Drosophila suzukii invasions and options for management

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Topics

Invasion history and dynamics

Seasonal biology and host range

Current management paradigm

Potential for area-wide management tactics

Spotted wing drosophila biology
Life cycle & Significance

Generation time (adult to adult):
10-15 days
Adults can live 1+ month
No known diapause

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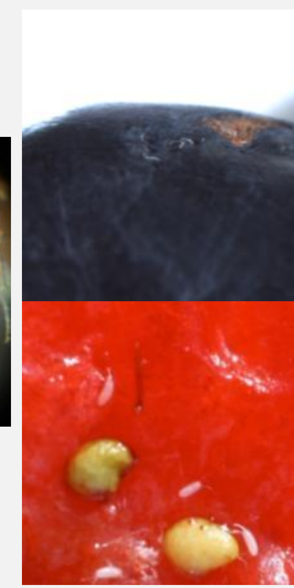

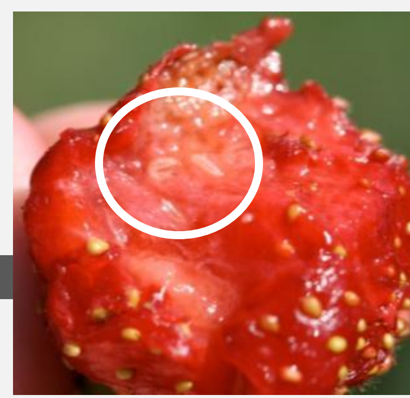

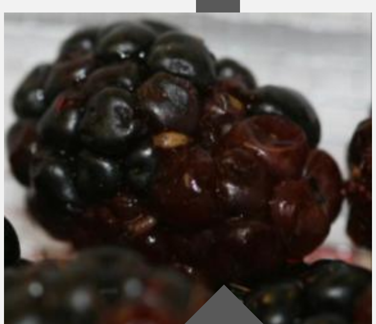

Pupate on or near fruit or outside of fruit in the soil

Spotted wing drosophila biology

Life cycle & Significance

Generation time (adult to adult):
10-15 days
Adults can live 1+ month
No known diapause

Zero tolerance for infestation in fresh marketed or whole frozen fruit

Pupate on or near fruit or outside of fruit in the soil

Spotted wing drosophila biology
Life cycle & Significance

Crop (# of respondents)	Average loss	Loss range	Pesticide use increase (# of respondents growing crop* with increased pesticide use)
2013			
Blueberries (139)	4.7%	0-100%	84% (99)
Blackberries (88)	12%	0-100%	87% (75)
Raspberries (67)	16.3%	0-100%	87% (59)
Strawberries (60)	3.9%	0-50%	70% (60)
Cherry (24)	3.1%	0-20%	59% (49)
Grape (49)	2%	0-20%	71% (24)

*Some respondents grew multiple host crops
Methods and data summarized at:
https://swd.ces.ncsu.edu/working-group-activities/swd-impacts-2013/
https://swd.ces.ncsu.edu/swd-impacts-2014/

Spotted wing drosophila biology
Life cycle & Significance

Crop (# of respondents)	Average loss	Loss range	Pesticide use increase (# of respondents growing crop* with increased pesticide use)
2014			
Blueberries (289)	13%	0-100%	201% (180)
Blackberries (131)	27%	0-100%	90% (81)
Raspberries (130)	41%	0-100%	186% (79)
Strawberries (133)	6%	0-55%	262% (81)
Cherry (81)	9%	0-100%	249% (58)
Grape (122)	12%	0-100%	87% (76)

*Some respondents grew multiple host crops
Methods and data summarized at:
https://swd.ces.ncsu.edu/working-group-activities/swd-impacts-2013/
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Spotted wing drosophila
Invasion history

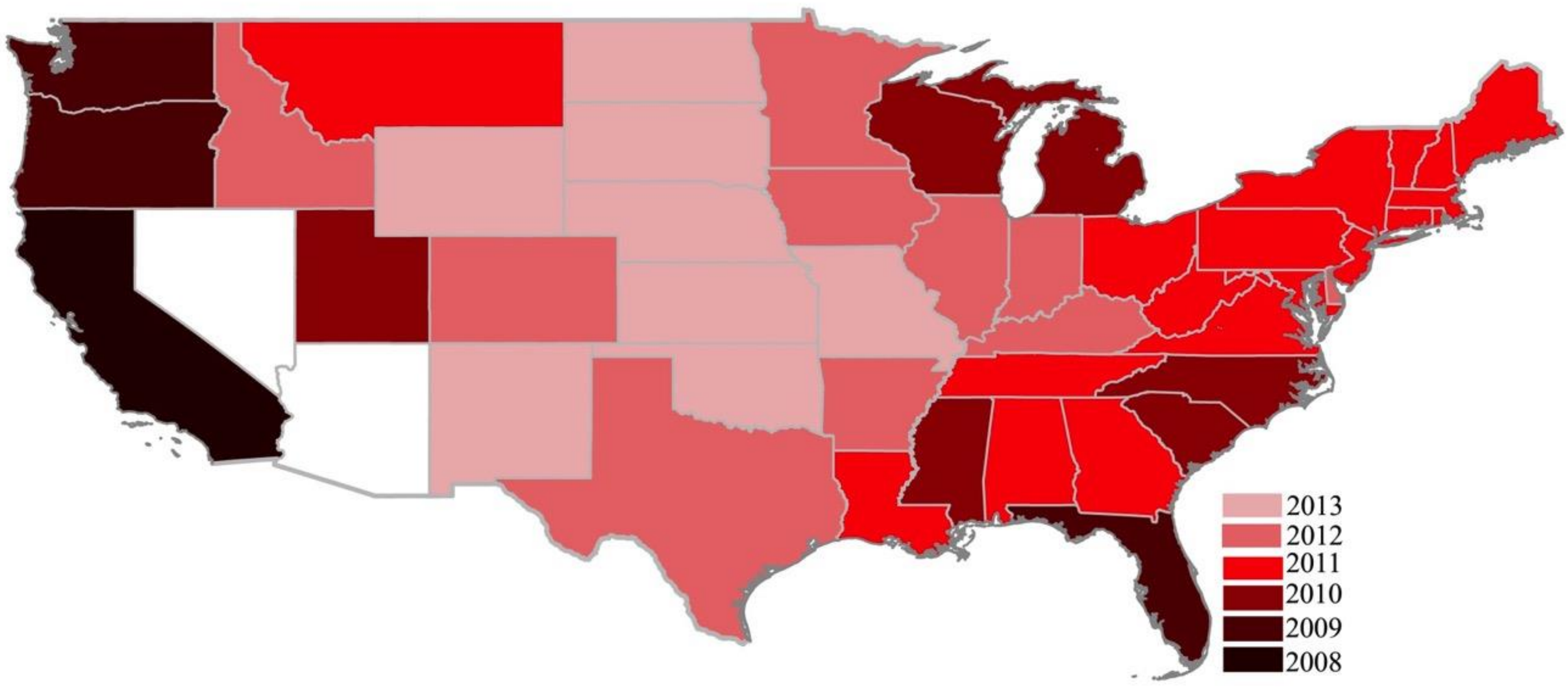
2008	2009	2010	2011	2012 to present
Detected in CA raspberries	Detected in OR, WA, FL, and western Canada	Detected in NC, SC, UT, LA, MI, WI, and eastern Canada	Detected throughout New England and Mid Atlantic (including VA)	Detected throughout the rest of the continental United States

