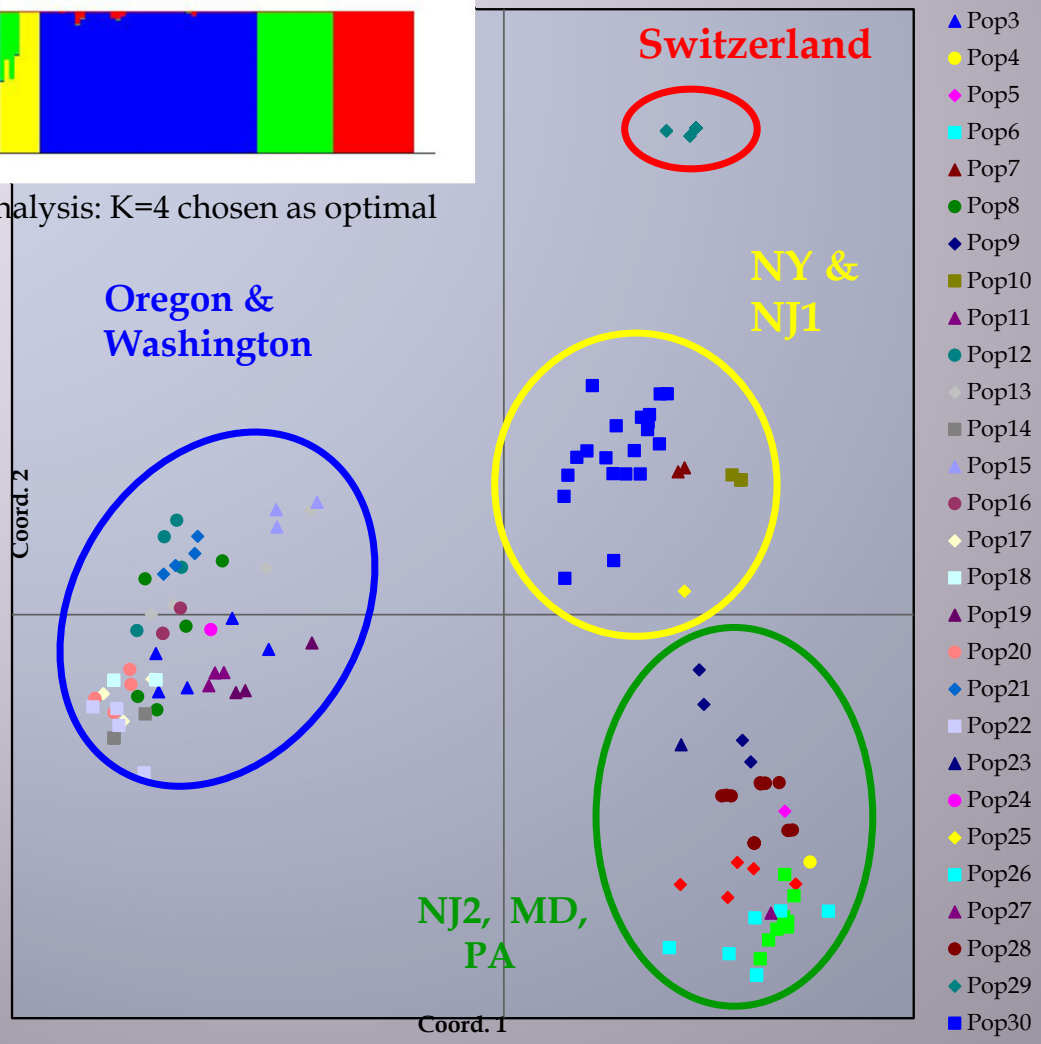
- All recovered populations from U.S. and EU belong to the same mitochondrial lineage (#6) distributed in China, Korea and Japan.
- All U.S. populations share the same mitochondrial haplotype.
- The U.S. haplotype differs from the Swiss haplotype (which also occurs in Japan).



Principal Coordinate Analysis (PCoA) of 23 microsatellite loci on adventive populations in U.S.A. and Switzerland

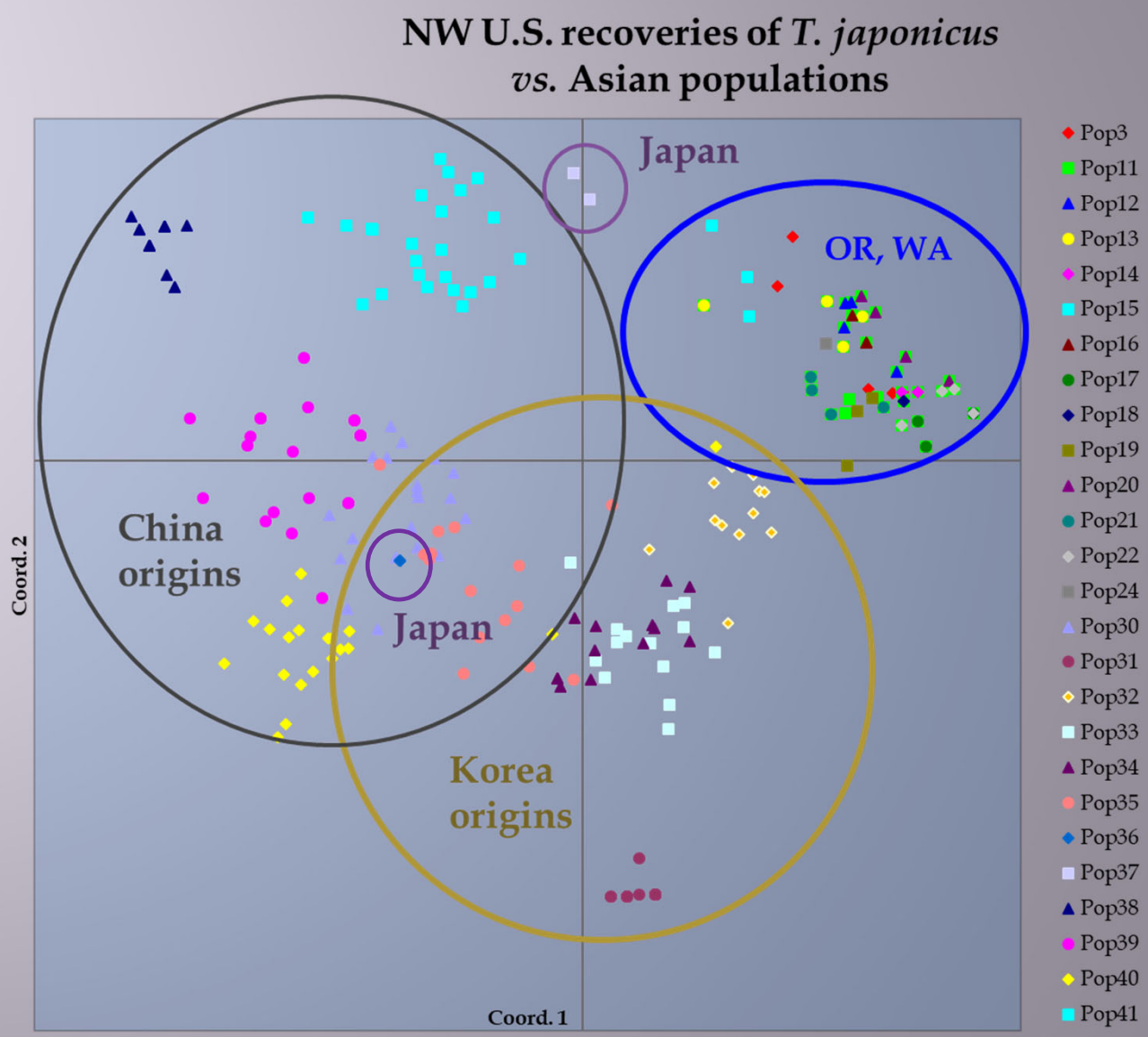


Structure analysis: K=4 chosen as optimal

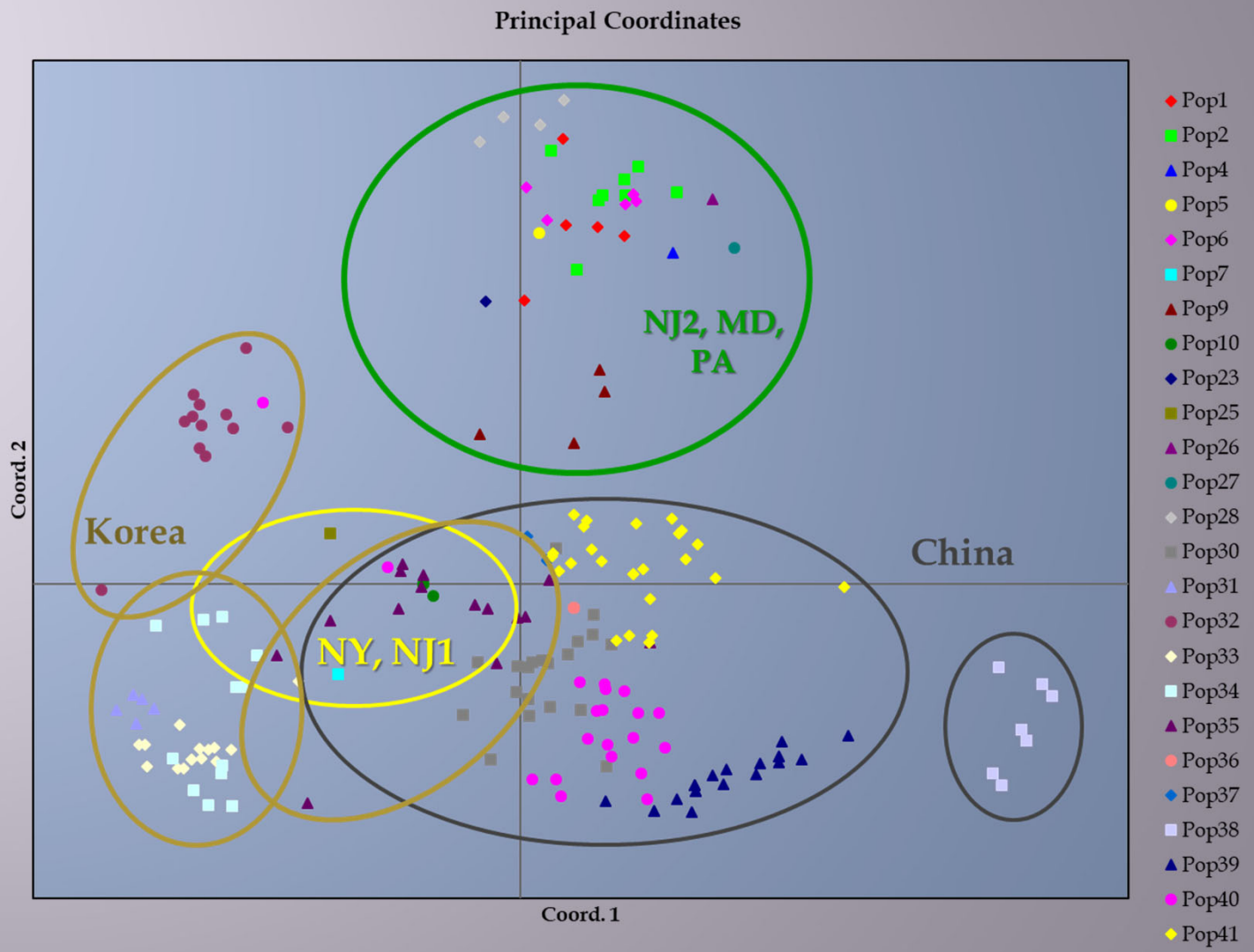


- Three genetic clusters in U.S. (NE, NW, mid-Atlantic states)
- Two clusters overlap in New Jersey
- Multiple introductions of *T. japonicus*
- U.S. populations are different from Switzerland

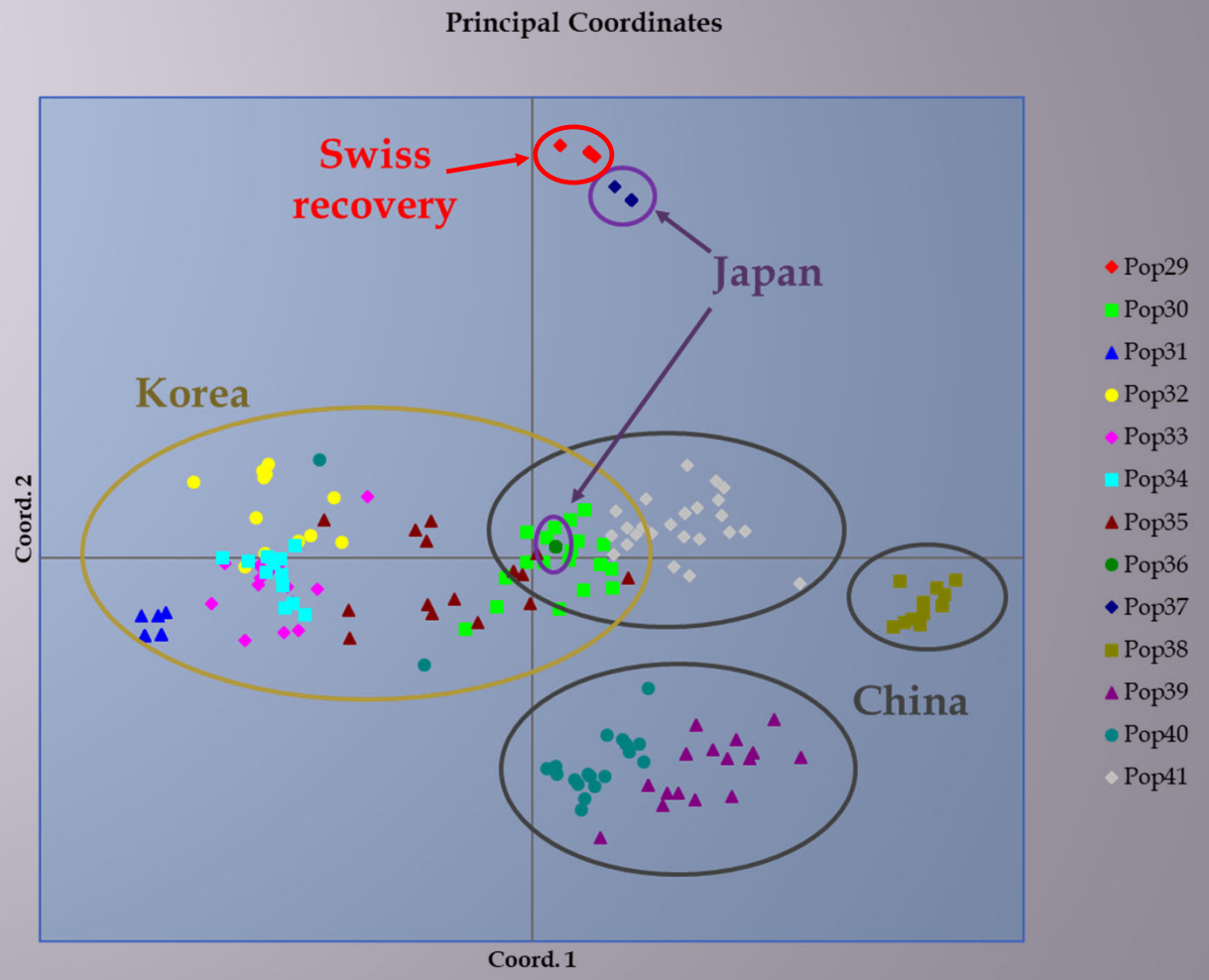
- NW U.S. (OR, WA) recoveries of *T. japonicus* represent a single population.
- No clear genetic match with native range populations sampled to date



- ✓ NY & NJ1 : closest similarity with some populations in China and Korea
- ✓ Mid-Atlantic states: no clear similarity with Asian populations sampled to date



- Swiss population is most similar to a reference population from Japan



Implications of adventive populations

- What will be impact of competition with indigenous parasitoids and predators? Will parasitoid guilds be affected?
- How will this impact non-target stink bugs and other spp.?
- APHIS regulates <u>inter</u>state but not <u>intra</u>state movement of exotic & beneficial insects
- Several U.S. states are now redistributing populations within their boundaries.

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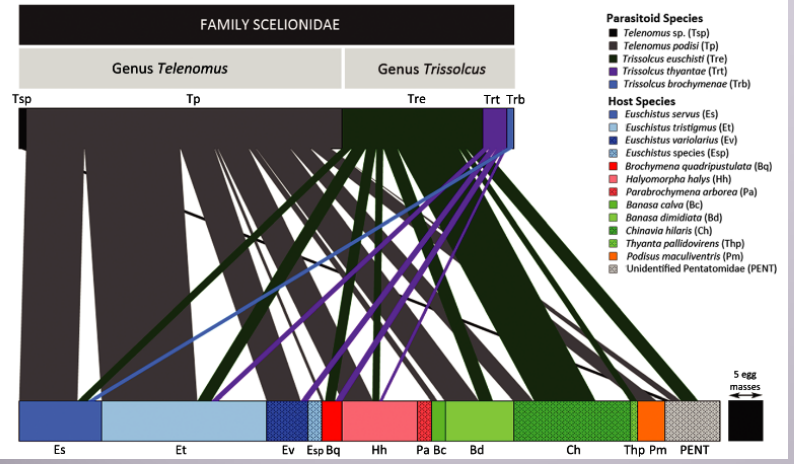
SPECIAL ISSUE: SPECIES INTERACTIONS, ECOLOGICAL NETWORKS AND COMMUNITY DYNAMICS

WILEY MOLECULAR ECOLOGY

A modified DNA barcode approach to define trophic interactions between native and exotic pentatomids and their parasitoids

Tara D. Gariepy[1] | Allison Bruin[1] | Joanna Konopka[1] | Cynthia Scott-Dupree[2] | Hannah Fraser[3] | Marie-Claude Bon[4] | Elijah Talamas[5]



DOI: 10.1002/ece3.2577

ORIGINAL RESEARCH

WILEY Ecology and Evolution Open Access

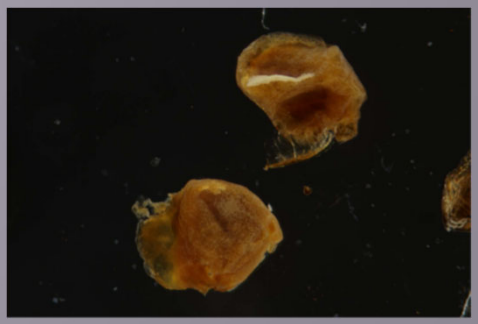
An exotic parasitoid provides an invasional lifeline for native parasitoids

Joanna K. Konopka[1,2,3] | Tim Haye[3] | Tara Gariepy[2] | Peter Mason[4] | David Gillespie[5] | Jeremy N. McNeil[1]

Some level of competition can be expected with native parasitoids, but displacement is not likely.

Successful parasitism

Unsuccessful parasitism (but host also dies)



Journal of Insect Science, (2019) 19(4): 15; 1–6
doi: 10.1093/jisesa/iez074
Research

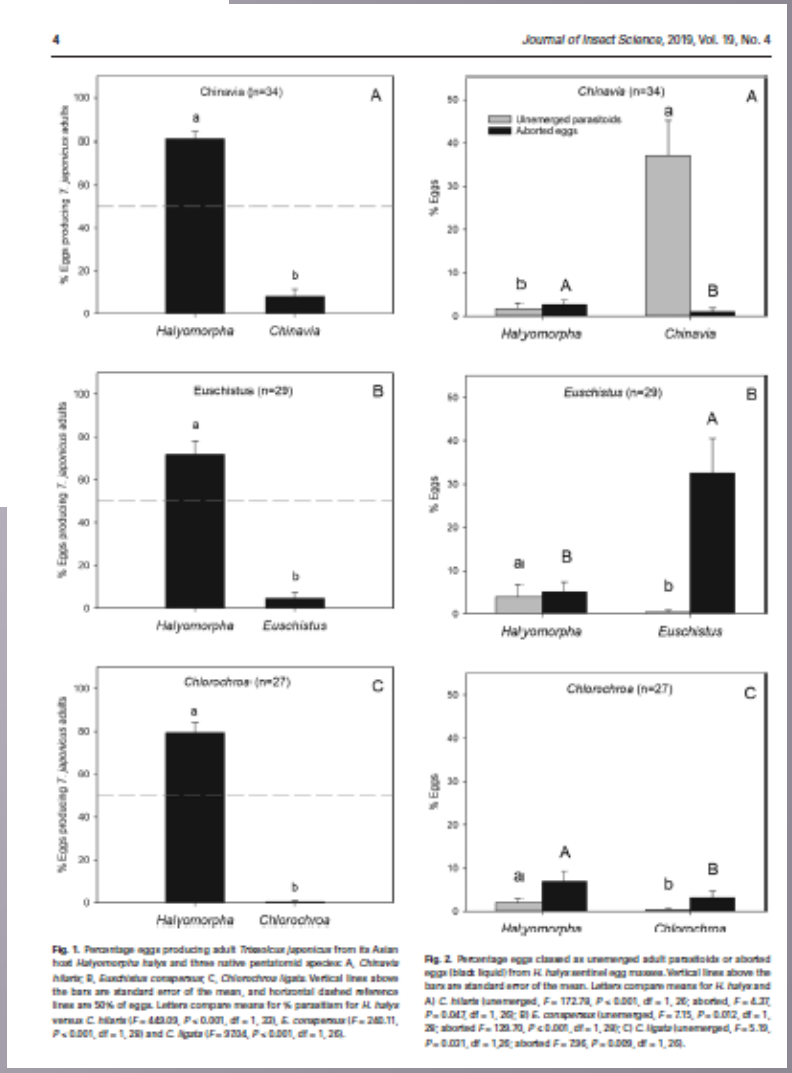
Trissolcus japonicus (Hymenoptera: Scelionidae) Causes Low Levels of Parasitism in Three North American Pentatomids Under Field Conditions

Joshua M. Milnes and Elizabeth H. Beers[1]

Despite close proximity of the paired egg masses, the rate of successful parasitism on all three native species was significantly less than that on BMSB eggs, and the rate of successful production of adult *T. japonicus* even lower.

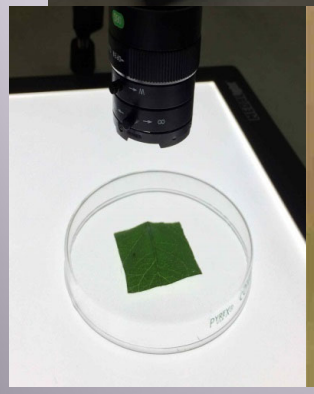
Table 1. Numbers of *T. japonicus* adults produced from sentinel egg masses of *H. halys* and native pentatomids

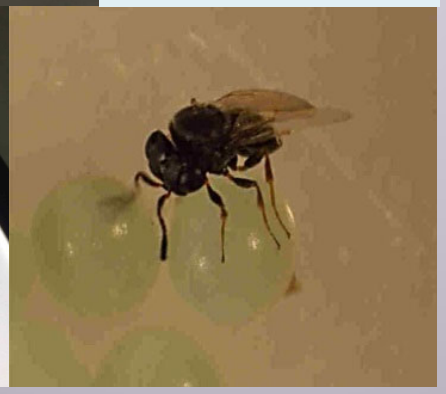
Variable	Pairs					
	H. halys	*C. hilaris*	*H. halys*	*E. conspersus*	*H. halys*	*C. ligata*
No. of replicate pairs	34		29		27	
No. of egg masses producing *T. japonicus* adults	33	10	28	3	27	1
Total *T. japonicus* adults	743	41	547	12	582	2
Total *T. japonicus* females	687	35	502	9	531	2
% female	92	85	92	75	91	100
% normal egg hatch (nymphs)	6.0	34.6	7.3	32.4	0.0	82.4

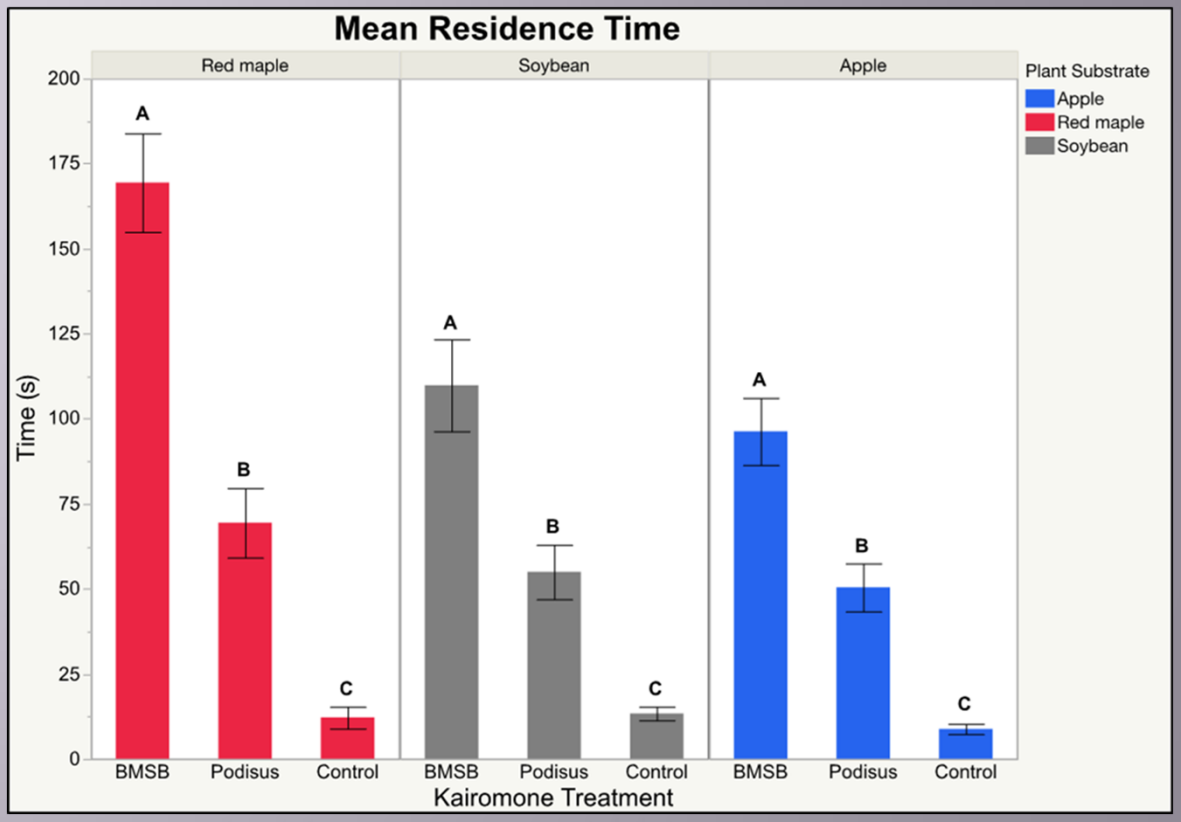


Influence of host kairomones on foraging of *T. japonicus*

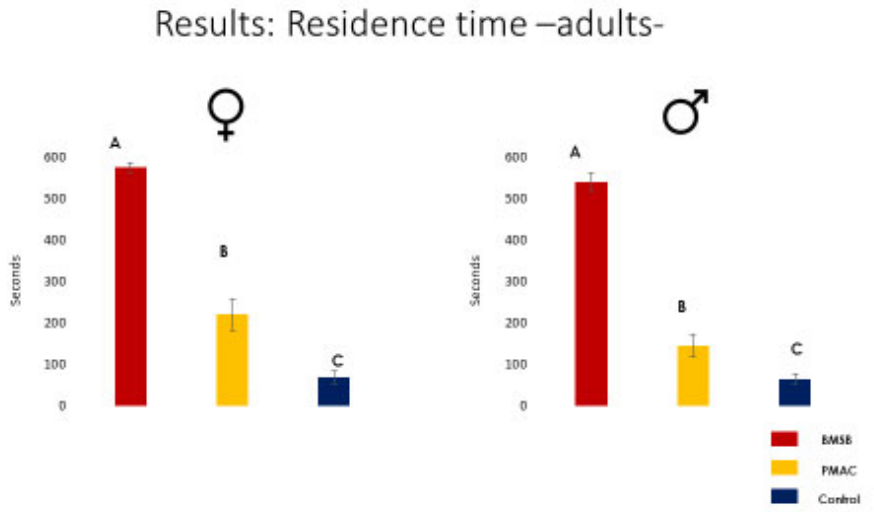
Ethovision used to track movements of female *T. japonicus* on leaves

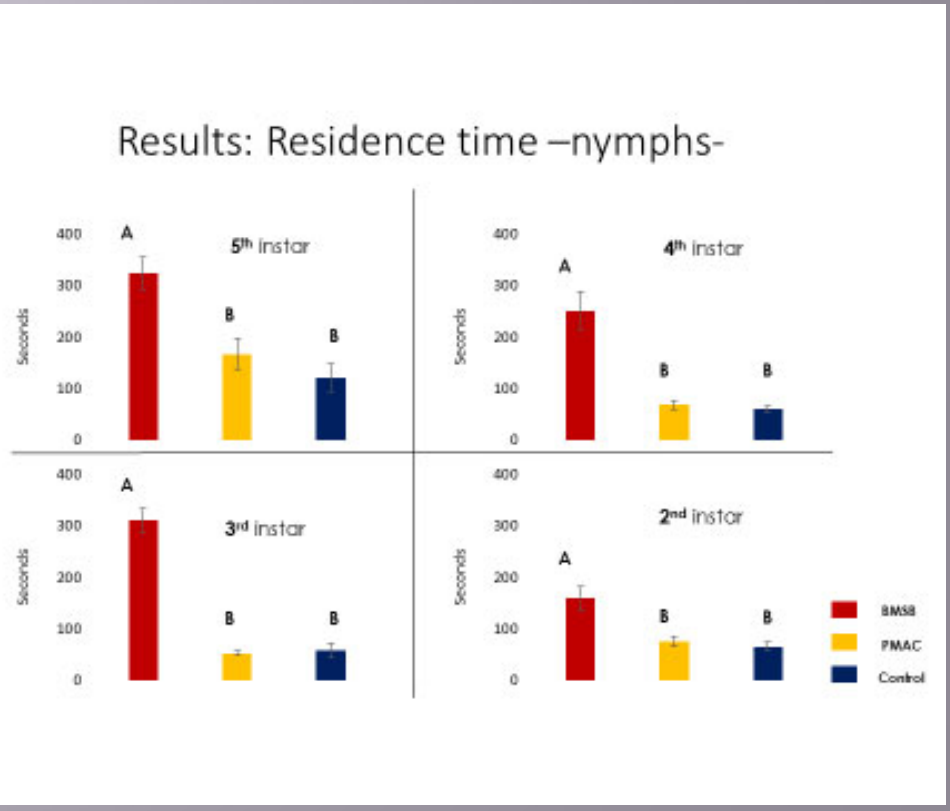






T. japonicus were exposed to adult BMSB & *Podisus* kairomones on red maple, apple, and soybean leaves. Results suggest that BMSB kairomones are cues for *T. japonicus* to invest more time searching for hosts. *Sean Boyle, M.S. thesis, UDel*





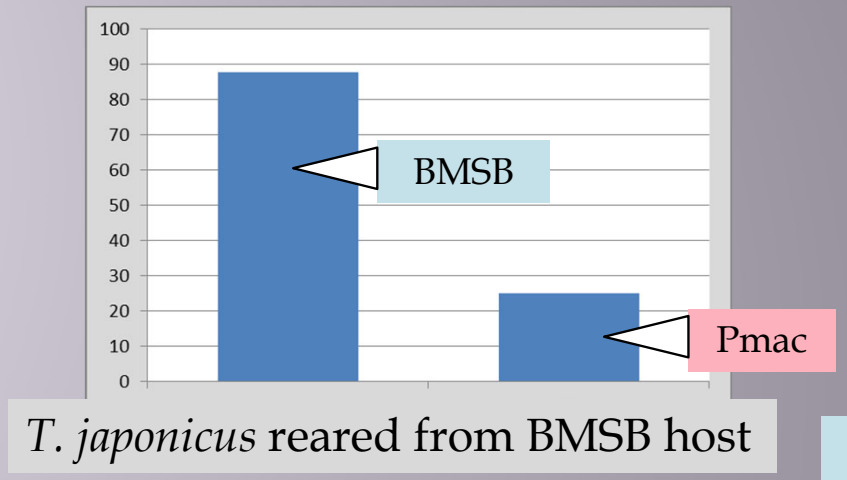
T. japonicus females were then exposed to male and nymph BMSB & *Podisus* kairomone traces. Wasps responded similarly, but at a lower intensity.

Robert Malek, Univ. Trento/ARS-BIIRU

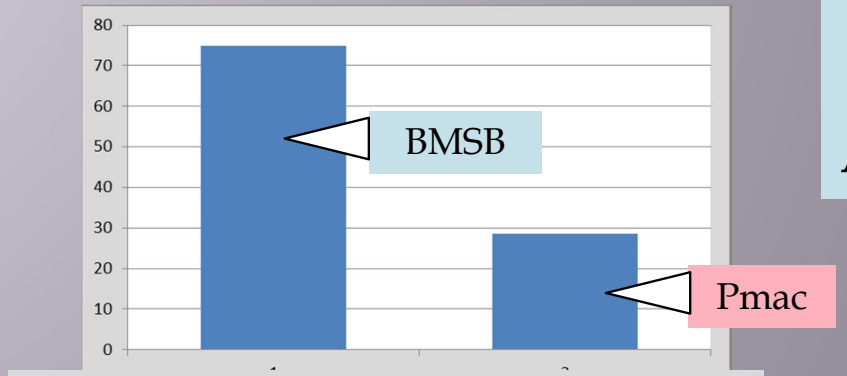
Searching in cage arena for egg mass

Single BMSB or Pmac Egg Mass exposed inside cage arena

Parent female *T. japonicus* reared from either BMSB or Pmac

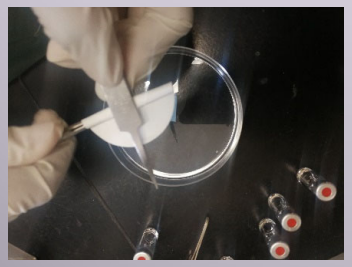


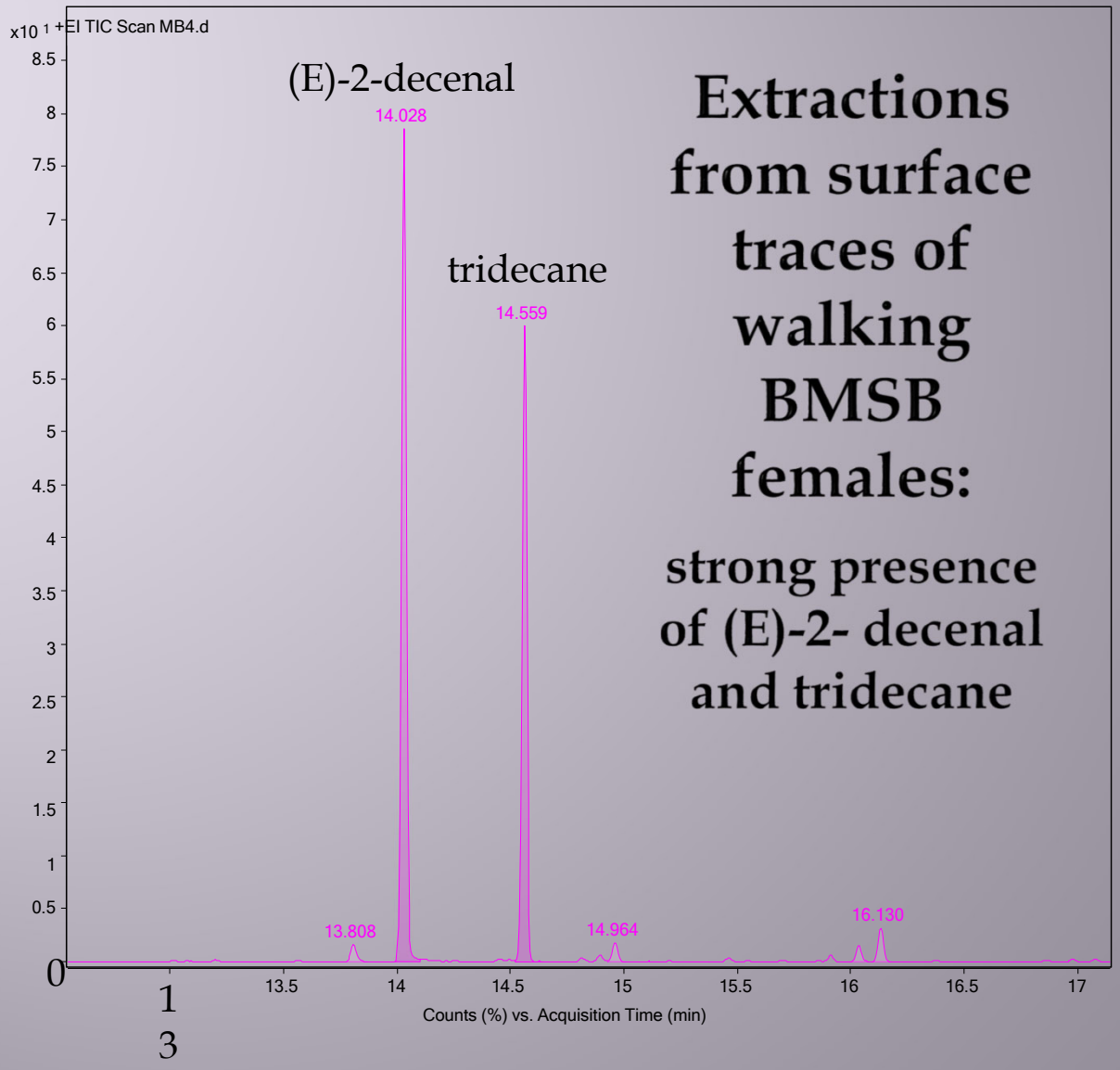
T. japonicus reared from BMSB host



T. japonicus reared from Pmac host

Percent of Egg Masses Attacked





Extractions from surface traces of walking BMSB females:

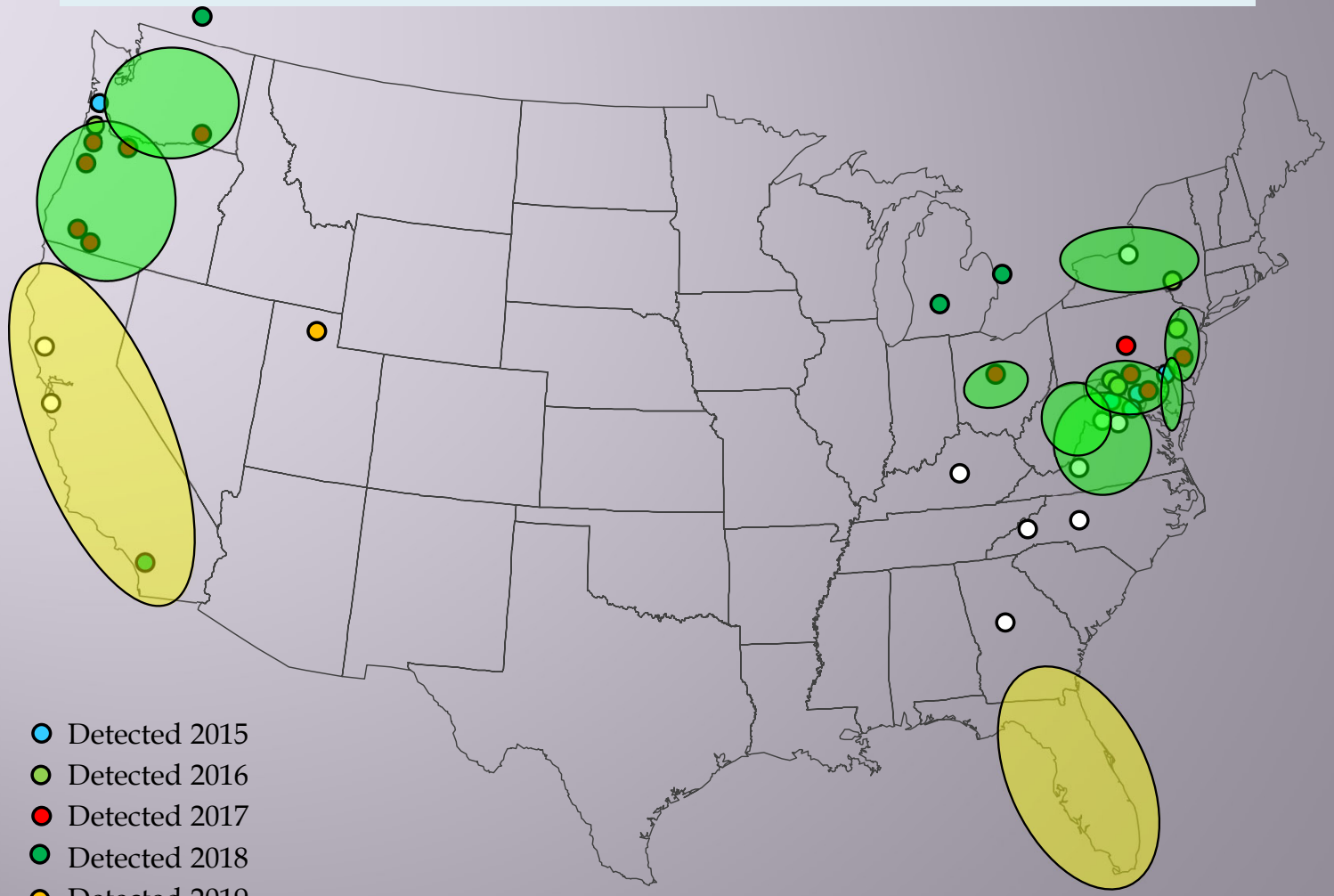
strong presence of (E)-2- decenal and tridecane