Records prior to CA identification: Damage to cherries in Japan in 1916 (Kanzawa 1939), Detected in HI in 1980s

Detected throughout Europe 2008-2014

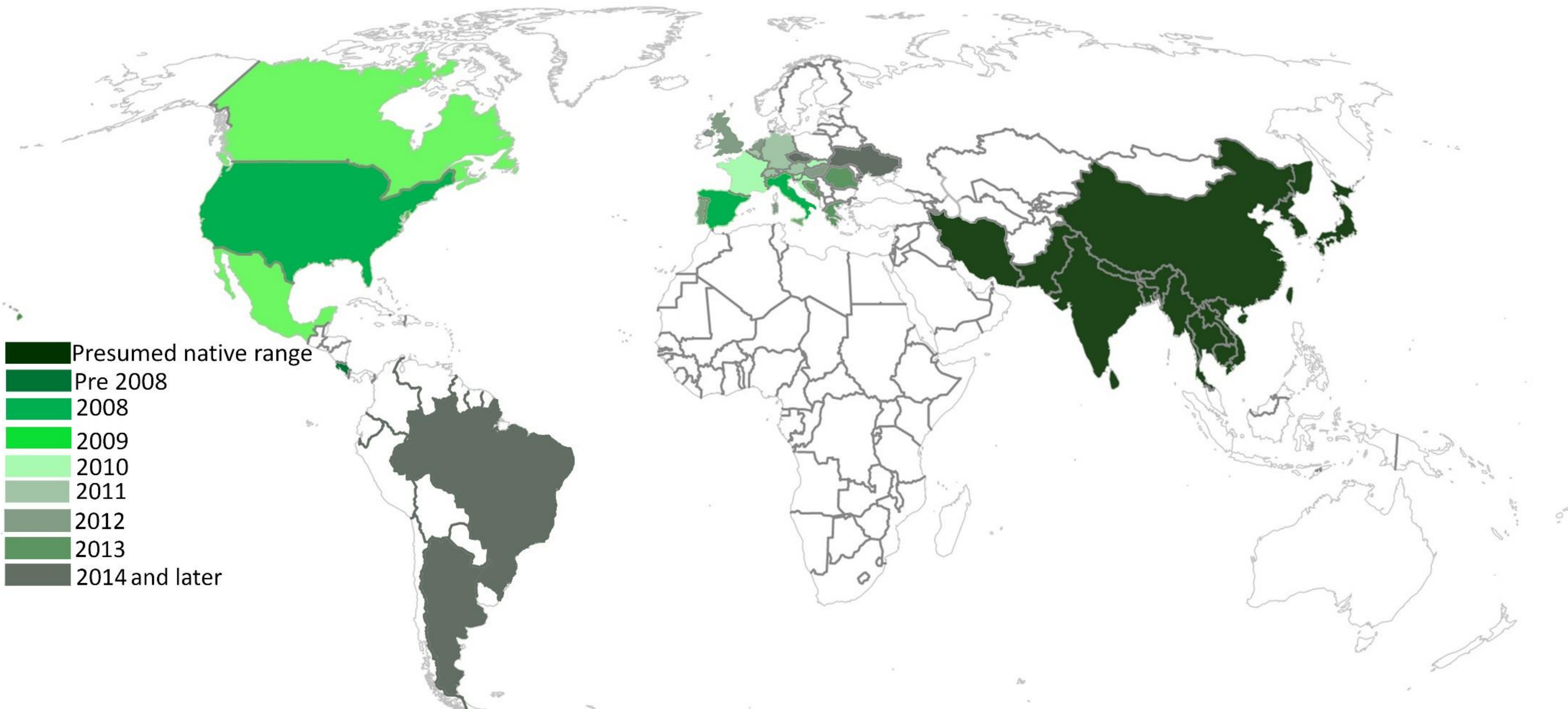
Detected in Brazil and Argentina 2014

Spotted wing drosophila
Invasion history



Detection dates via USDA Cooperative Agricultural Pest Survey Pest Tracker, http://pest.ceris.purdue.edu/

Spotted wing drosophila
Invasion history

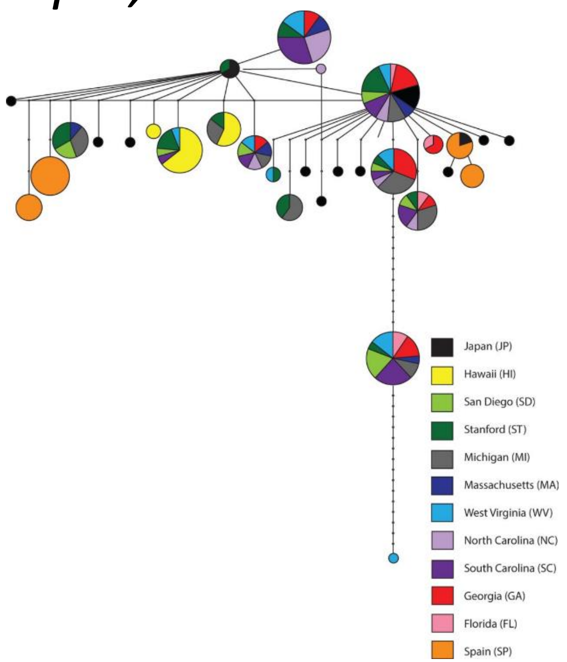


Detection dates via CABI, http://www.cabi.org/isc/datasheet/109283 and Asplen et al. 2015