1
3

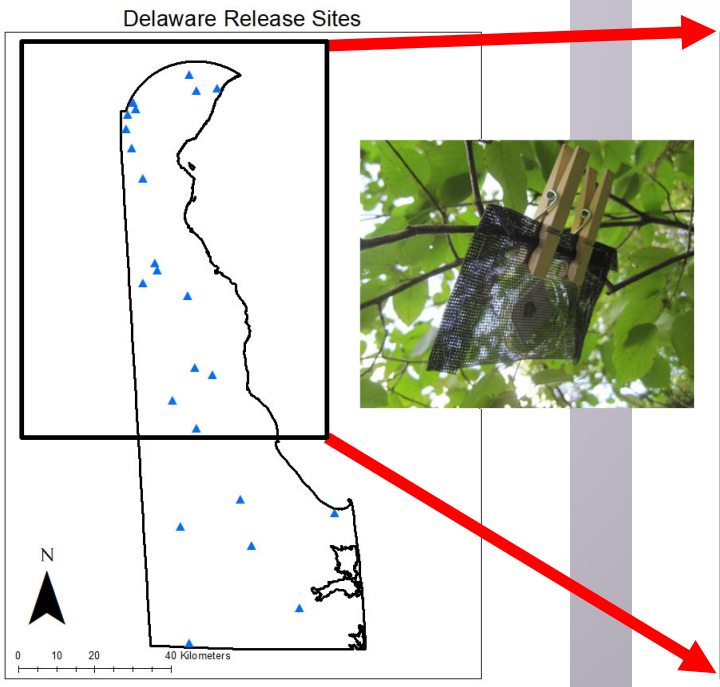
Implications of adventive populations

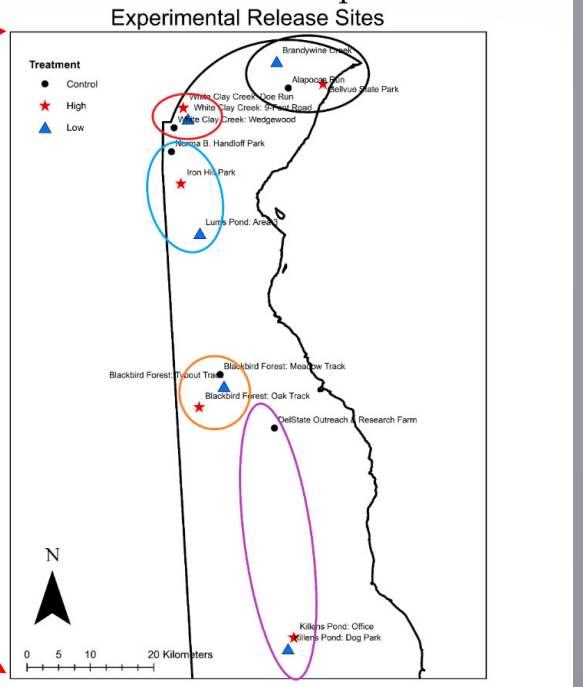
- What will be impact of competition with indigenous parasitoids and predators? Will parasitoid guilds be affected?
- How will this impact non-target stink bugs and other spp.?
- APHIS regulates interstate but not intrastate movement of exotic & beneficial insects
- Several U.S. states are now redistributing populations within their boundaries.

U.S. mass rearing & distribution of adventive *Trissolcus japonicus* (as of 2019)



Field releases in participating states (DE shown as an example) conducted as an experiment to measure establishment success as a function of the numbers of parasitoids released at a site.





Additional replicates in neighboring states

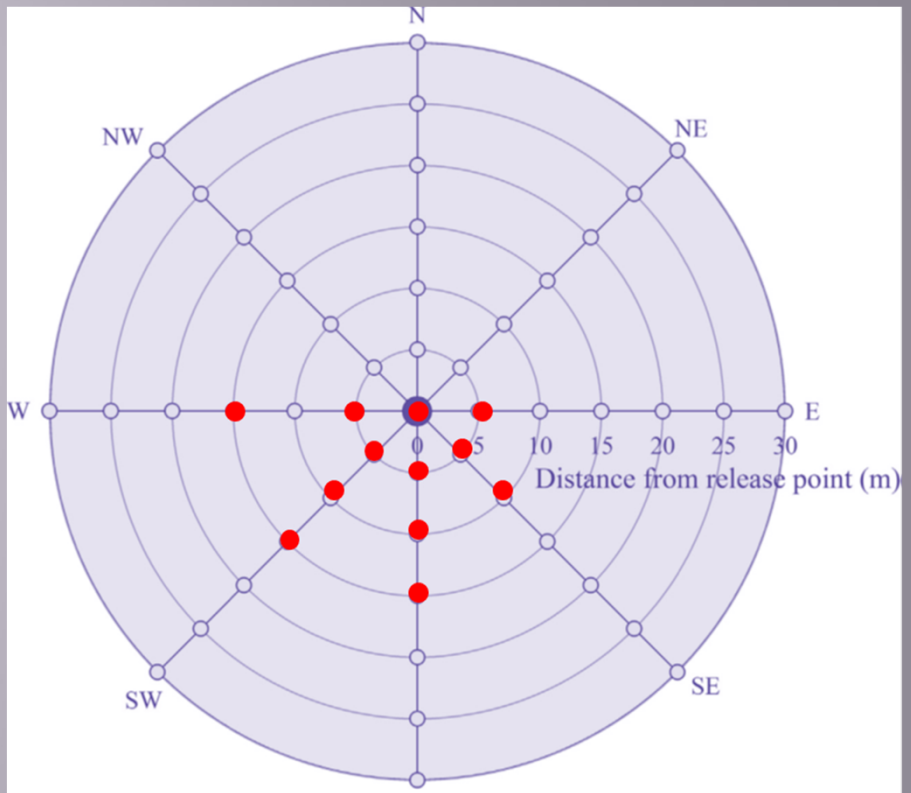
A) High release: 15-20 parasitized egg masses per release, ca. 400 ♀Tj
B) Low release: 1-2 parasitized egg masses per release, ca. 40 ♀Tj
C) Control (no released wasps)

Dispersal and foraging of *T. japonicus*

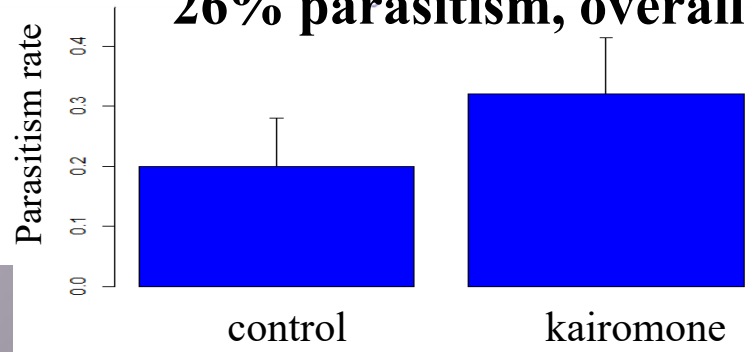
~1500 female adult wasps released
Half of trees exposed to BMSB adults (contact kairomone)

Dispersal and foraging of *T. japonicus*

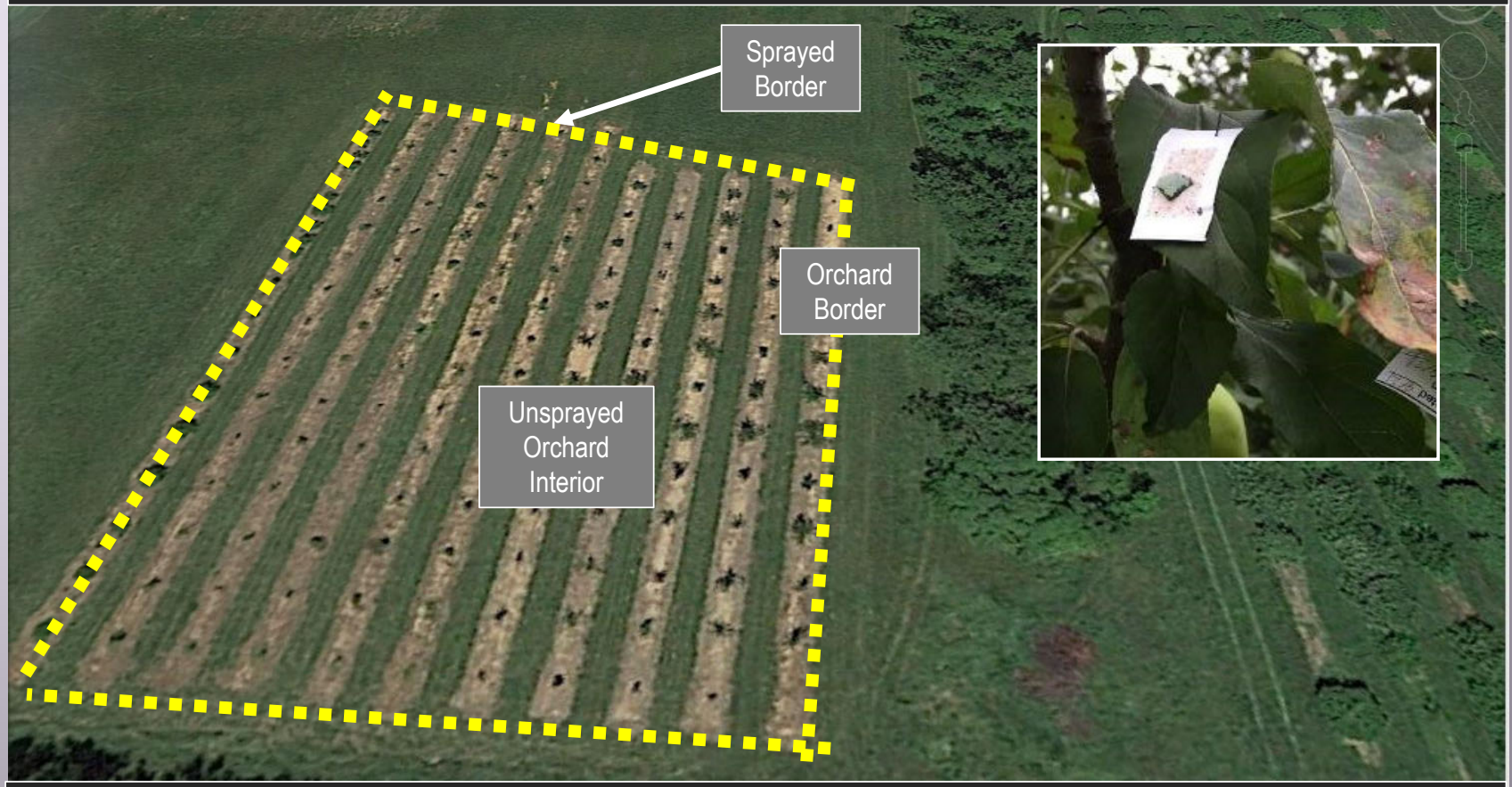
~1500 female adult wasps released
Half of trees exposed to BMSB adults



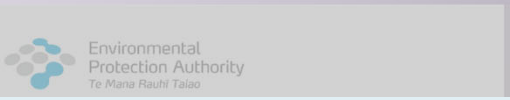
26% parasitism, overall



Integrating *Trissolcus japonicus* into Orchard IPM Systems



T. japonicus adults can successfully parasitize eggs & parasitized eggs hatch following insecticide treatments, with greatest survivorship from those present in unsprayed refugia due to use of advanced IPM tactics such as border sprays, attract and kill or alternate row spray patterns.



Pre-emptive Biological Control of BMSB in New Zealand

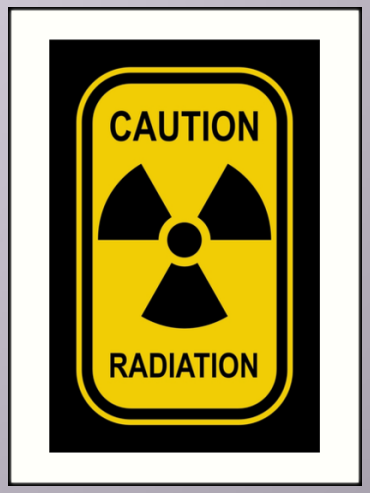
- NZ EPA weighs both beneficial and adverse effects of introductions
- Application to release *Trissolcus japonicus* under the NZ EPA Hazardous Substances and New Organisms (HSNO) Act.
- Considered potential adverse effects on Māori culture & traditions
- Allows <u>conditional</u> release of *T. japonicus* to support an eradication program in the event of a BMSB incursion.
- If BMSB becomes established in New Zealand, an unconditional release approval may be requested at that time.

Caron V. (2019) Biological control stocktake for the brown marmorated stink bug *Halyomorpha halys* Stål. CSIRO, Australia

Report Recommendations:

- Studies of potential Australian natural enemies of BMSB needed
- *T. mitsukurii* is already present in Australia (introduced against *Nezara viridula*)
- Host specificity testing needed for *T. japonicus* & *T. mitsukurii*
- *T. japonicus* unlikely to be permitted if many native Australian pentatomids are attacked (77 spp. recorded)

Another potential approach: Sterilize non-native *T. japonicus*, reducing the non-target risk of its introduction (a variation on augmentative biocontrol)



Petition for the release of *Trissolcus japonicus* (Hymenoptera: Scelionidae) for biological control of *Halyomorpha halys* (Hemiptera: Pentatomidae) in Canada

Submitted by:

P. K. Abram[1], T. Haye[2], K. A. Hoelmer[3], T.D. Gariepy[4], P.G. Mason[5]

[1]Agriculture and Agri-Food Canada, Agassiz Research and Development Centre, Agassiz, British Columbia, Canada
[2]CABI Switzerland, Delémont, Switzerland
[3]Beneficial Insects Introduction Research Unit, United States Department of Agriculture, Agricultural Research Service, Newark, Delaware, USA
[4]Agriculture and Agri-Food Canada, London Research and Development Centre, London, Ontario, Canada
[5]Agriculture and Agri-Food Canada, Ottawa Research and Development Centre, Ottawa, Ontario, Canada

Cover Photo: Tim Haye

TABLE OF CONTENTS

ABSTRACT 4
1.0 INTRODUCTION 5
2.0 PROPOSED ACTION 7
2.1 OBJECTIVES OF THE RELEASE 7
2.2 CHOICE OF BIOLOGICAL CONTROL AGENT 7
2.3 REARING/CONTAINMENT FACILITY 8
2.4 DISPOSAL OF UNWANTED HITCHHIKERS 8
2.5 LOCATION OF THE RELEASE 8
2.6 METHODS OF RELEASE 9
2.7 AGENCIES AND OR INDIVIDUALS INVOLVED IN THE RELEASE 9
2.8 CURRENT BIOLOGICAL CONTROL OF THE TARGET PEST IN CANADA 9
3.0 TARGET PEST INFORMATION 11
3.1 TAXONOMY 11
3.2 ECONOMIC IMPACT OF THE TARGET PEST 11
3.3 LIFE HISTORY OF THE TARGET PEST 13
3.4 DISTRIBUTION OF THE TARGET PEST 15
3.5 ECONOMICALLY AND ENVIRONMENTALLY IMPORTANT SPECIES RELATED TO THE TARGET 15
4.0 BIOLOGICAL CONTROL AGENT INFORMATION 21
4.1 TAXONOMY 21
..... 22
4.2 IDENTIFICATION OF BIOLOGICAL CONTROL AGENT AND VOUCHER SPECIMENS 22
4.3 NATURAL GEOGRAPHIC RANGE, AREAS WHERE INTRODUCED 23
4.4 SOURCE OF THE BIOLOGICAL CONTROL AGENT 24
4.5 HOST-AGENT INTERACTIONS 25
4.6 LIFE HISTORY 27
4.7 KNOWN HOST RANGE 27
4.8 HISTORY OF PAST USE OF BIOLOGICAL CONTROL AGENT 28
4.9 ELIMINATION OF CONTAMINANTS FROM CULTURE 28
4.10 SOP FOR HANDLING IN QUARANTINE 28
4.11 CLOSELY RELATED SPECIES IN NORTH AMERICA 29
5.0 HOST-SPECIFICITY TESTING 31
5.1 SELECTION OF TEST INSECTS 31
5.2 LABORATORY TESTS ON NORTHEASTERN NORTH AMERICAN HEMIPTERA 32
5.2.1 Methods 32
5.2.2 Results and discussion 36
..... 41
5.2.3 Conclusions 41
5.3 LABORATORY TESTS ON NORTHWESTERN NORTH AMERICAN HEMIPTERA 43
5.3.1 Methods 43

5.3.2 Results and discussion 44
5.3.3 Conclusions 45
5.4 LABORATORY TESTS ON EUROPEAN HEMIPTERA 47
5.4.1 Methods 47
5.4.2 Results and discussion 49
5.4.3 Conclusions 51
5.5 LABORATORY AND FIELD TESTS ON ASIAN HEMIPTERA 51
5.5.1 Methods 51
5.5.2 Results and discussion 53
5.5.3 Conclusions 55
5.6 HOST RANGE TESTS: GENERAL CONCLUSIONS 57
6.0 ENVIRONMENTAL AND ECONOMIC IMPACTS OF THE PROPOSED RELEASE 59
6.1 IMPACTS ON VERTEBRATES 59
6.2 IMPLICATIONS OF NOT RELEASING THE BIOLOGICAL CONTROL AGENT 59
6.3 DIRECT IMPACTS ON TARGET AND NON-TARGET SPECIES 61
6.4 EFFECTS ON PHYSICAL ENVIRONMENT 62
6.5 INDIRECT EFFECTS 62
6.5.1 Indirect impacts on plants 62
6.5.2 Competition or hybridization with indigenous stink bug parasitoids 63
6.6 POSSIBLE DIRECT OR INDIRECT EFFECTS ON THREATENED AND ENDANGERED SPECIES 64
7.0 POST-RELEASE MONITORING 65
7.1 BIOLOGICAL CONTROL AGENT ESTABLISHMENT AND SPREAD 65
7.2 BIOLOGICAL CONTROL AGENT AND TARGET DENSITIES OVER TIME 65
7.3 HOST-SPECIFICITY AND ATTACK RATES ON THE TARGET SPECIES AND NON-TARGET SPECIES 66
7.4 CHANGES IN THE TARGET PEST AND IN THE GROWTH, SURVIVAL AND REPRODUCTION OF SELECTED NON-TARGET SPECIES POPULATIONS 66
8.0 PRE-RELEASE COMPLIANCE 66
8.1 REFERENCE SPECIMENS 66
8.2 PLANNED LOCATION AND TIMING OF THE FIRST RELEASES 66
9.0 REFERENCES 67

- Petition for field release has been filed in Canada in 2018 (now in review)
- Petition for field release in U.S. is nearing completion for submission

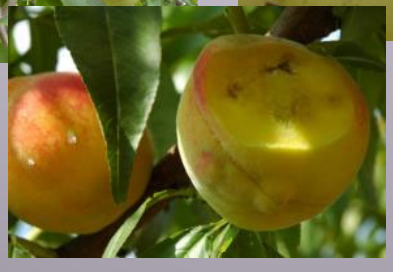
Summary

T. Mituskurii / Photo: S. Valley / ODA

- Adventive *Trissolcus japonicus* has established in 13 U.S. states, British Columbia, Ontario, Switzerland, and Italy, and can be expected to continue to spread naturally to surrounding regions.
- Adventive *Trissolcus mitsukurii* has been recovered in N. Italy.
- Biological characteristics of *Trissolcus* favor its dispersal by natural & other adventive means.
- Adventive populations of *Trissolcus japonicus* are being redistributed within their respective U.S. state boundaries to accelerate the impacts of *T. japonicus* on BMSB populations.

PennState
College of Agricultural Sciences

BMSB IS STILL A SERIOUS PEST OF FRUIT



Evolution of BMSB Management in Specialty Crops

Identification of effective insecticides

- Pyrethroids and neonicotinoids

Frequent applications (calendar-basis)

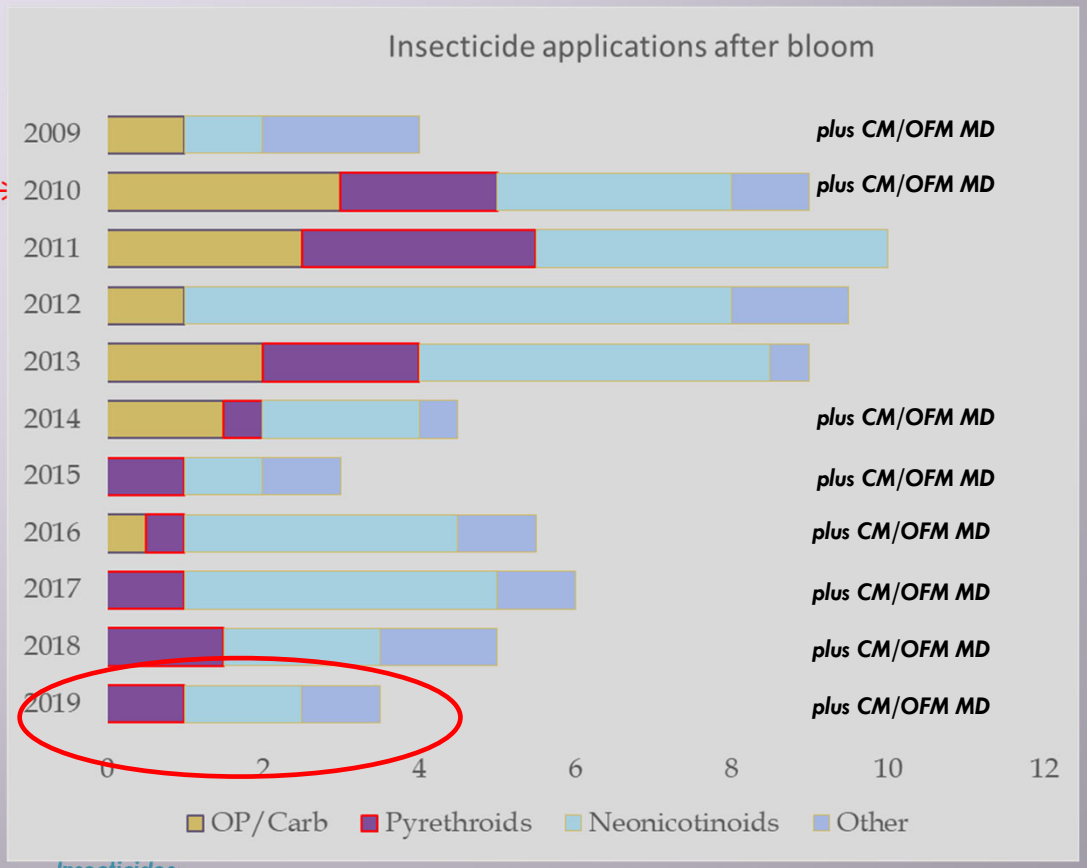
Use of pheromone traps for dictating applications (threshold based)

Strategies to minimize insecticide inputs

- Perimeter/border spraying
- Attract and Kill

CHANGES IN INSECTICIDE APPLICATIONS - APPLES

2009-2019 seasons
(Commercial apple orchard, PA)



Insecticides:
Carbamates (IRAC Group 1A) – methomyl,
Organophosphates (IRAC Group 1B) – phosmet,
Pyrethroids (IRAC Group 3A) – fenpropathrin, lambda cyhalothrin, bifenthrin,
Neonicotinoids (IRAC Group 4A) – acetamiprid, clothianidin, thiametoxam, dinotefuran, thiacloprid,
Other (IRAC Groups 5, 18, 28) – methoxyfenozide, spinetoram, rynaxypyr, indoxacarb.

Other apple pests required control:

- *Codling moth*
- *Oriental fruit moth*
- *Plum curculio*
- *Japanese beetle*
- *Tufted apple budmoth*
- *Aphids*
- *Leafhopers*

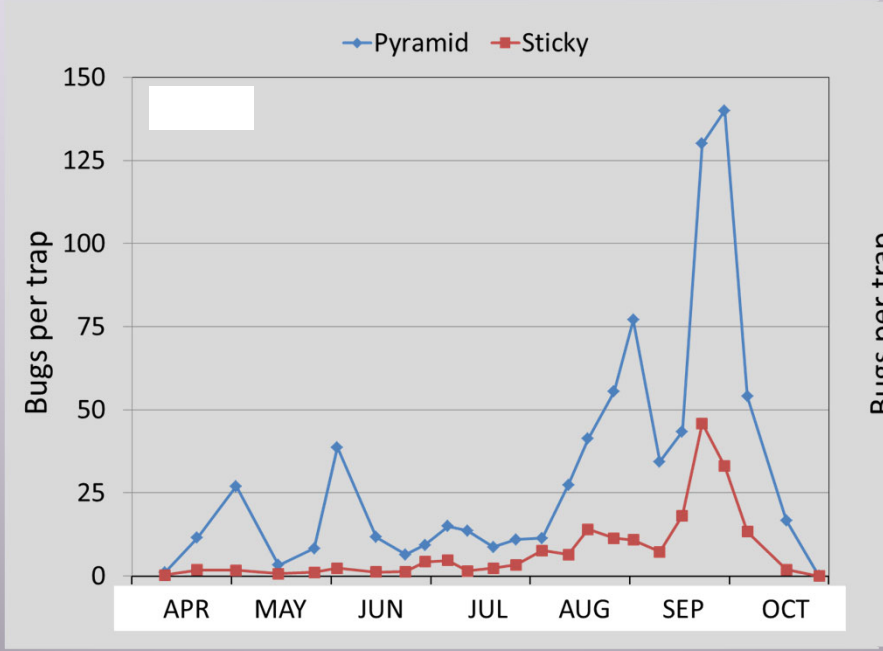
BMSB Pheromone Trap Thresholds

10 cumulative adults/trap
in eastern apples/peaches

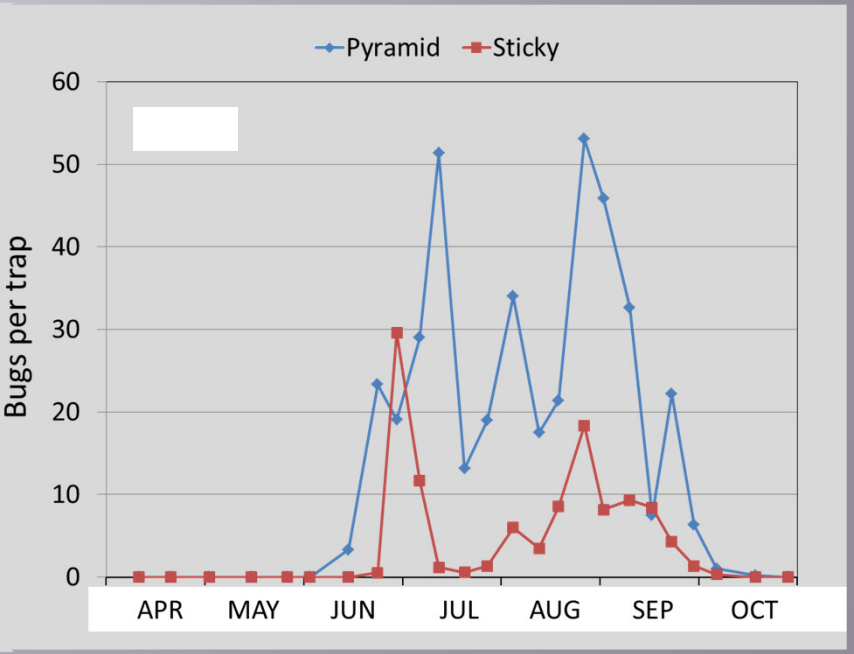
Threshold being reassessed
with more user-friendly panel trap

Pyramid Traps Capture More Bugs, but Captures are Highly Correlated

Adults



Nymphs

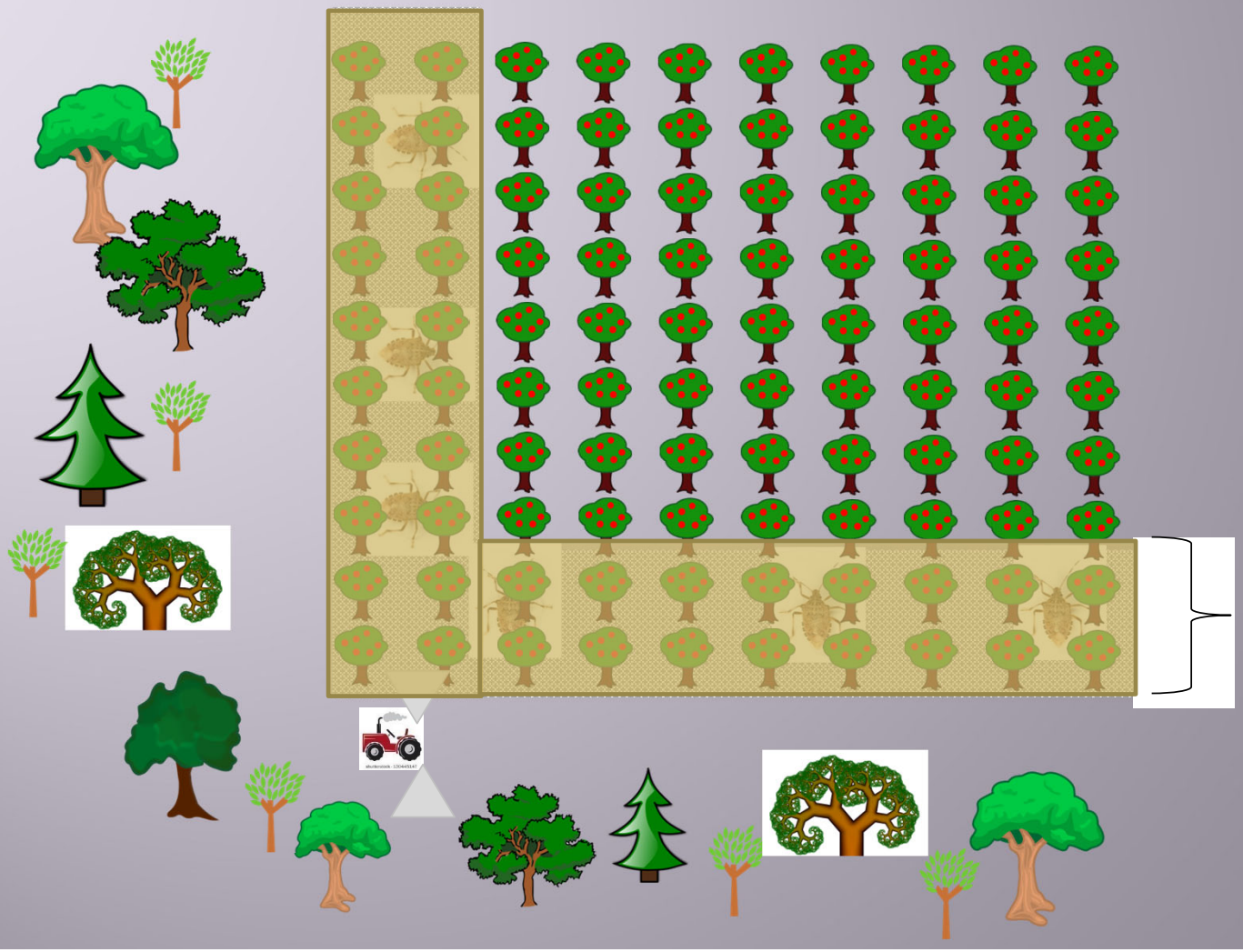


Developing a Decision Support Tool for Apple Orchards Using Clear Sticky Panels

Threshold-Based Management Regime	No. Triggered Insecticide Applications	% Fruit Injury at Harvest
1 Adult/Trap	4.8	2.67
4 Adults/Trap	2.3	4.33
4 Nymphs/Trap	1.0	6.99
Always Sprayed (Calendar-Based Sprays)	8.3	0.89
Never Sprayed (Control)	0.0	5.67

A cumulative threshold of 4 adults/trap appears promising and is being validated in commercial orchards across the region.

Border Sprays where BMSB is a Border Pest



Spray border rows only

BMSB alternative management trials

Net exclusion trials

- net barrier between crop and potential source of BMSB infestation
- utilize existing deer fences

Krawczyk et al. 2014. PA Fruit News

Crop trapping *(work of Deonna Soergel, former graduate student)*

- based on differences in attractiveness of various crops
- sunflowers and pepper, sunflowers and peaches…

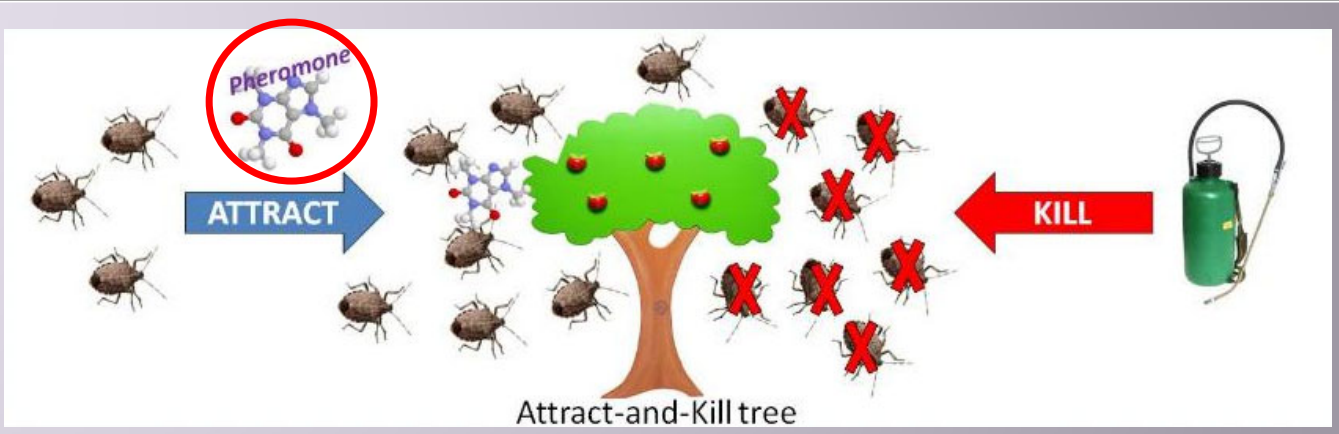
Soergel et al. 2015. Environ Entomol.

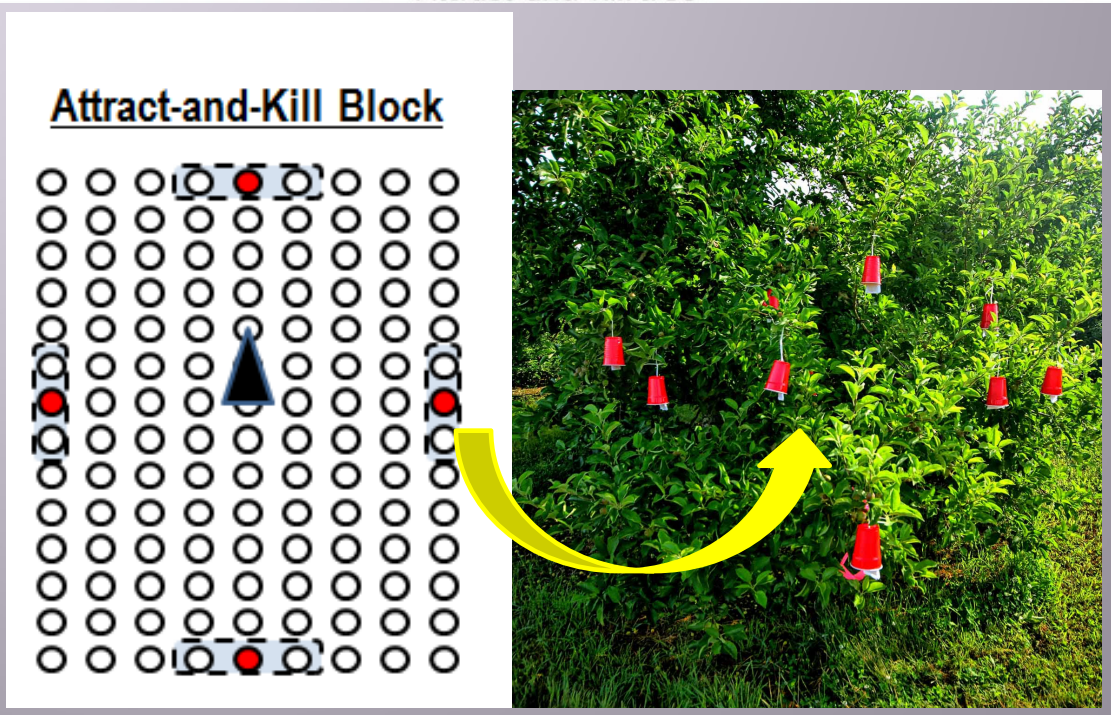
Attract and kill

- Individual border trees baited with BMSB attractants
- Baited net traps outside orchards

Morrison et al. 2018. Pest Manag Sci
Kuchar et al. 2017. J Environ Ent.