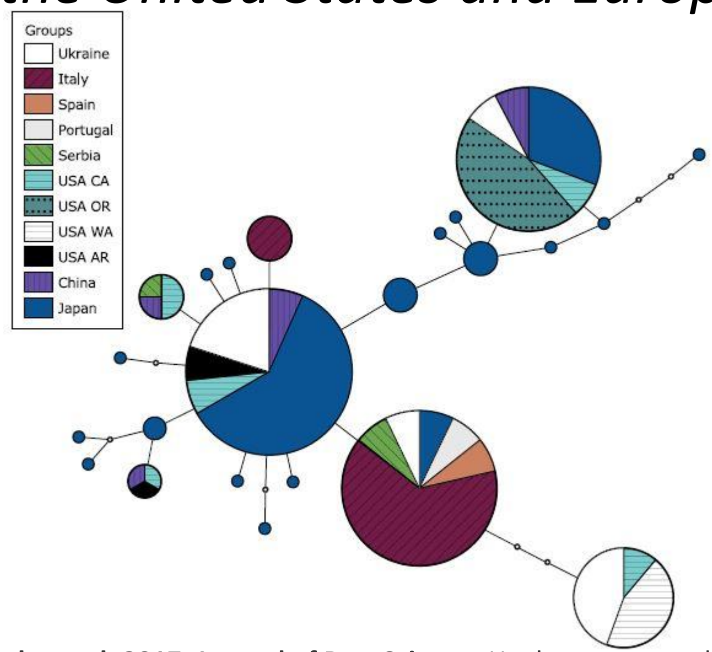
NC STATE UNIVERSITY

Spotted wing drosophila
Invasion biology

Invasion routes are unclear, but population genetic studies suggest multiple, recurrent invasions in both the United States and Europe



Adrion, et al. 2014. Molecular Biology and Evolution. Haplotype network for locus 26206. Each node represents a haplotype and the size of the node is proportional to the number of individuals carrying that haplotype. Edges connecting nodes/vertices denote single mutational steps. Within each node, the individuals carrying each haplotype are shaded by population of origin.



Lavinienko et al. 2017. Journal of Pest Science. Haplotype network of *COI* gene fragment (606 bp) for *D. suzukii* sampled from Ukraine, other European countries, USA, China and Japan. *Small white circles* represent undetected intermediate haplotypes, and each line corresponds to a mutational step. *The area of the circles* represents the amount of identical *COI* gene sequences in the alignment.

Genome wide strategy: Single Nucleotide Polymorphism (SNP) discovery using NGS

Antoine Abrieux and Joanna Chiu, Department of Entomology and Nematology, UC Davis

Goals

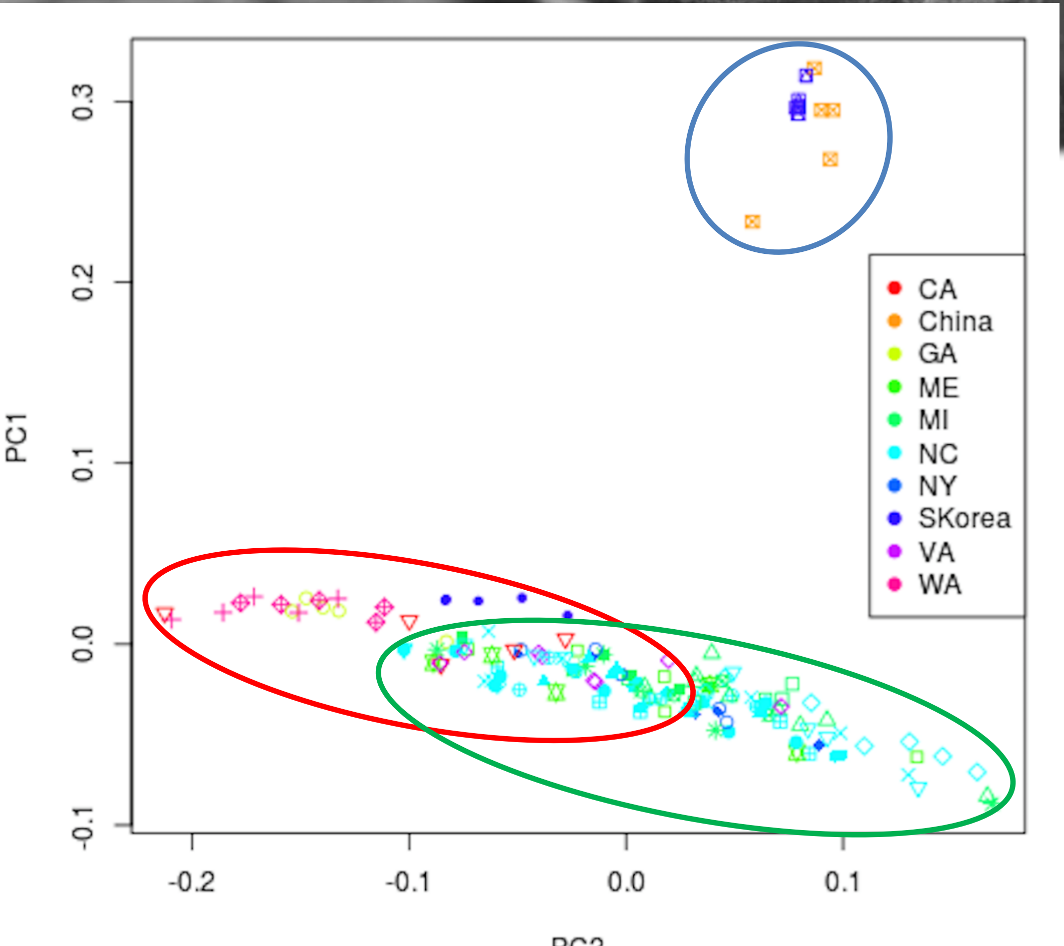
Characterize long distance movement and sources of *D. suzukii*

Understand the genetic architecture of traits underlying invasion success

Evolution of phenotypic traits in natural populations which may affect efficacy of management programs (e.g. insecticide/cold tolerance, in certain populations)

Year to year differences in climatic conditions from source may affect risk and population size of migrants (prediction).