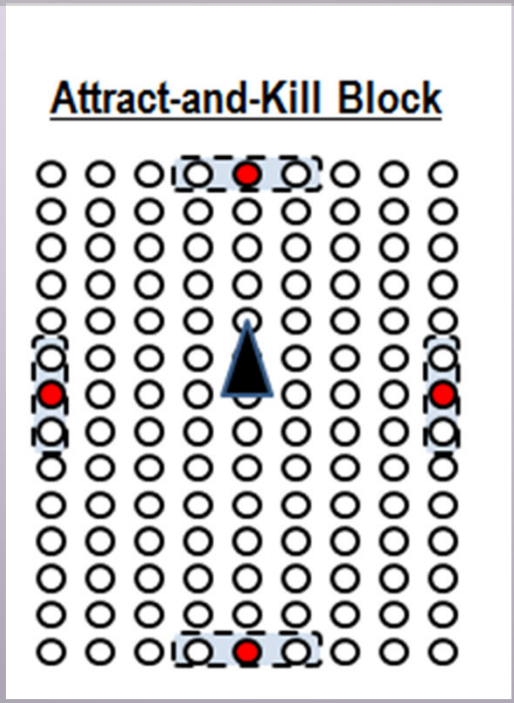
Attract-and-Kill Set-Up in Apple Orchards



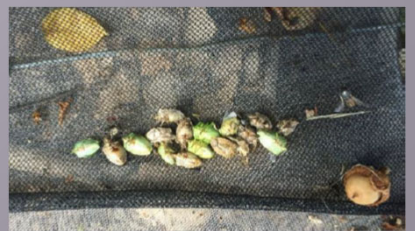


Pheromone-Based Attract & Kill Strategy

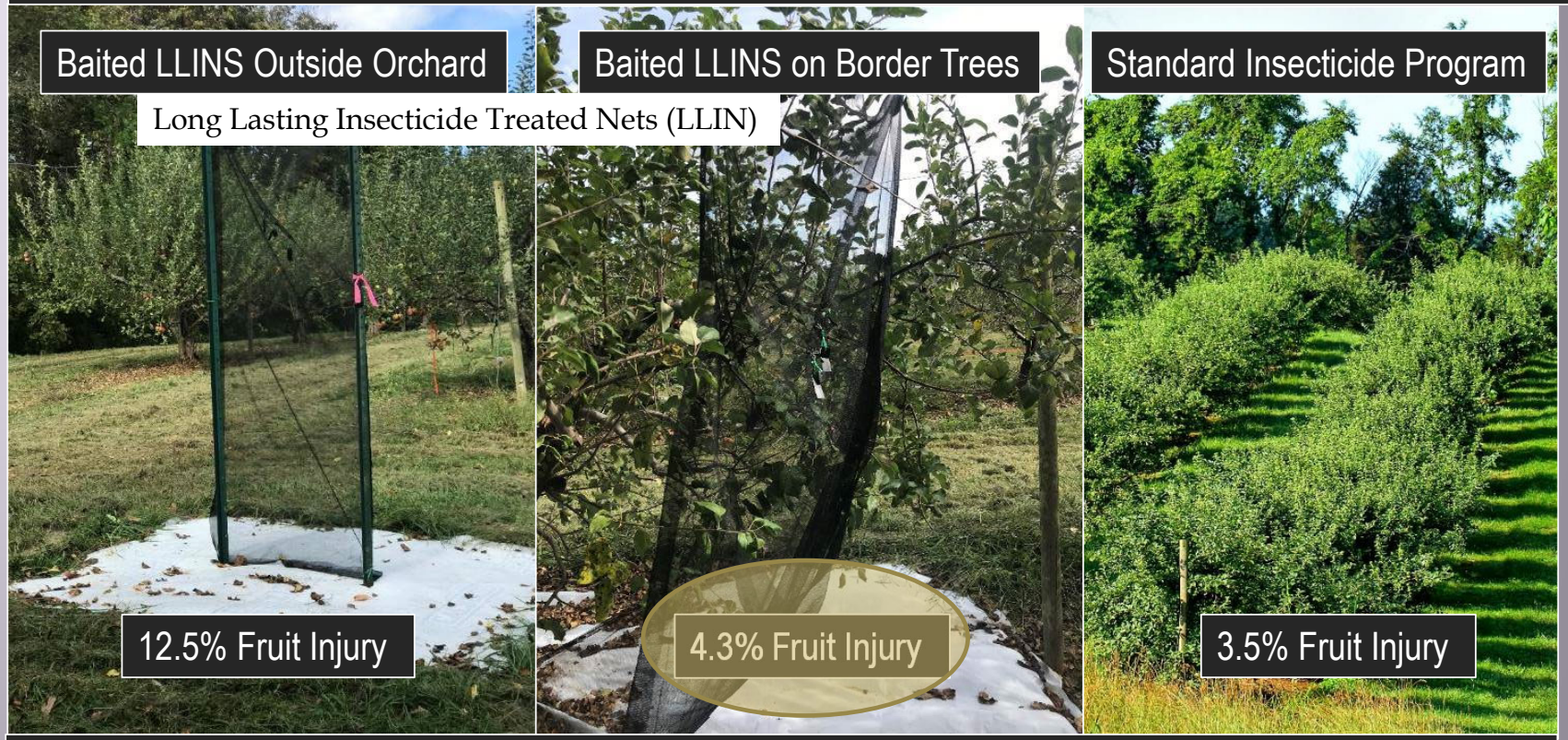
Initial Approach: Pheromone-baited trees and adjacent trees sprayed weekly. Remainder or orchard sprayed based on threshold basis.



Newer Approach: Bugs lured to "Ghost Traps;" deltamethrin impregnated netting (PemaNet by Vestergaard). Placed around orchard perimeter.



Behaviorally Compatible “Attract and Kill” For Commercial Orchards As a Replacement for Insecticides



Combining pheromone lures, host plant stimuli (apple tree), and killing agent (LLIN) maximizes attraction & retention on select fruit trees at orchard border and results in fruit injury that is equivalent to standard insecticide programs. Baited LLINs deployed outside orchards do not work well due to behavioral cues being separated from one another.

SUMMARY…

BMSB Management Information provided by:
Tracy Leskey, USDA ARS, AFRS, Kearneysville, WV tracy.leskey@usda.gov
Jim Walgenbach, North Carolina State Univ. Jim_Walgenbach@ncsu.edu
Greg Krawczyk, Pennsylvania State Univ. gxk13@psu.edu

BMSB unique biology and behavior create serious challenge for farmers and homeowners. Integrated approach incorporating all aspects of IPM is the best solution to mitigate the economic impact of this pest.

Lures and traps are effective in detecting the presence of BMSB and should be used to decide if BMSB treatments are needed. The placement of traps and understanding of “active space” for various BMSB lure/trap combinations is crucial for the development of practical trapping recommendations.

Biological control and utilization of bio-rational approaches are crucial elements of effective BMSB management programs.

Alternative BMSB management options such as attract and kill or “ghost” net traps are effective elements to support IPM based insect pests management programs in fruit.

SWD Management Summary Information provided by:
Cesar Rodriguez-Saona, Rutgers Univ. crodriguez@njaes.rutgers.edu

Sustainable Spotted Wing Drosophila Management for United States Fruit Crops

USDA National Institute for Food and Agriculture (NIFA) Specialty Crops Research Initiative (SCRI)

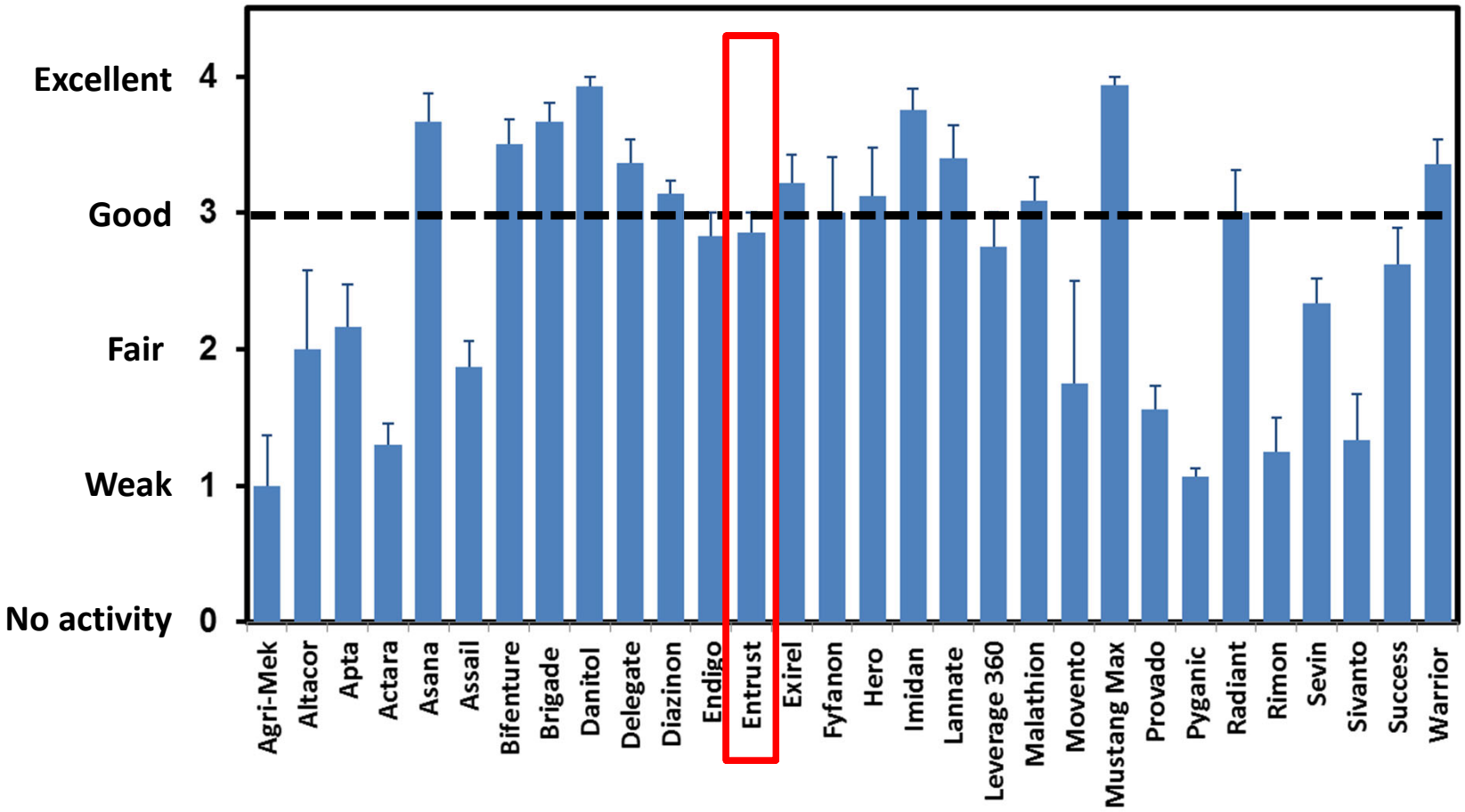
Award number 2015-51181-24252

Four years: 15 Sept 2015 through 14 Sept 2019

Research on SWD Trapping Lures/Baits

CHEMICAL CONTROL

2014 summary rankings of insecticide efficacy against SWD
10 states, 20 state x crop combinations



Information provided by Michigan State University, North Carolina State University, Washington State University, University of Maine, University of California Berkeley, Rutgers University, Oregon State University, University of Georgia, Cornell University, and University of Florida.

Examples:

MI blueberry SWD spray program

Timing	Product	Rate
First SWD, if ripe fruit	Lannate	1 lb
week 2	Danitol	16 oz
week 3	Delegate	6 oz
week 4	Mustang Max	4 oz
week 5	Imidan	1.33 lb
week 6	Danitol	16 oz
week 7	Imidan	1.3 lb
week 8	Mustang Max	4 oz

SWD Management Programs in GA Blueberries

Management Strategy	Weekly rotations
Export-friendly, maximum modes of action	Imidan (phosmet), Malathion 8F, Delegate (spinetoram), and Danitol (fenpropathrin)
Short preharvest interval (PHI)	Mustang Max (zeta-cypermethrin) and Malathion 8F
Reduced risk	Delegate and Exirel (cyantraniliprole)
Organic	Entrust and Pyganic

Visit to Australia & New Zealand – February 2020

Research on Biocontrol of *Drosophila suzukii* in the USA

Kent Daane - University of California, Berkeley, USA

Xingeng Wang & Kim Hoelmer -

USDA-ARS Beneficial Insects Introduction Research Unit, Newark DE, USA

Cesar Rodriguez-Saona - Rutgers University, Chatsworth, NJ

How much is bio-control (parasitoids) already present in North America?

Resident larval parasitoids:

Leptopilina heterotoma
Leptopilina boulardi
Asobara tabida

} Failed to develop from SWD (except one Italian *L. heterotoma* population showing some success)

Resident pupal parasitoids:

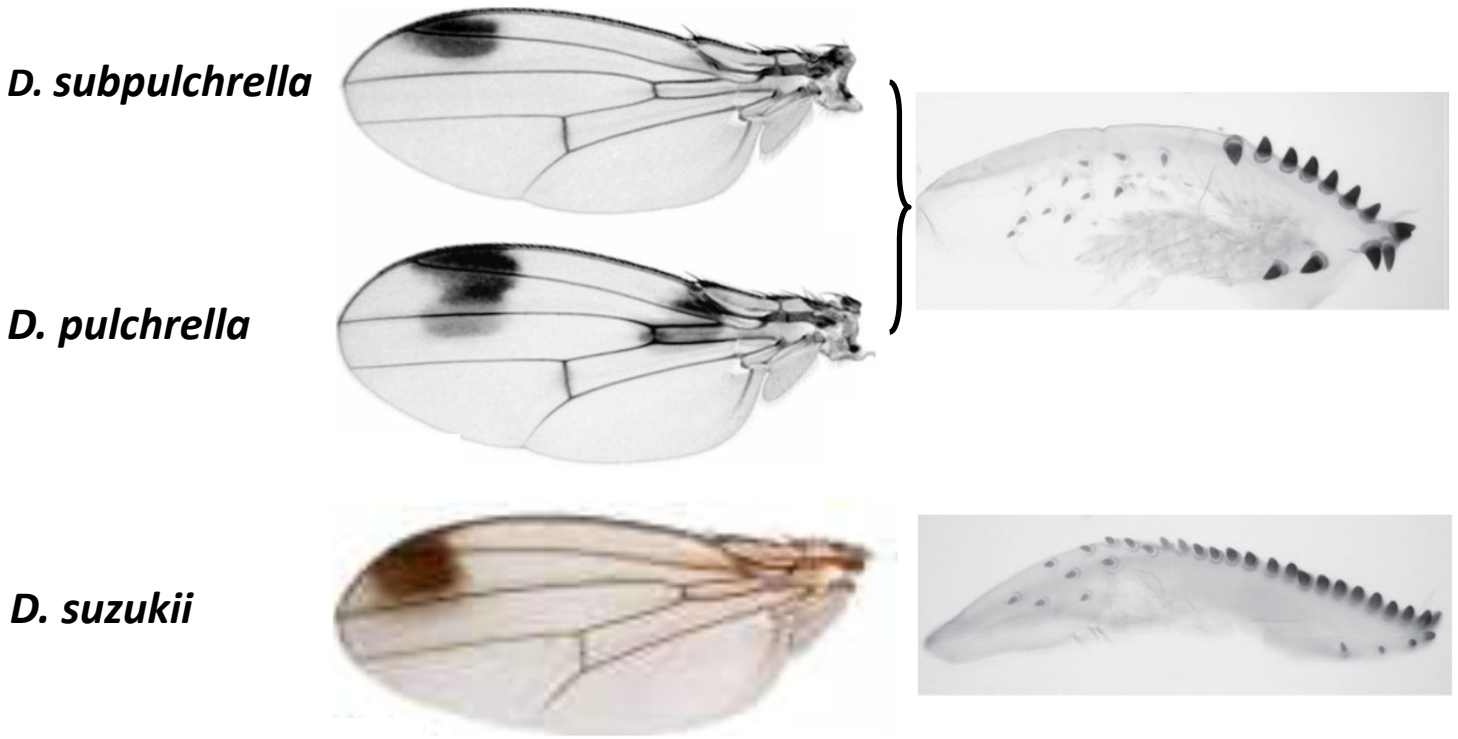
Pachycrepoideus vindemiae
Trichopria drosophilae

} Readily attacked and developed from SWD, but at low levels in field

Collected parasitoids in South Korea and China

	Family	Parasitoid species	Host	Country
Larval parasitoids	**Braconidae**	***Asobara japonica***	SWD, other drosophilids	SK, CHN
		Asobara leveri	SWD, other drosophilids	SK, CHN
		Asobara brevicauda	SWD	SK
		Asobara triangulata	SWD	SK
		Asobara mesocauda	SWD	SK, CHN
		Asobara unicolorata	SWD	CHN
		Asobara spp.	SWD	CHN
	Figitidae	***Ganaspis brasiliensis***	SWD	SK, CHN
		Leptopilina japonica	SWD	SK, CHN
		Leptopilina formosana	SWD, other drosophilids	SK
		Leptopilina boulardi	Other drosophilids	SK
		Leptopilina spp.	SWD	CHN
Pupal parasitoids	**Pteromalidae**	*Pachycrepoideus vindemiae*	Other drosophilids	SK
	Diapriidae	*Trichopria drosophilae*	SWD, other drosophilids	SK, CHN

Co-occurrence of three closely related species in *suzukii* subgroup on fresh fruits in China or Japan



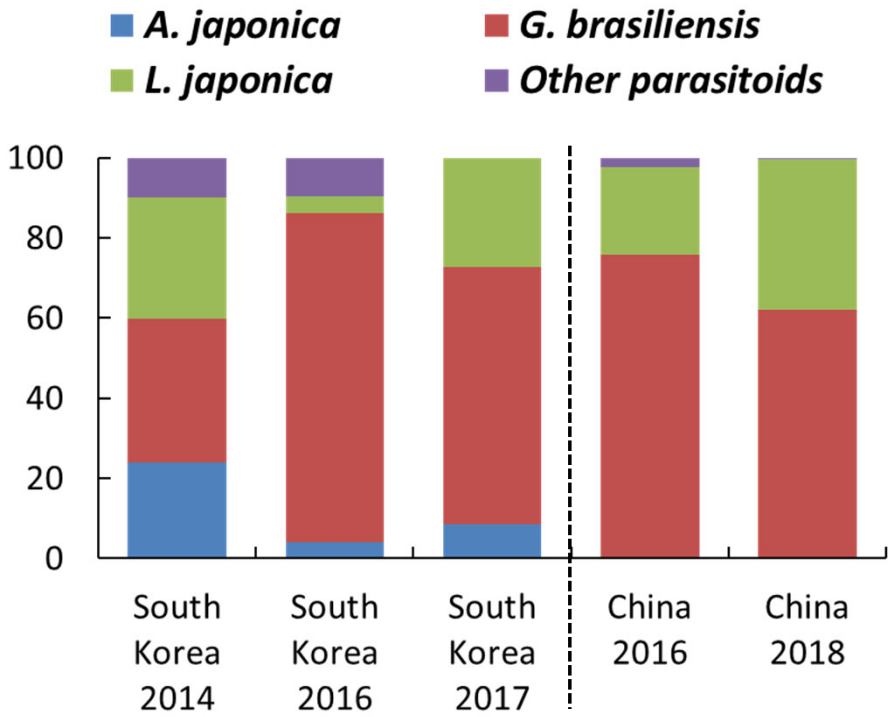
(Giorgini et al. 2018, Girod et al. 2018; Images by Takamori et al. 2006, Atallah et al. 2014)

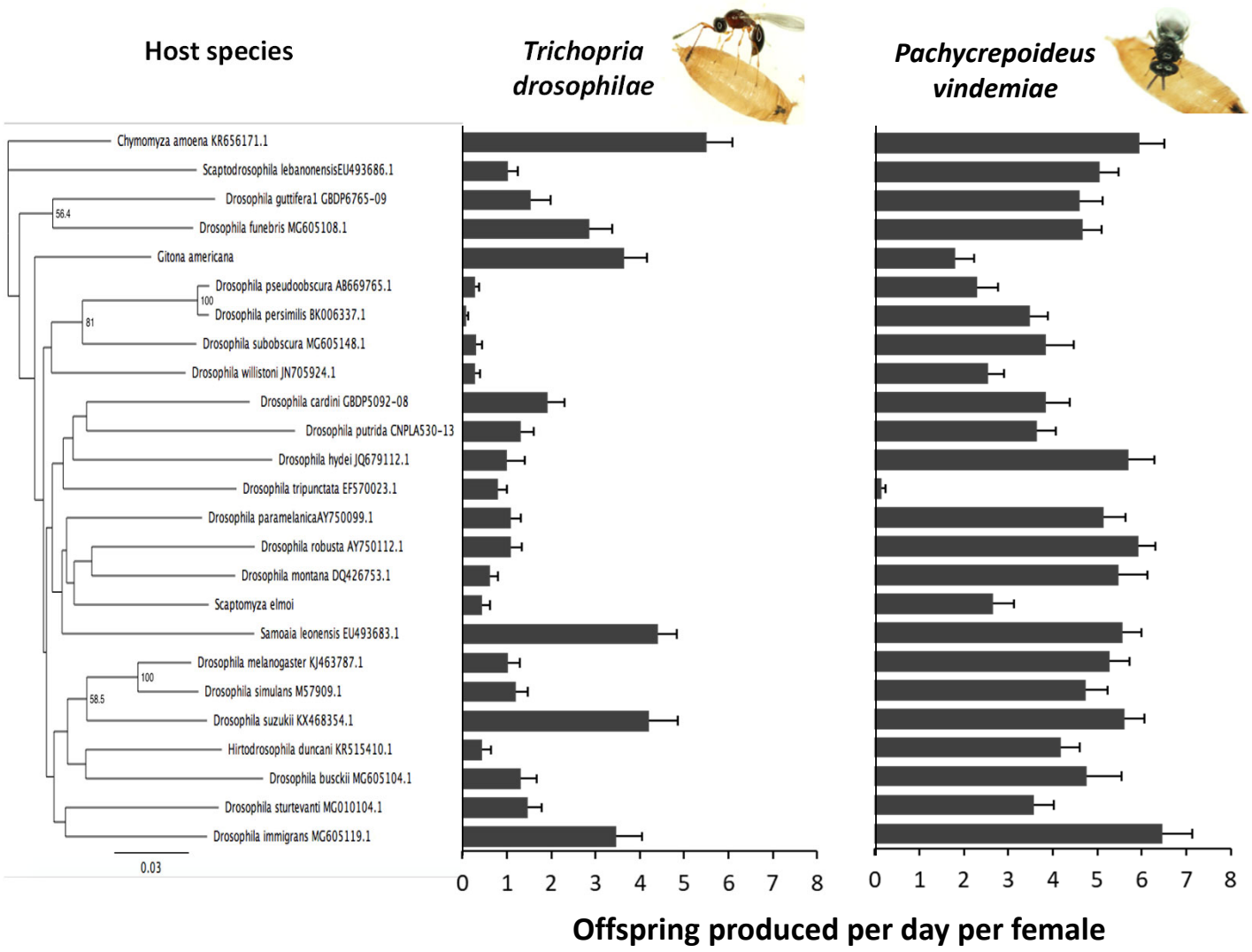
Native SWD parasitoids discovered in East Asia

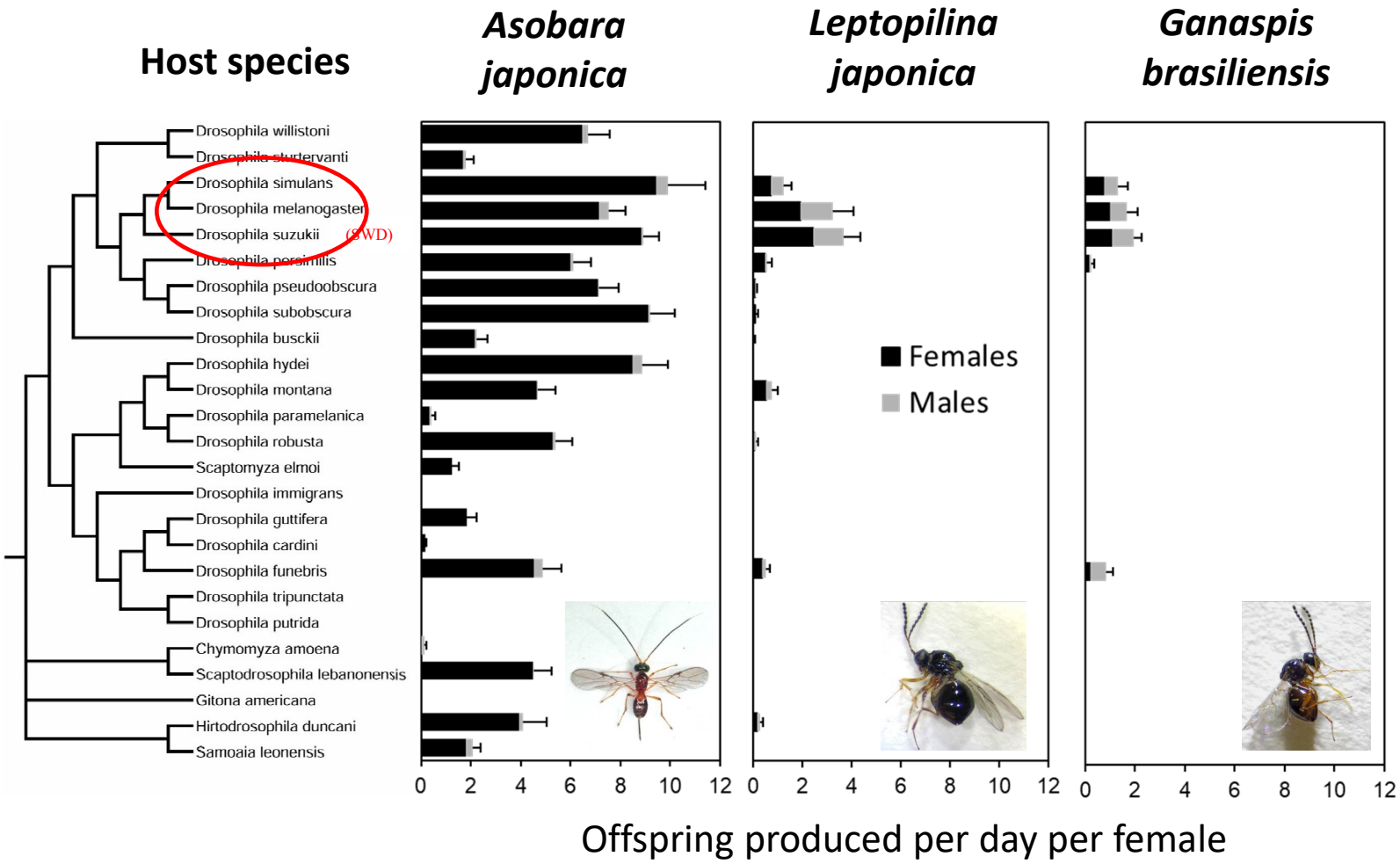
Larval parasitoids (13 species)	**Braconidae**	***Asobara japonica***
		Asobara leveri
		Asobara brevicauda
		Asobara mesocauda
		Asobara triangulate
		Asobara unicolorata
		Asobara pleuralis
		Tanycarpa chors
		Areotetes striaferus
	Figitidae	***Ganaspis brasiliensis***
		Leptopilina japonica
		Leptopilina formosana
		Leptopilina sp.
Pupal parasitoids	**Pteromalidae**	*Pachycrepoideus vindemiae*
	Diapriidae	*Trichopria drosophilae*

(Daane et al. 2016, Guerrieri et al. 2016, Giorgini et al. 2018, Girod et al. 2018)

Composition of larval SWD parasitoids on fresh fruits




Host species
Trichopria drosophilae
Pachycrepoideus vindemiae
Chymomyza amoena KR656171.1
Scaptodrosophila lebanonensisEU493686.1
Drosophila guttifera1 GBDP6765-09
Drosophila funebris MG605108.1
Gitona americana
Drosophila pseudoobscura AB669765.1
Drosophila persimilis BK006337.1
Drosophila subobscura MG605148.1
Drosophila willistoni JN705924.1
Drosophila cardini GBDP5092-08
Drosophila putrida CNPLA530-13
Drosophila hydei JQ679112.1
Drosophila tripunctata EF570023.1
Drosophila paramelanicaAY750099.1
Drosophila robusta AY750112.1
Drosophila montana DQ426753.1
Scaptomyza elmoi
Samoaia leonensis EU493683.1
Drosophila melanogaster KJ463787.1
Drosophila simulans M57909.1
Drosophila suzukii KX468354.1
Hirtodrosophila duncani KR515410.1
Drosophila busckii MG605104.1
Drosophila sturtevanti MG010104.1
Drosophila immigrans MG605119.1
56.4
100
81
100
58.5
0.03
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
Offspring produced per day per female


Host species
Asobara japonica
Leptopilina japonica
Ganaspis brasiliensis
Drosophila willistoni
Drosophila sturtevanti
Drosophila simulans
Drosophila melanogaster
Drosophila suzukii (SWD)
Drosophila persimilis
Drosophila pseudoobscura
Drosophila subobscura
Drosophila busckii
Drosophila hydei
Drosophila montana
Drosophila paramelanica
Drosophila robusta
Scaptomyza elmoi
Drosophila immigrans
Drosophila guttifera
Drosophila cardini
Drosophila funebris
Drosophila tripunctata
Drosophila putrida
Chymomyza amoena
Scaptodrosophila lebanonensis
Gitona americana
Hirtodrosophila duncani
Samoaia leonensis
Females
Males
0 2 4 6 8 10 12
Offspring produced per day per female

Pending Petition for Field Release:
Ganaspis brasiliensis

SUMMARY

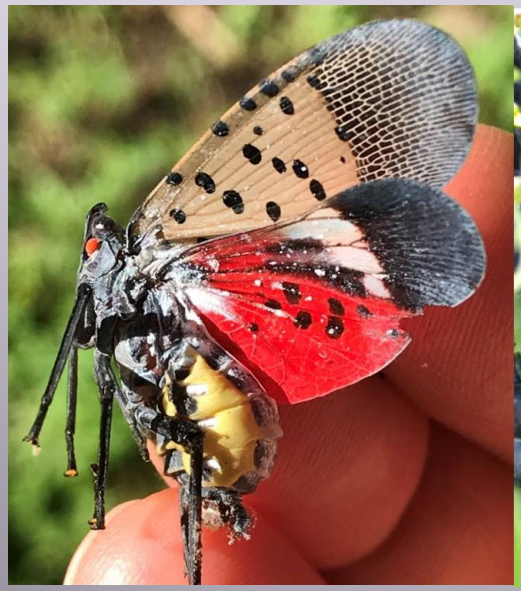
- ✓ **Significant progress in understanding biology and ecology of SWD**
- ✓ **Effective baits and lures are available to detect SWD populations before infestations occur**
- ✓ **A number of conventional insecticides are effective against SWD but repeated applications may result in:**
  - ➢ Insecticide resistance and residue issues
  - ➢ Secondary pests
- ✓ **Majority of SWD activity in the field occurs during dawn and dusk, and making insecticide applications during these times will result in much better control of SWD**

SUMMARY (2)

- ✓ Organic management remains a challenge
- ✓ An integrated approach including behavioral, cultural, biological, and chemical control isnecessary to control SWD
- ✓ Adult SWD flies can be trapped year round & wild plant species present in wooded areas serve as viable hosts of SWD
- ✓ Implementing behavioral and cultural strategies in wooded areas earlier in the season may help reduce populations
- ✓ Genetic control seems to be promising
- ✓ Multi-institutional collaborations are the key to dealing with major challenges like SWD

THE RISK POSED BY THE INVASIVE SPOTTED LANTERNFLY

J. URBAN & H. LEACH – PENN STATE UNIV.
T. LESKEY - USDA-ARS AFRS
J. GOULD & H. BROADLEY – APHIS &
K. HOELMER - ARS



SLF SCRI CAP Project

Biology, Management, and Reducing the Impact of the Spotted Lanternfly on Specialty Crops in the Eastern USA

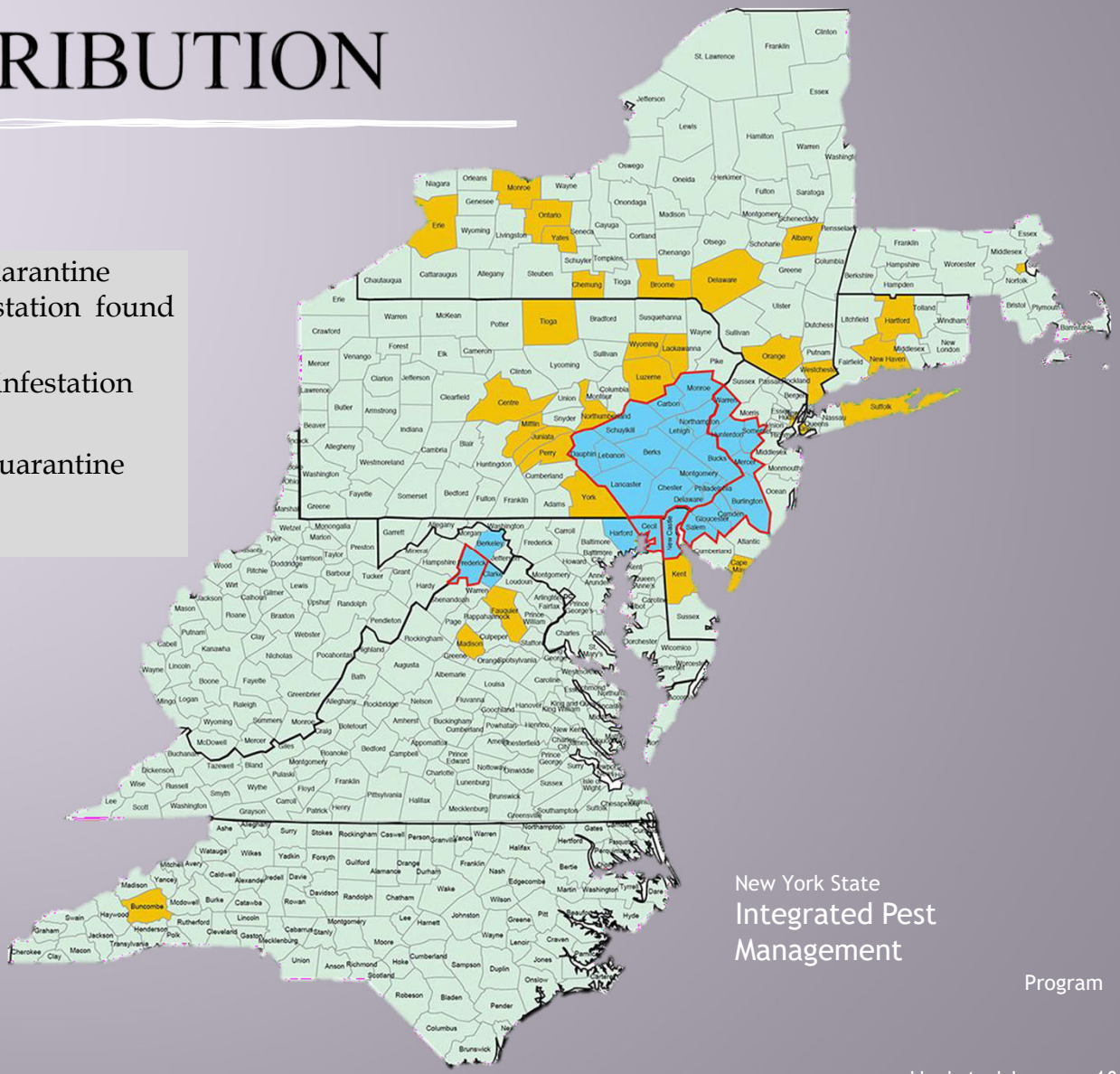
$7,308,194 over 4 years

> $5,000,000 matching funds from in kind use of grower land for research

- **Penn State – Julie Urban (PI)**
- **USDA ARS**
- **USDA APHIS**
- **Cornell**
- **NE IPM**
- **Rutgers**
- **Temple**
- **University of Delaware**
- **University of Rhode Island**
- **Virginia Tech**

DISTRIBUTION

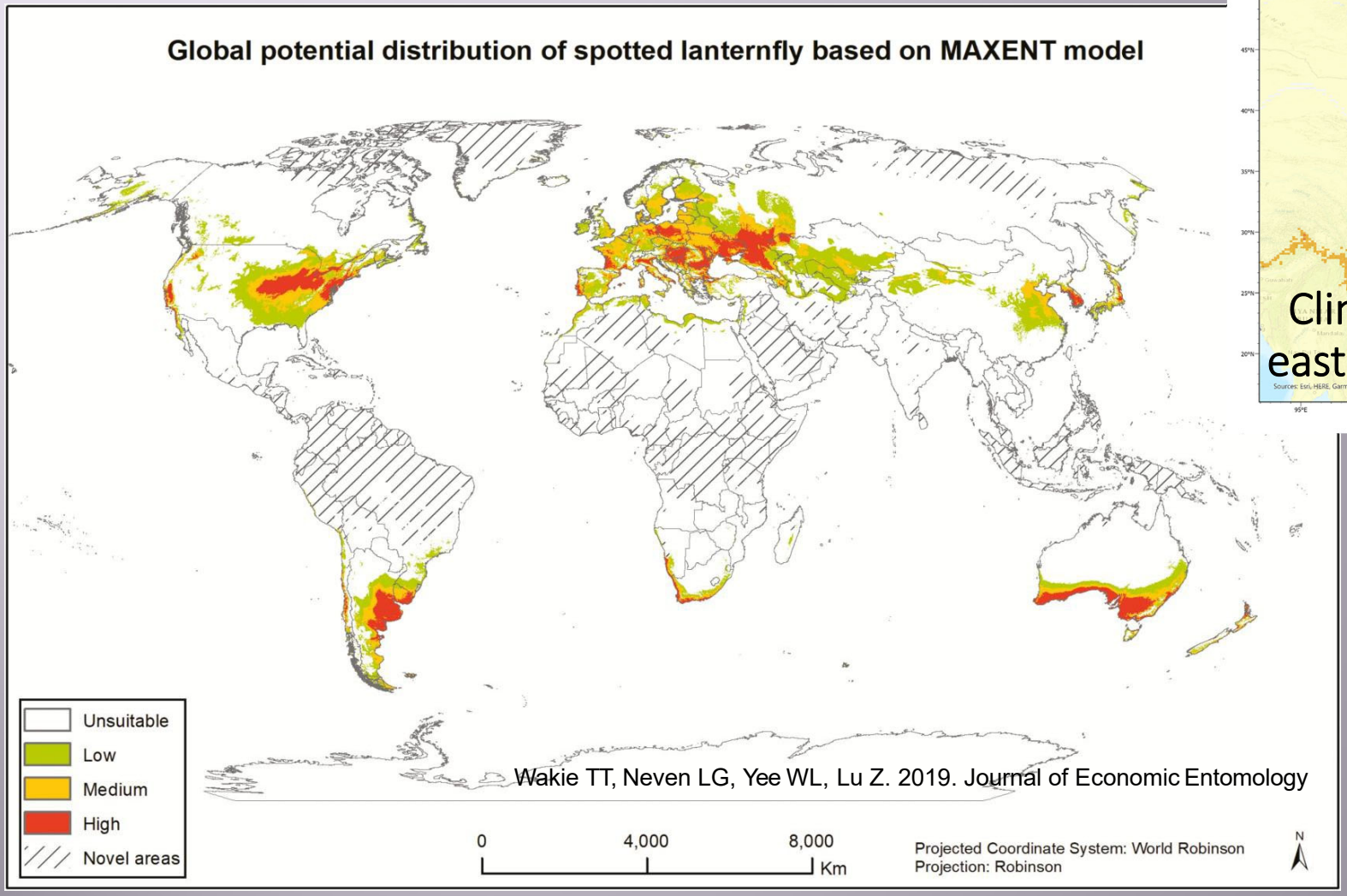
- NY external quarantine areas. SLF infestation found
- SLF found, no infestation
- Internal state quarantine areas



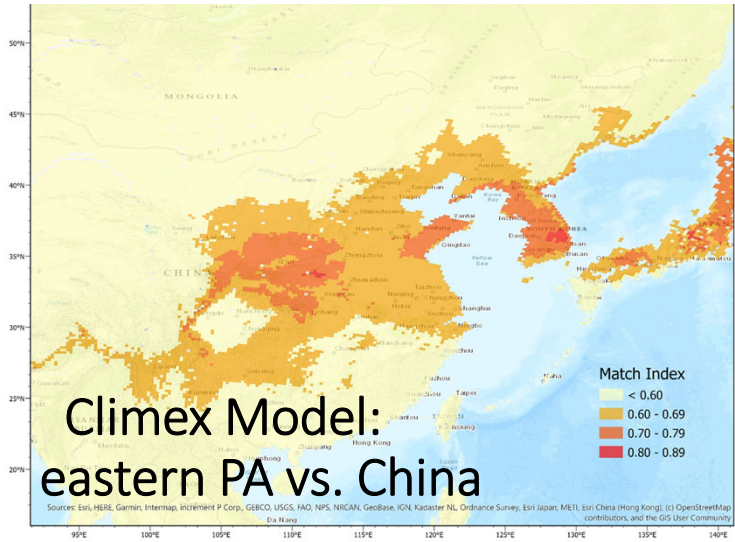
New York State
Integrated Pest Management
Program