Principle component analysis: SNP discovery and population structure within *D. suzukii*



157 samples, 31226 SNPs after filtering (LD based SNPs pruning)

Grouping States/Regions together, Autosome only, up to scaffold17

Topics

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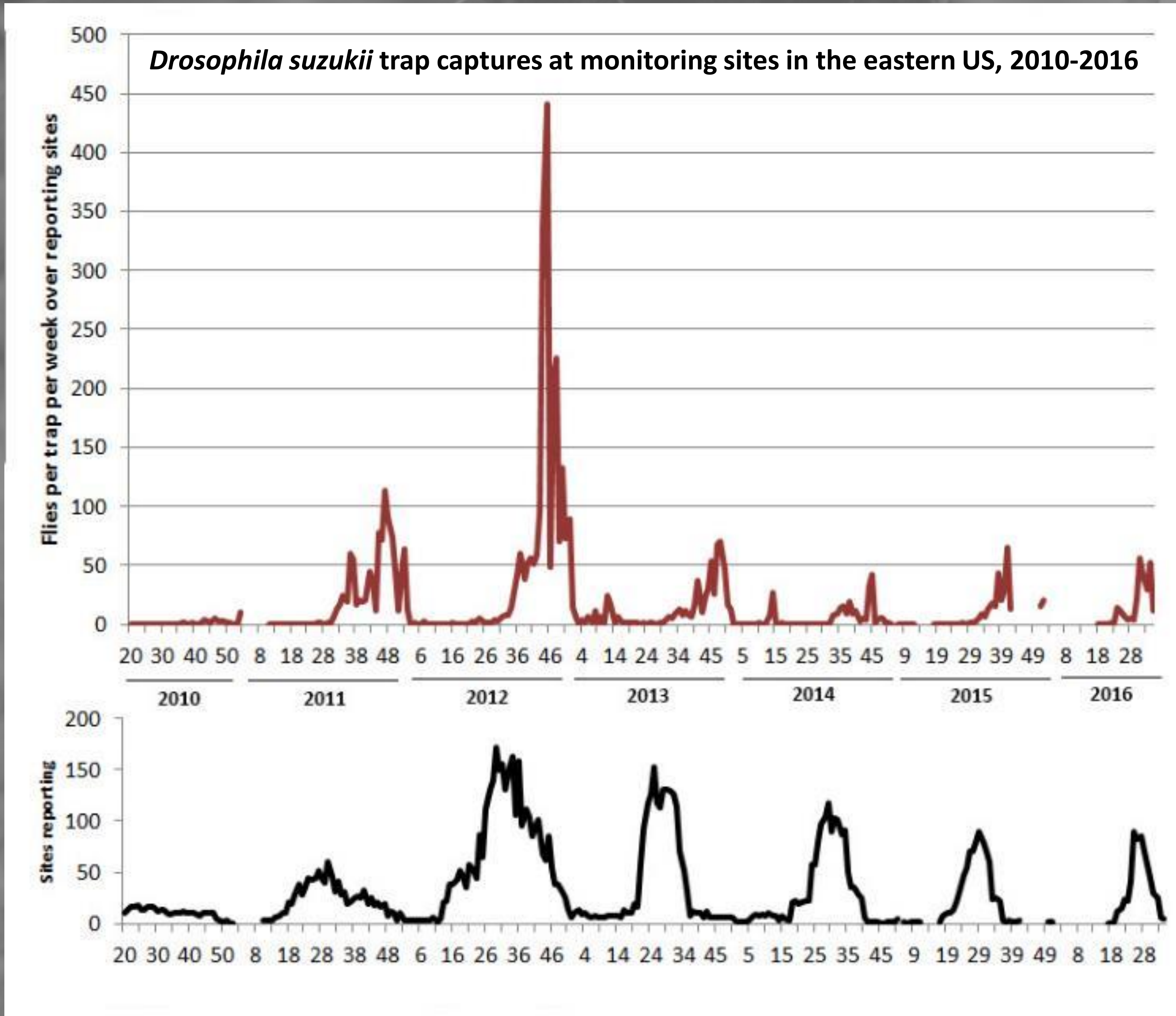
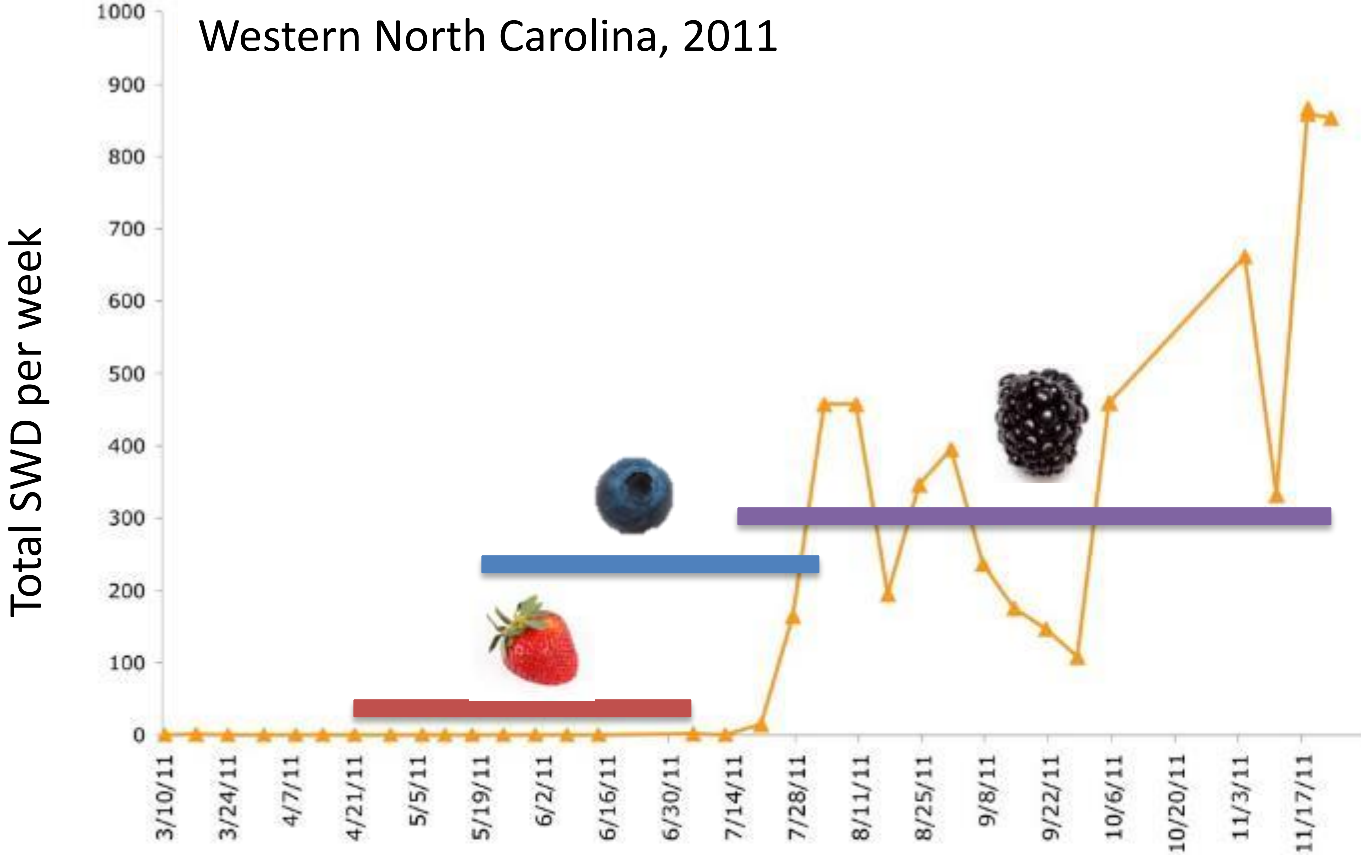
Potential for area-wide management tactics