PennState

Updated January 10, 2020



Wakie TT, Neven LG, Yee WL, Lu Z. 2019. Journal of Economic Entomology

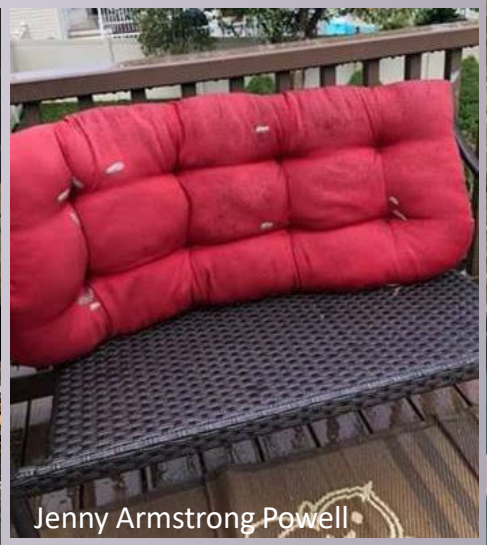


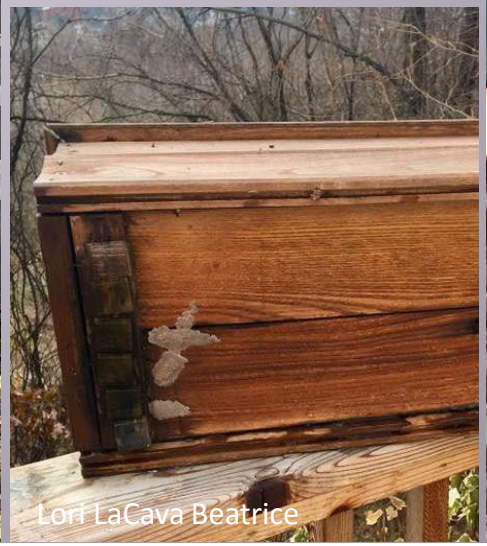
Climex Model:
eastern PA vs. China

SLF Egg masses

Brandon Zimmerman

Zil Fessler

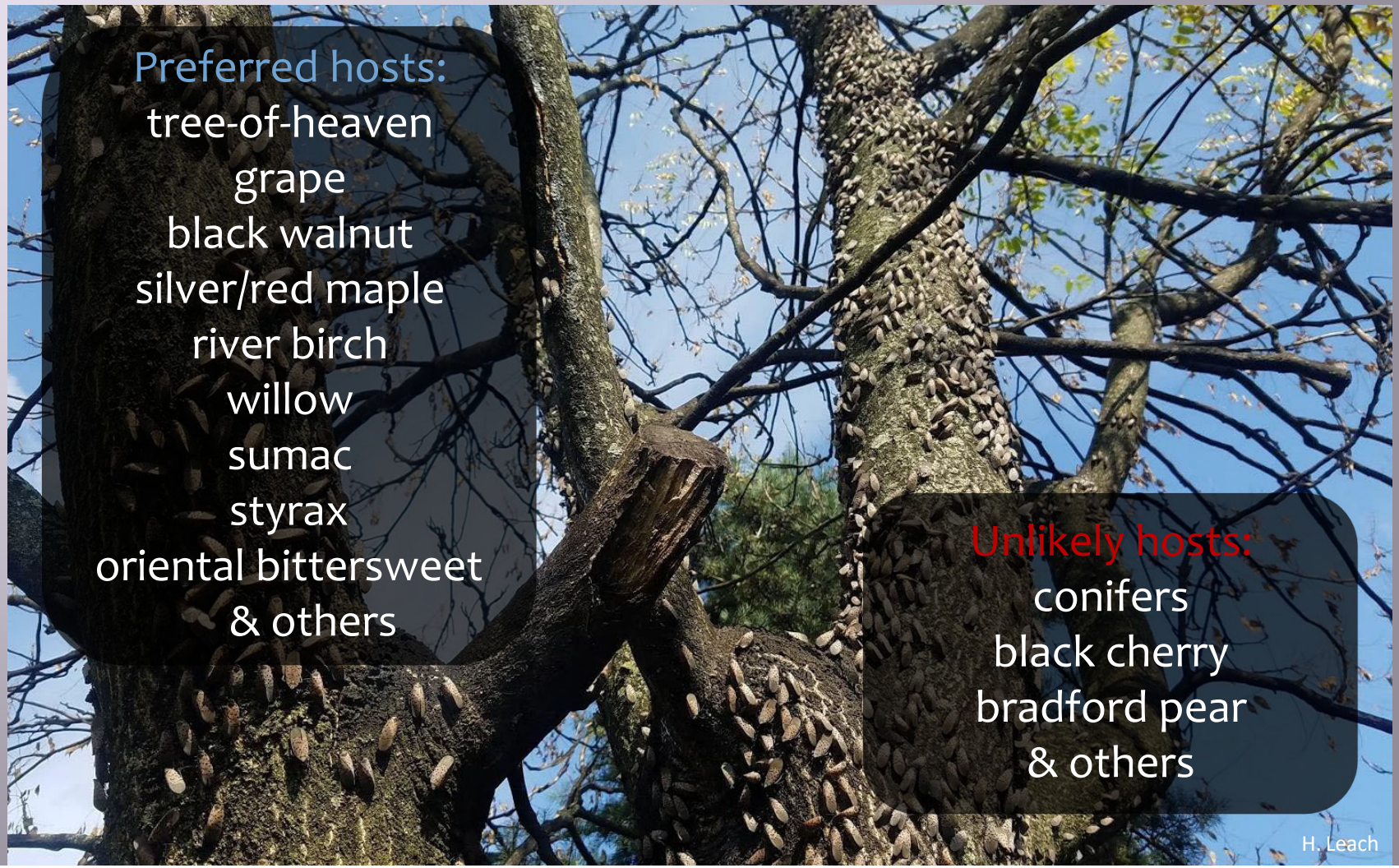

Jenny Armstrong Powell

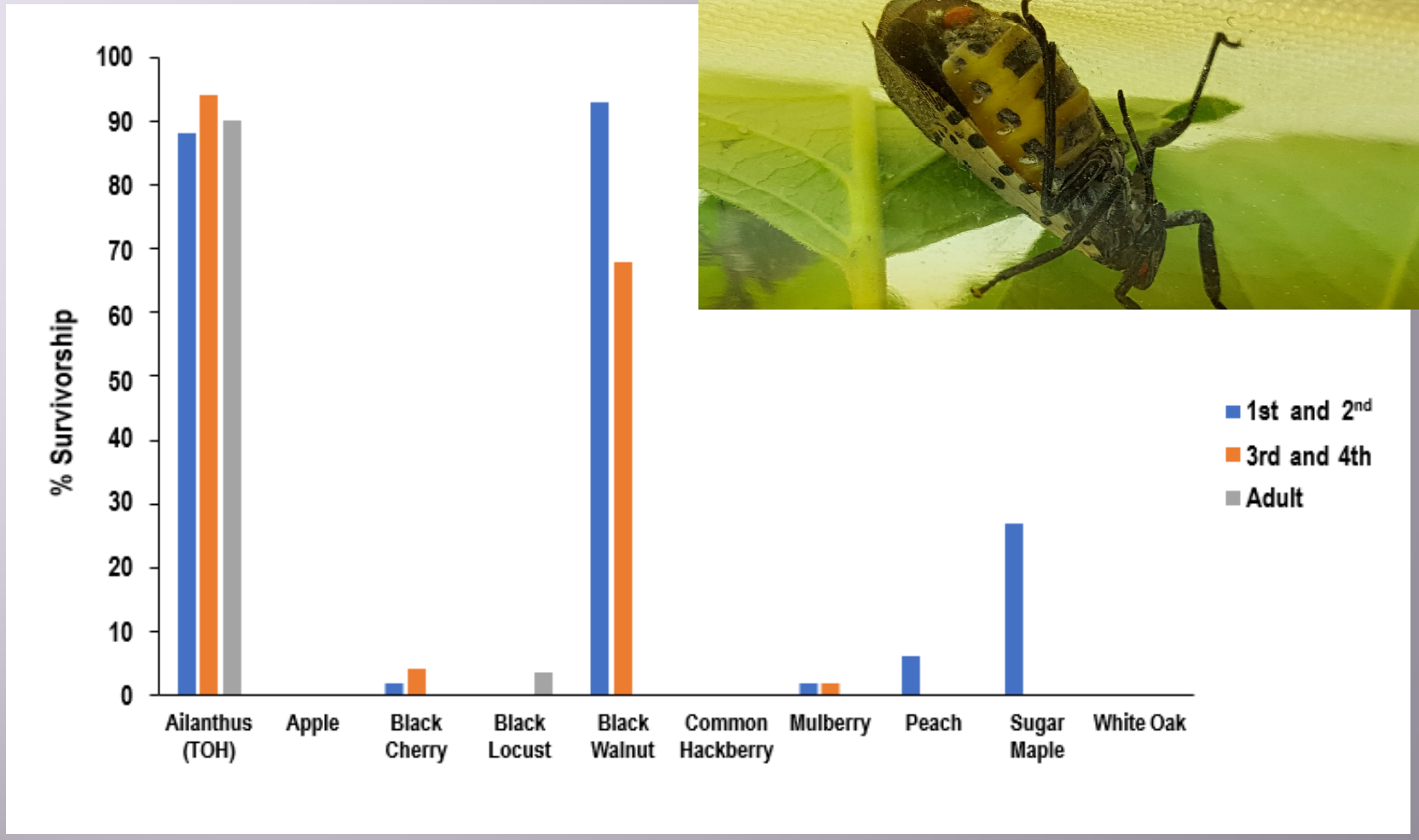

Lori LaCava Beatrice

Liz Willow

SLF have been observed feeding on specialty crops including grape and apple. To date, damage to grape vines and loss of yield has been reported. So far, no known impacts on mature apple trees. But impacts on young trees or possible disease transmission are being investigated.

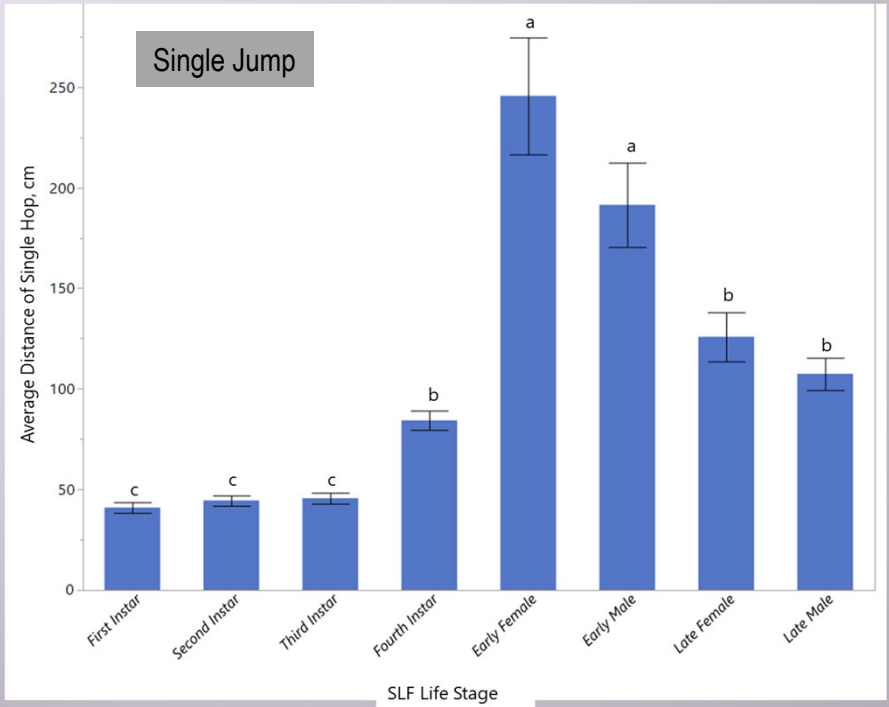
Host Range of SLF

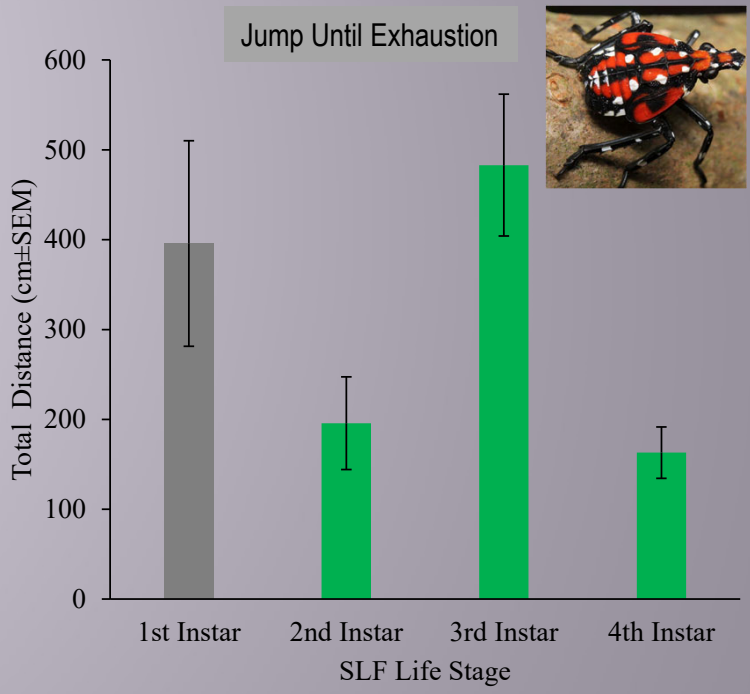




SLF will feed on a variety of hosts, especially as young instars, but their host range narrows as they mature. Greatest survivorship in single diet laboratory trials on Tree of Heaven. However, this does not provide insight into survivorship on mixed host diets.

Dispersal Capacity of SLF (Jumping Behavior)





Multiple hosts are likely used by SLF based on field observations, and mobility studies support that they can easily move among hosts in the environment.

Does SLF require TOH?

SLF can complete development to adulthood exclusively on:

Tree of heaven Black walnut Chinaberry Tulip tree Sawtooth oak Hops Oriental bittersweet Butternut

Data provided by Miriam Cooperband (USDA-APHIS), Kelli Hoover (PSU)

H. Leach

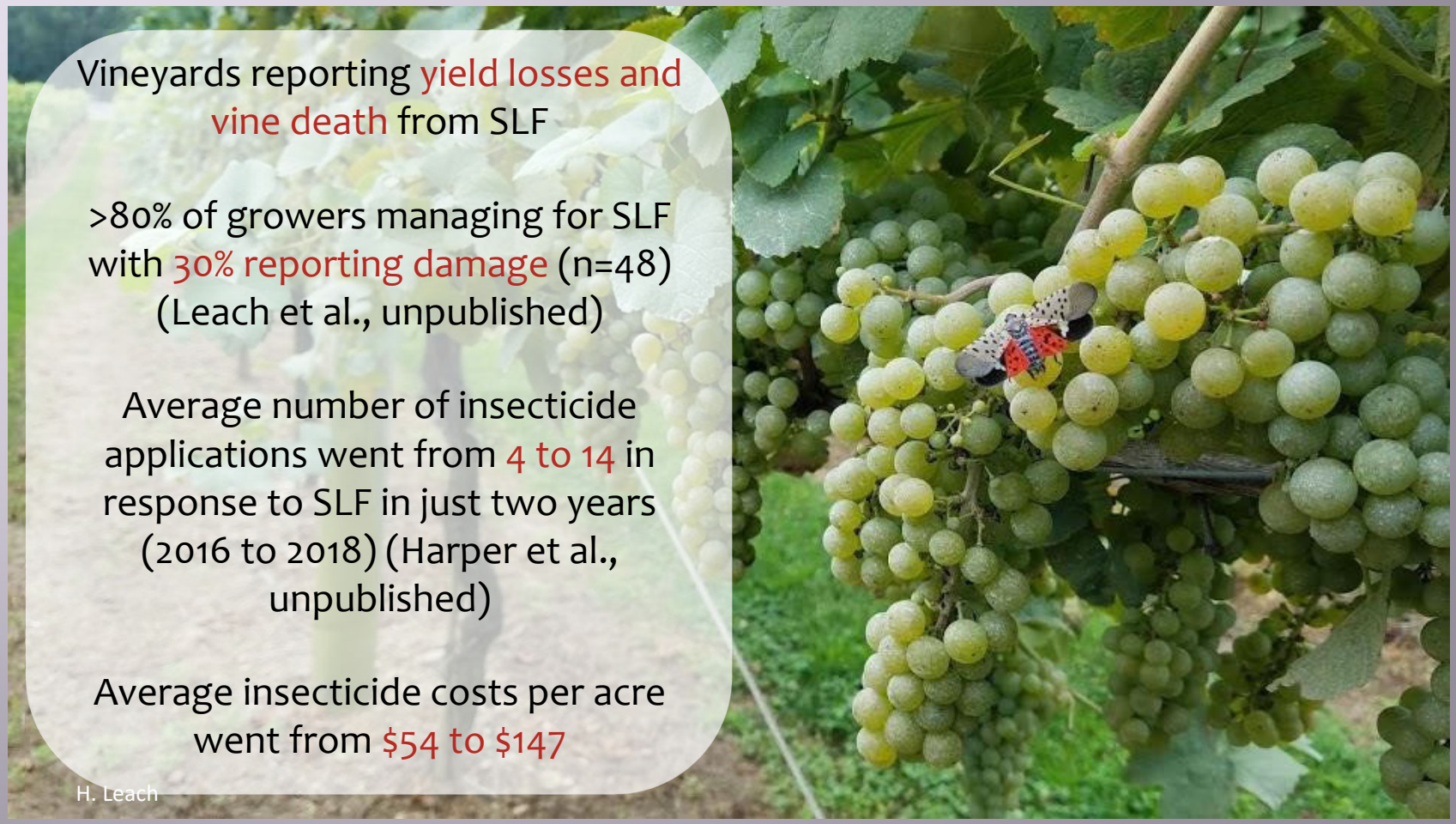
SLF damage to vines

Vineyards reporting yield losses and vine death from SLF

>80% of growers managing for SLF with 30% reporting damage (n=48) (Leach et al., unpublished)

Average number of insecticide applications went from 4 to 14 in response to SLF in just two years (2016 to 2018) (Harper et al., unpublished)

Average insecticide costs per acre went from $54 to $147



H. Leach

Damage to Vineyards

Beekman Orchard, May 23, 2019

Damage to Vineyards

September 12, 2019

SLF management

1	Stop the spread
2	Scrape eggs
3	Band trees to catch nymphs
4	Remove tree-of-heaven
5	Apply insecticides

SLF trapping

PDA

Jack Tobias

PennState

Insecticide control

SLF are **easy to kill** with many broad-spectrum insecticides

Most effective chemicals
include: dinotefuran
carbaryl thiamethoxam
zeta-cypermethrin
malathion bifenthrin
beta-cyfluthrin

H. Leach

Stopping the spread

Tree-of-heaven as trap tree

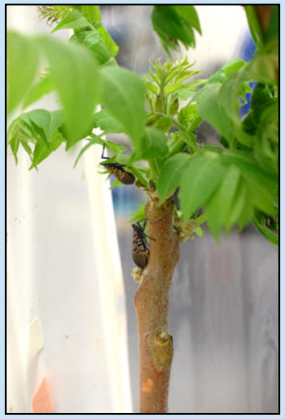
Majority of trees killed, remaining trees are treated with **systemic insecticide** (bark spray dinotefuran)

Monitoring and Biosurveillance

USDA modified traps are the most behaviorally compatible trap design with greatest SLF and fewest non-target captures. No current SLF lures are effective at increasing trap captures. This is an active area of research.