Drosophila suzukii trap captures at monitoring sites in the eastern US, 2010-2016
Flies per trap per week over reporting sites
500
450
400
350
300
250
200
150
100
50
0
20 30 40 50 8 18 28 38 48 6 16 26 36 46 4 14 24 34 45 5 15 25 35 45 9 19 29 39 49 8 18 28
2010
2011
2012
2013
2014
2015
2016
Sites reporting
200
150
100
50
0
20 30 40 50 8 18 28 38 48 6 16 26 36 46 4 14 24 34 45 5 15 25 35 45 9 19 29 39 49 8 18 28

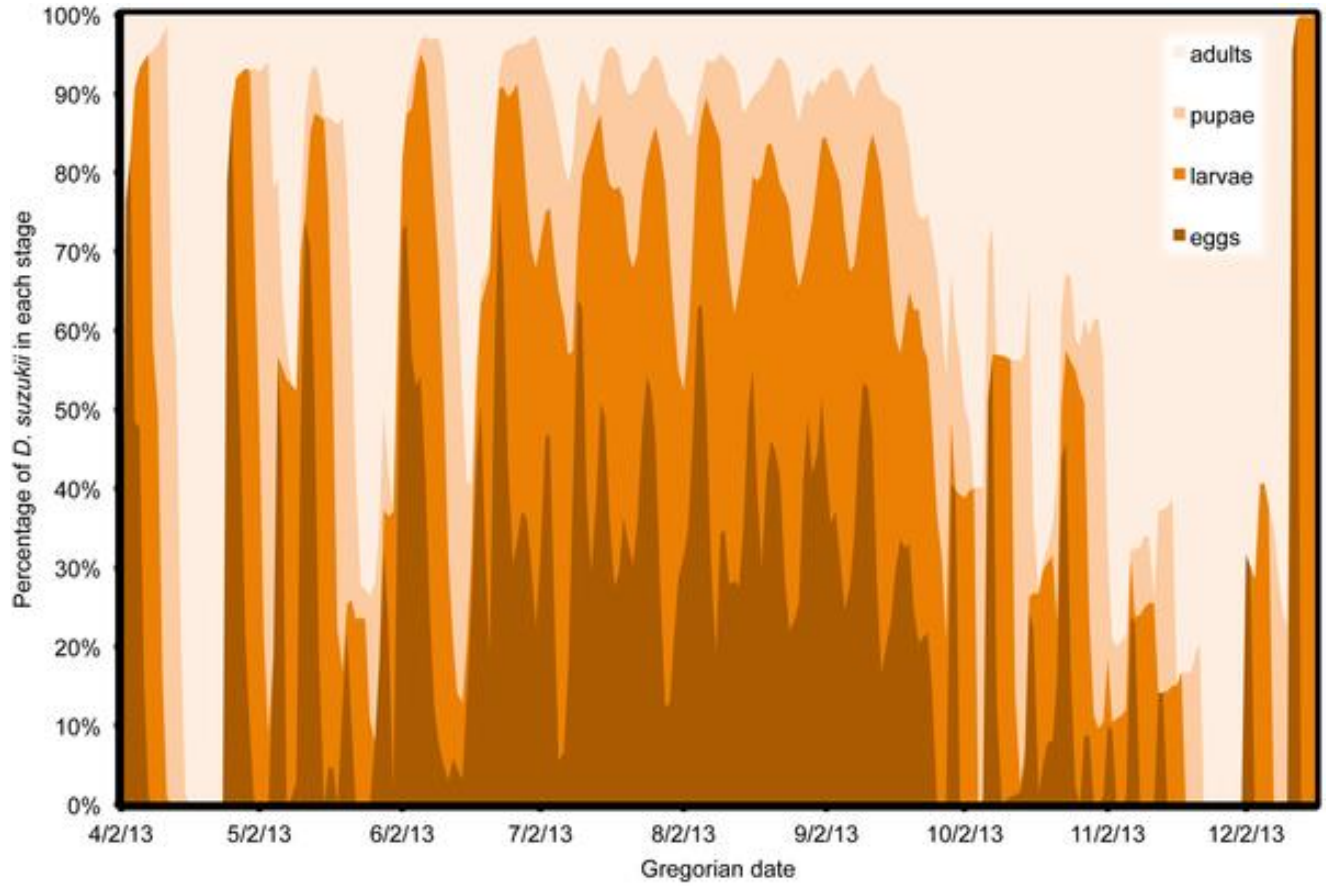
Seasonality influences crop use

Crops grown "early" are at lower risk than those grown later



Population structure influences crop risk

Some regions may experience periods of time where immature SWD are not present…

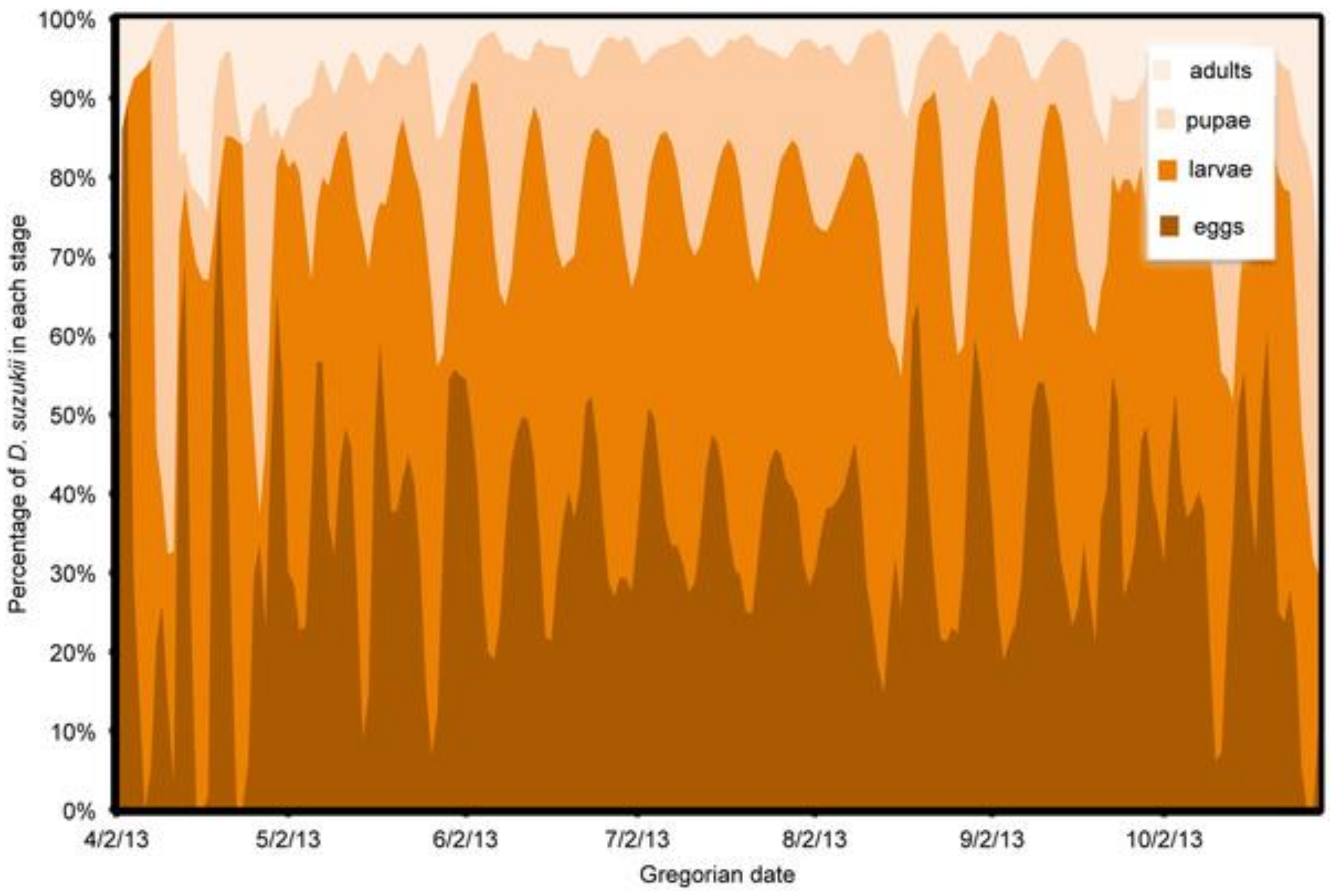


Estimates of SWD population structure in Salem (Oregon), US during 2013.

Oregon State University OSU

Wiman et al. 2014. PLoS Computational Biology.

Population structure influences crop risk
…While other regions do not



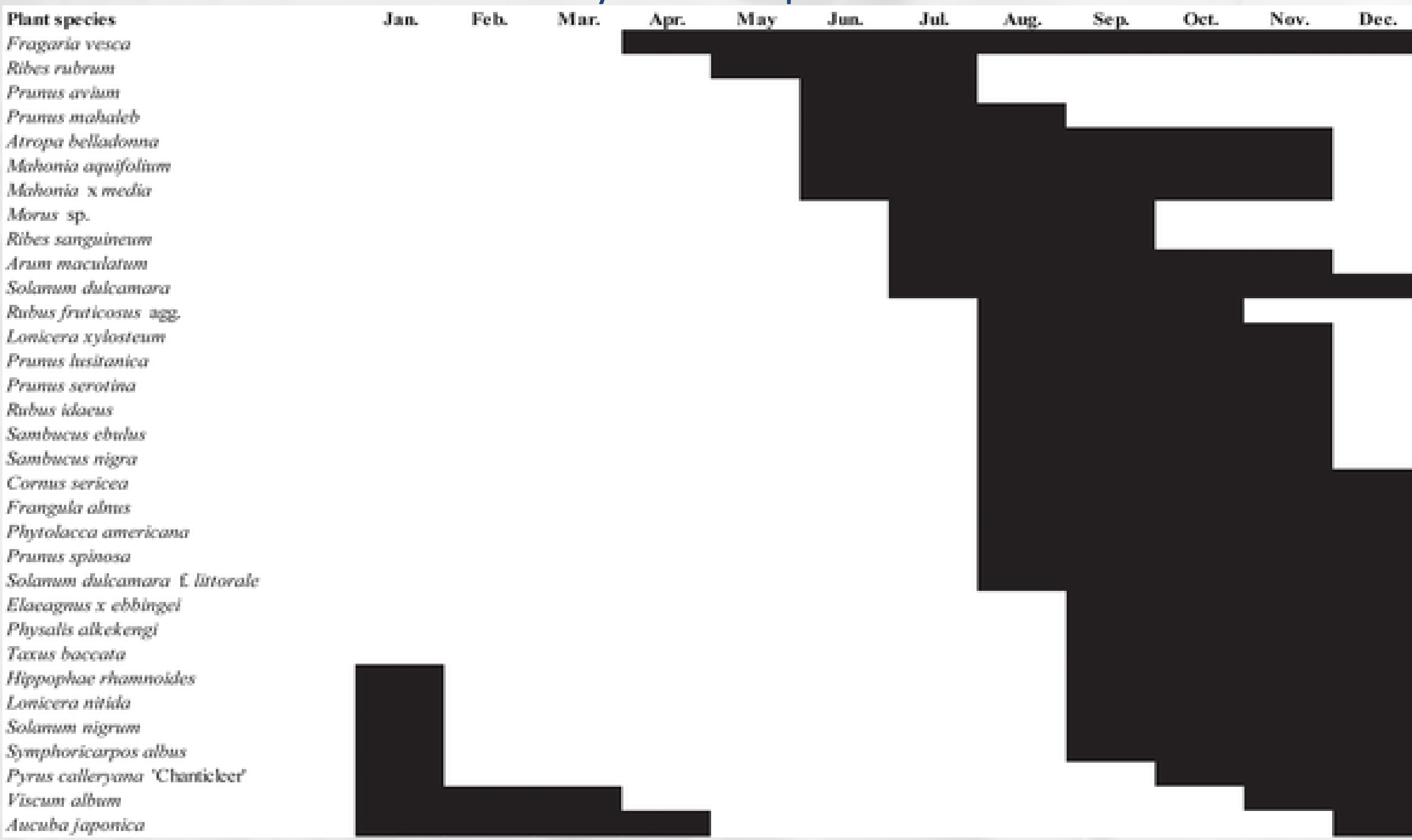
Estimates of SWD population structure in Wilmington (North Carolina), US during 2013.