USDA

United States Department of Agriculture



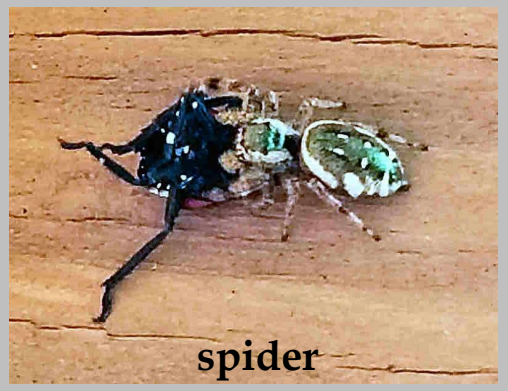
Development of biological control methods against invasive spotted lanternfly

APHIS, ARS, Penn State, Cornell

(some) Predators of SLF in North America

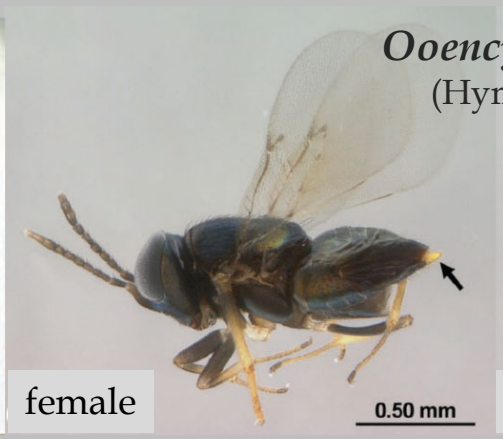
Apoecilus cynicus
(Hemiptera: Pentatomidae)

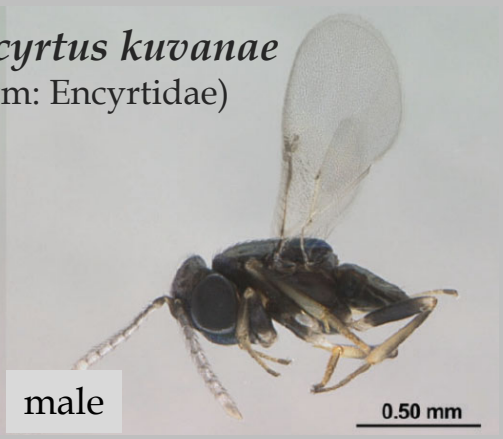
Arilus cristatus
(Hemiptera: Reduviidae)



Surveys for Native Parasitoids in PA

- Collections of ~3700 nymphs in 2017 found no native parasitoids
- Surveys found low parasitism (7% of egg masses and 20% of eggs within those) by *Ooencyrtus kuvanae* at a few sites
  - Native to Asia, introduced against gypsy moth in 1908 (not recorded from SLF in China – a new association?)





Fungal pathogens

Two fungal pathogens in PA found attacking SLF

In 2018, ***Batkoa major*** found attacking SLF in one location with >80% mortality

PennState

Fungal pathogens

Two fungal pathogens in PA found attacking SLF

In 2015, ***Beauveria bassiana*** found attacking SLF in multiple locations and at low levels

H. Leach

PennState

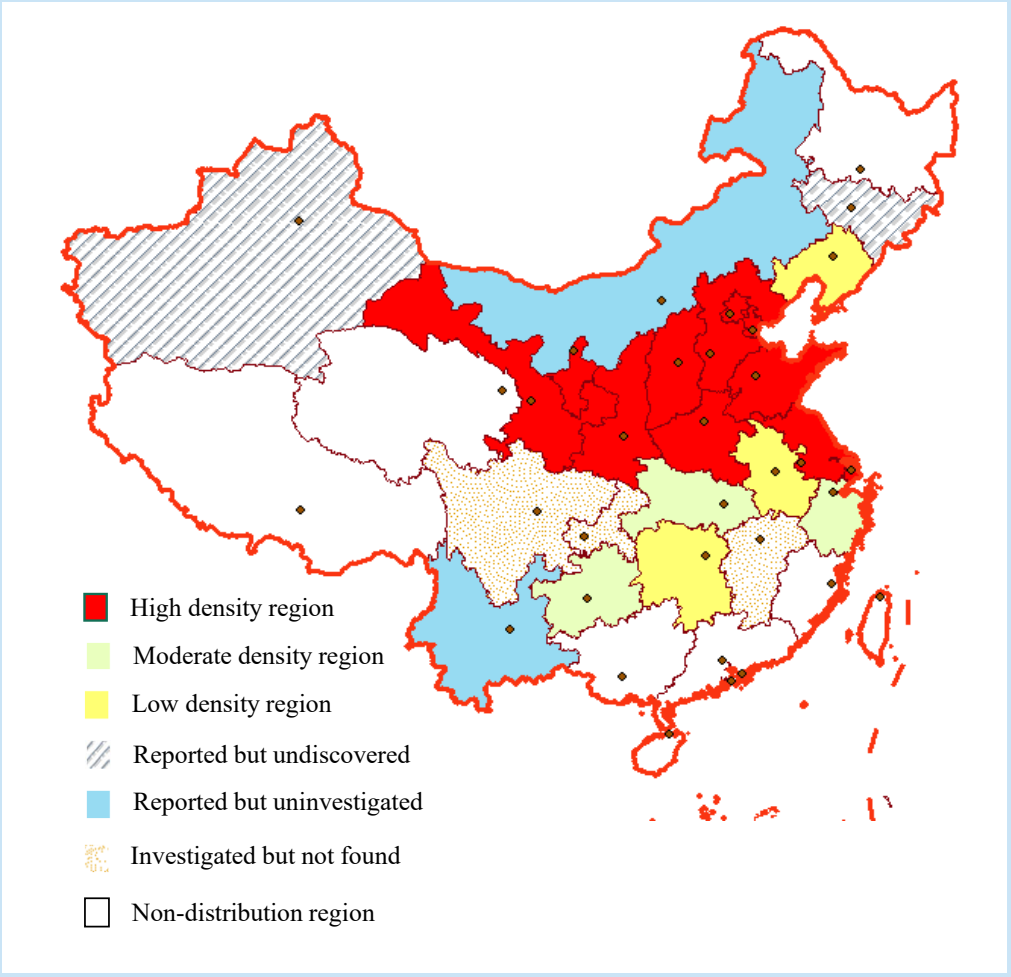
Beauveria (BoteGHA) Field Study, Norristown Farm Park

Potential Classical Biocontrol Agents

Anastatus orientalis Yang & Choi
(Hymenoptera: Eupelmidae)
Egg parasitoid

Dryinus sinicus
(Hymenoptera: Dryinidae)
Nymphal parasitoid

Foreign Exploration in China 2015-2019



Host Specificity Testing: Non-Target Species

- Selected 11 priority species - large-bodied, univoltine, overwinter as eggs, and lay eggs on above-ground portions of plants.
- Have started testing 6 of these

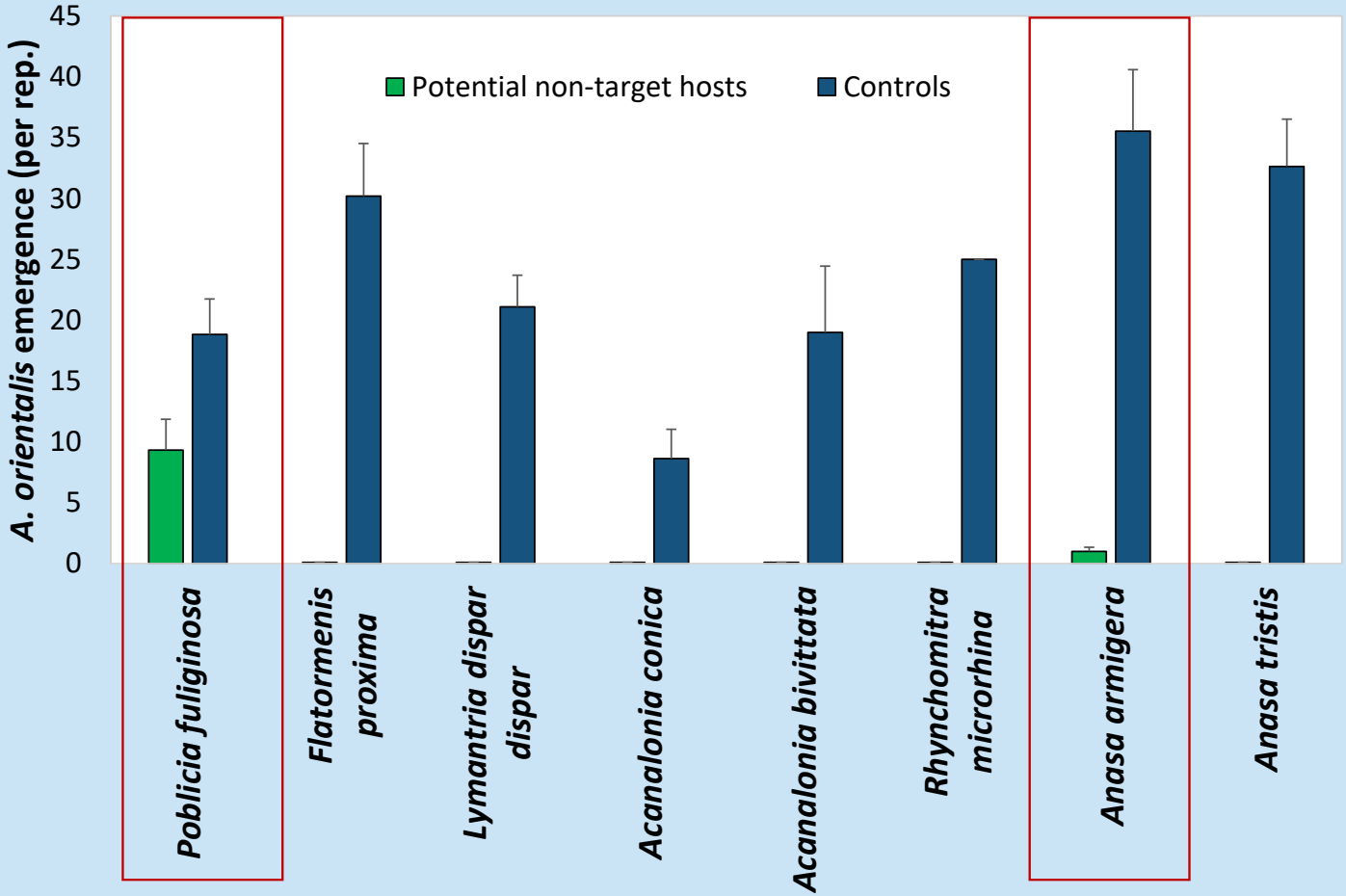
1. *Poblicia fuliginosa* (Fulgoridae)
2. *Calyptoproctus marmoratus (Fulgoridae*)
3. *Rhynchomitna microrhina* (Dictyopharidae)
4. *Acanalonia conica* (Acanaloniidae)
5. *Acanalonia bivattata* (Acanaloniidae)
6. *Flatormenis proxima* (Flatidae)

- Also testing other insects with egg masses (e.g. squash bugs, stink bugs, silk moths)

Poblicia fuliginosa

Anastatus Host Specificity Testing

Results from 2018-2019



Non-target species testing	N
Poblicia fuliginosa	12
Flatormenis proxima	5
Lymantria dispar dispar	30
Acanalonia conica	30
Acanalonia bivittata	5
Rhynchomitra microrhina	1
Anasa armigera	30
Anasa tristis	25

Parasitism of *P. fuliginosa* & *A. armigera* eggs

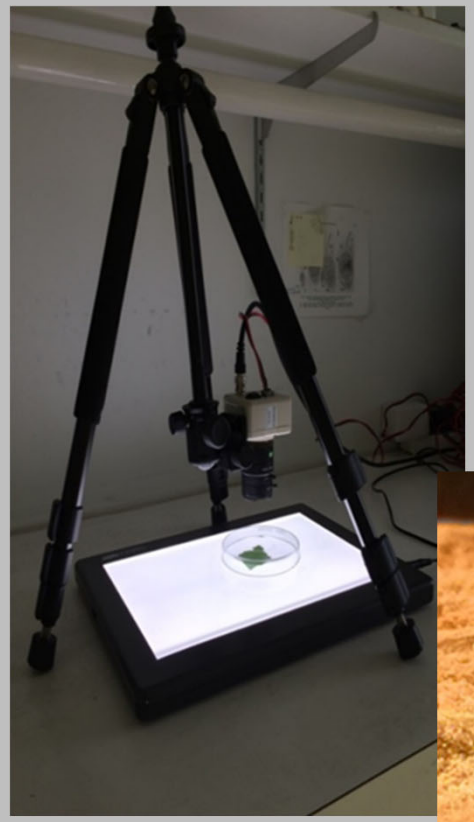
Lycorma egg mass

Poblicia egg mass

- Only males from *Anasa* and mostly males from *Poblicia*, female that emerged were very small
- Eggs of *Poblicia* and *Anasa* are smaller than those of SLF.

Females from SLF

Females from *Poblicia*



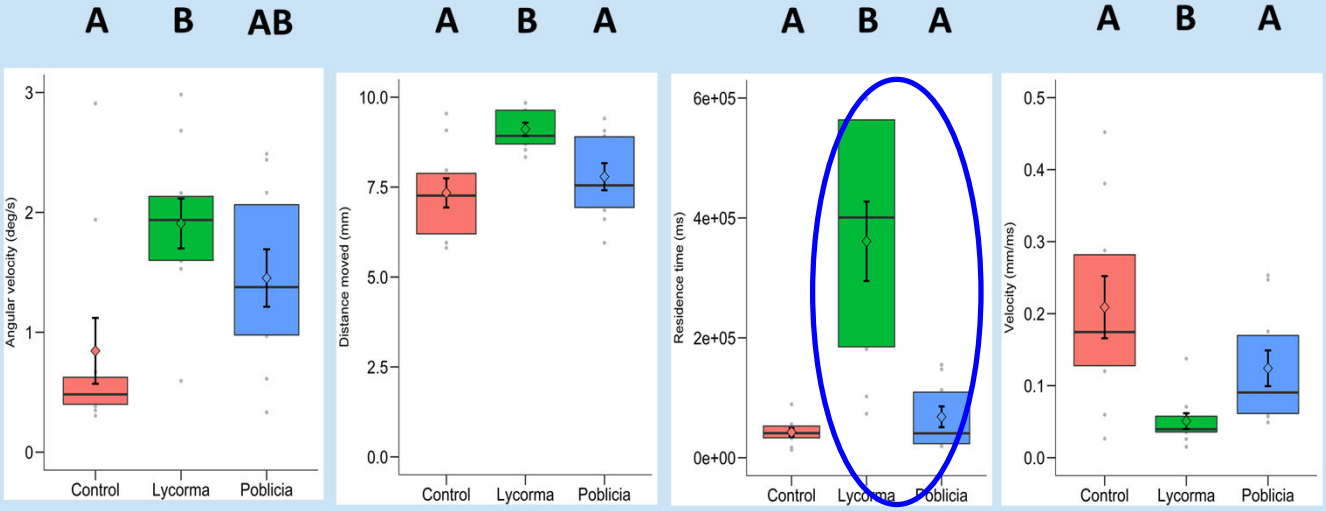
Influence of host kairomones on foraging and oviposition behavior of *Anastatus*

- *Female wasps detect chemical traces resulting in intensified searching behavior*

Behavioral Response to adult *Poblicia* and SLF chemical footprints

- *Anastatus orientalis* exhibited behavioral changes to increase searching in response to traces left by adult spotted lanternfly.
  - Residence Time
  - Velocity & Turning
  - Distance Travelled

- Responses to chemical traces left by *Poblicia* adults did not differ from the control.

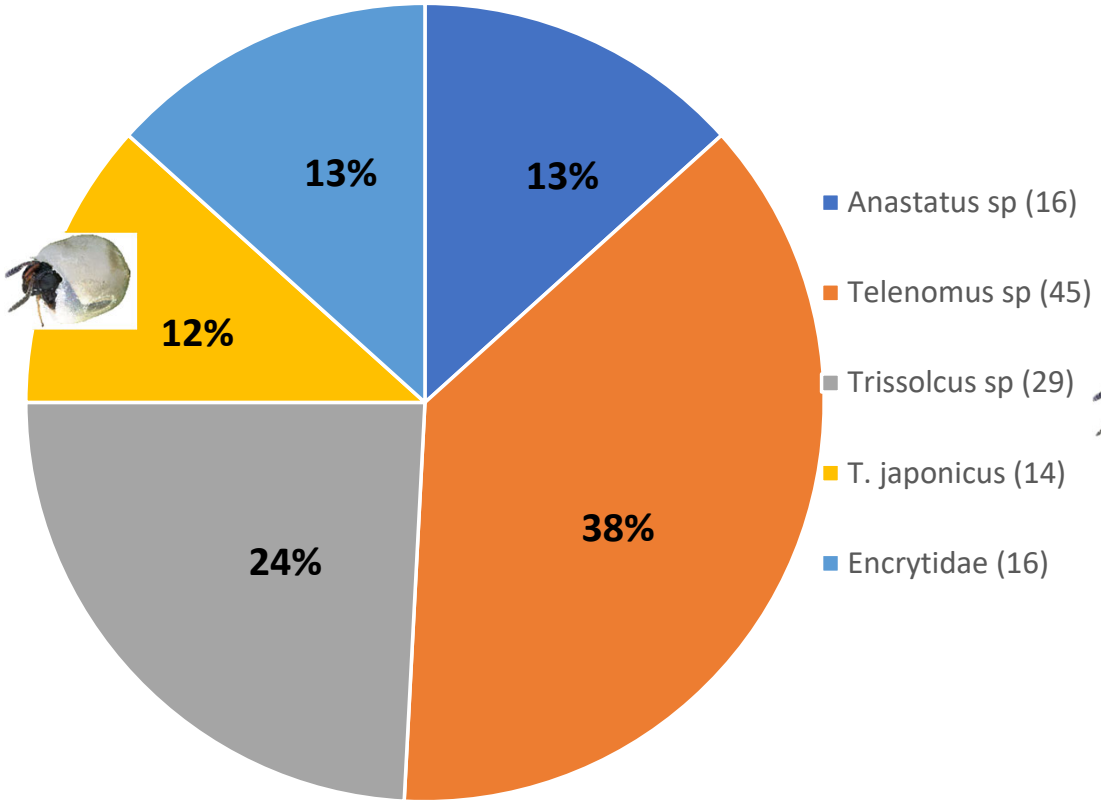


Conclusions

- We have discovered and are studying two potential biocontrol agents
- Much more needs to be learned before biological control can be implemented

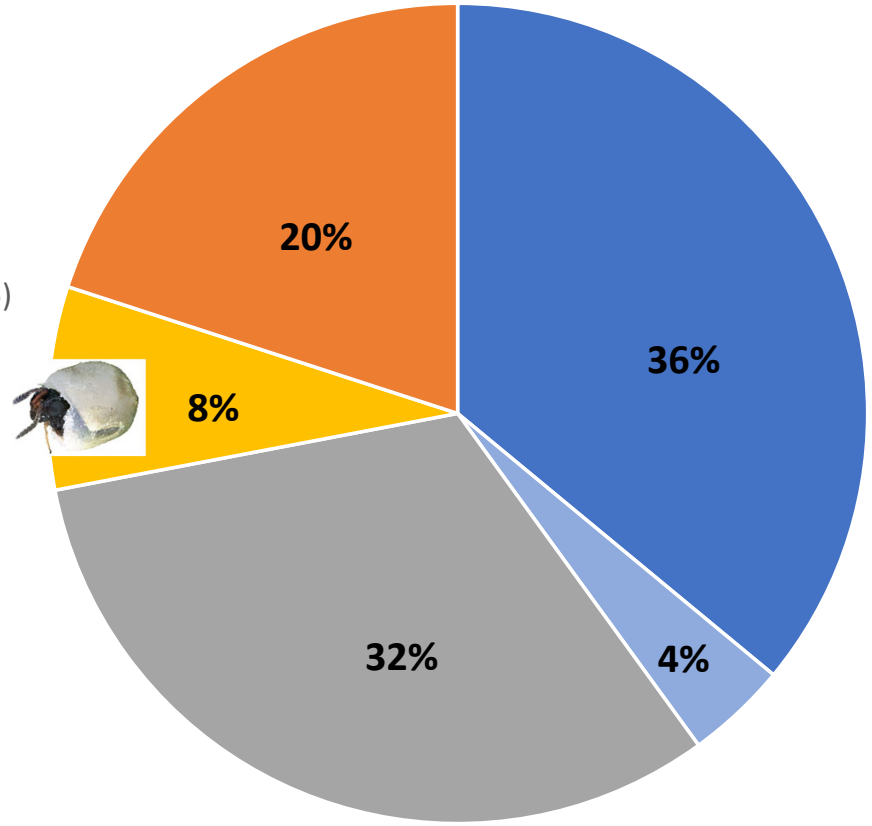
Parasitoid samples

Yellow Sticky Cards



82% female *T. japonicus*

Sentinel egg masses



93% female *T. japonicus*