Oregon State UNIVERSITY OSU

Wiman et al. 2014. PLoS Computational Biology.

Potential host range is extremely broad

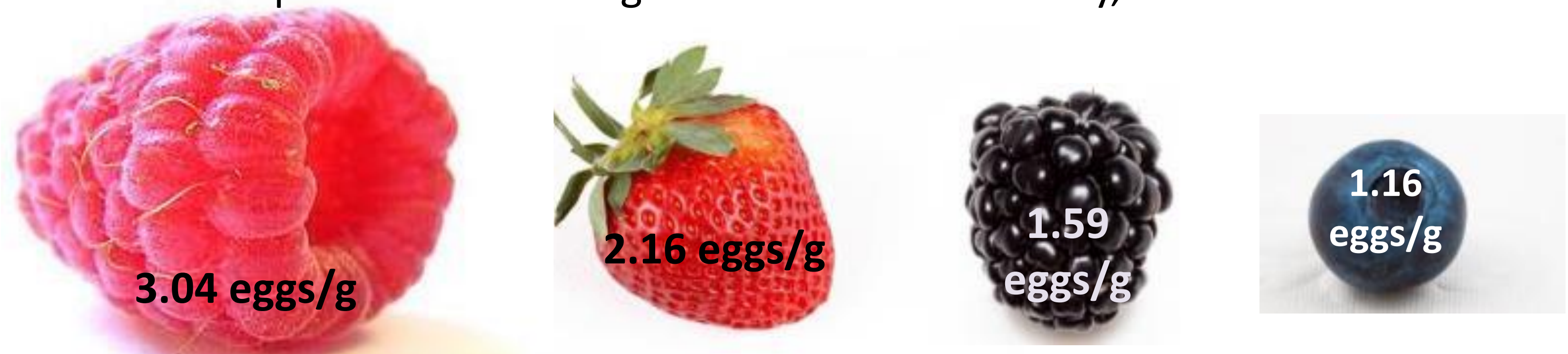
The fruit seasonality (recorded in the sampling sites in Picardy in 2011–2012) of the plant species that successfully hosted Drosophila suzukii.



Poyet M, Le Roux V, Gibert P, Meirland A, Prévost G, et al. (2015) The Wide Potential Trophic Niche of the Asiatic Fruit Fly Drosophila suzukii: The Key of Its Invasion Success in Temperate Europe?. PLoS ONE 10(11): e0142785. doi:10.1371/journal.pone.0142785
http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0142785

Some crop hosts are preferred over others in both the field and laboratory

When presented with 20g of fruit in the laboratory, female flies laid



Berry size proportional to number of eggs laid during 4 hours of exposure. (Burrack et al. 2013)

Flies prefer to lay eggs in raspberries over other crop hosts when given a choice.

More flies survive, develop faster, and can tolerate higher larval densities in raspberries than in other diets.

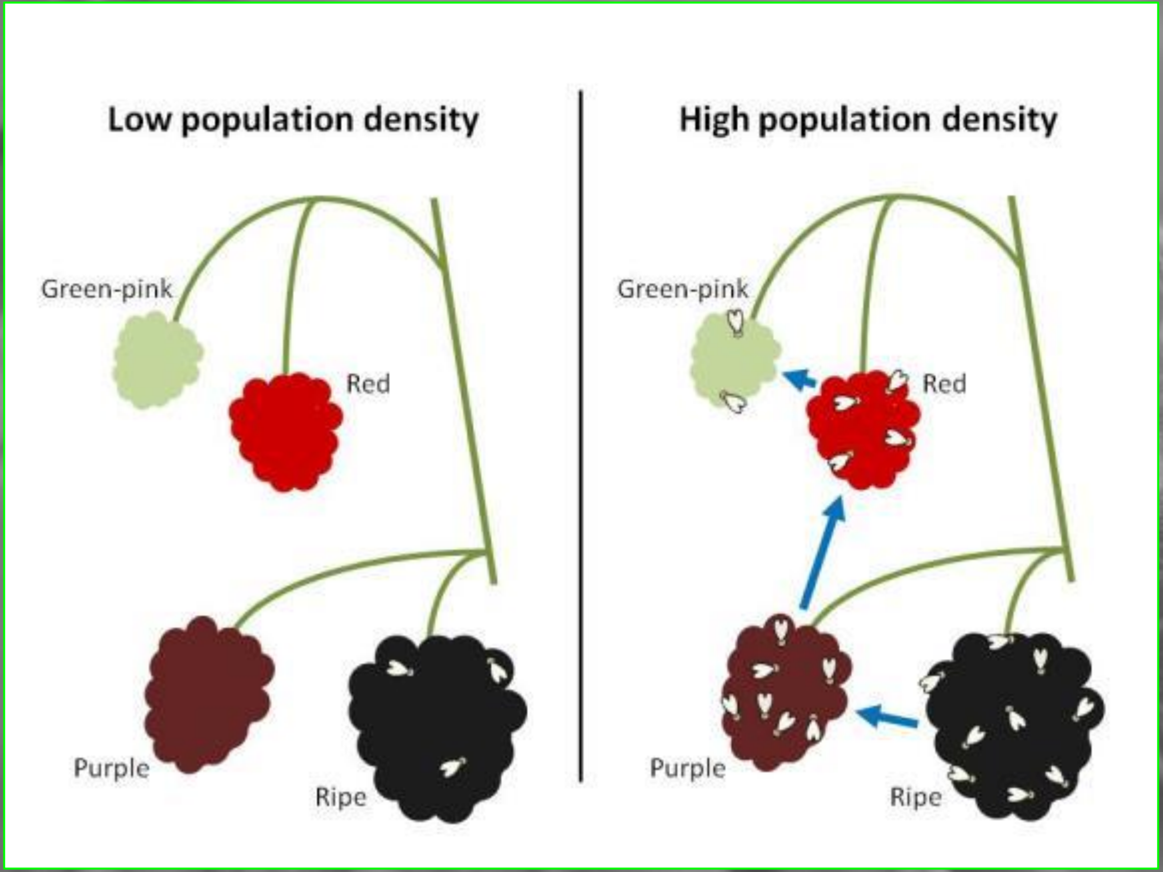
Drosophila suzukii *Infestation timing*

Blackberry ripeness stages

Raspberry ripeness stages

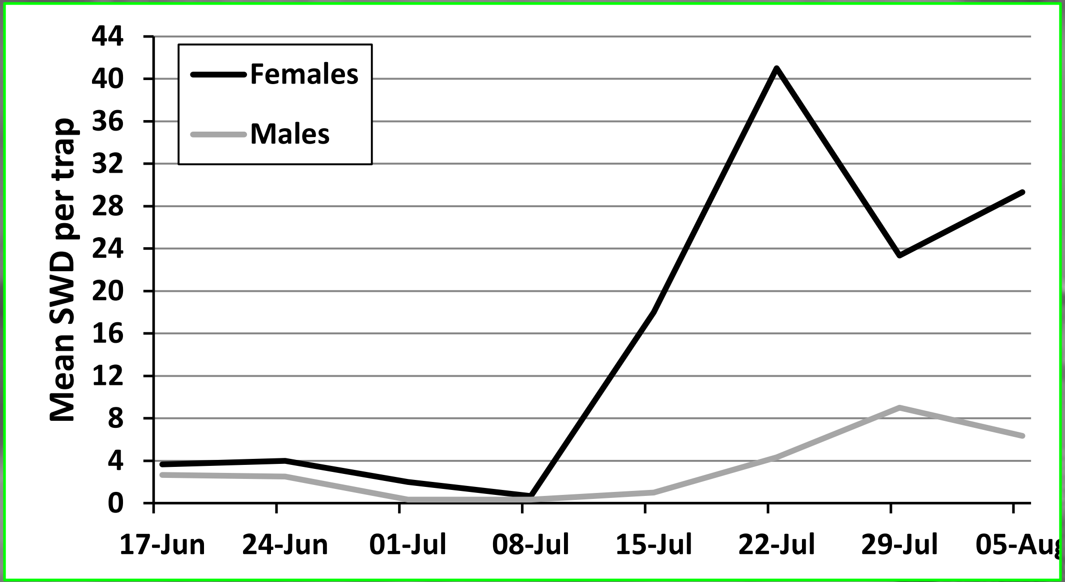
Katie Swoboda, PhD candidate

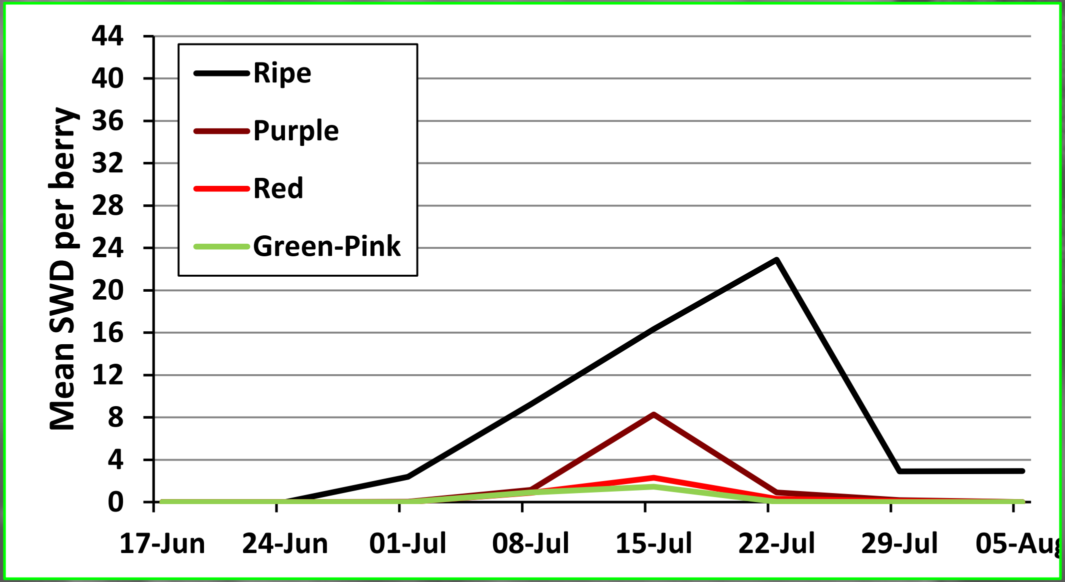
Fruit become susceptible to infestation when they first ripen, but risk can be reduced by decreasing populations



Swoboda-Bhattarai and Burrack. 2016. Acta Horticulturae.

Because there appears to be "spill-over" from ripe fruit to less ripe fruit





Week*Stage: $F_{[12,342]} = 12.49$, $P < 0.0001$

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Monitoring tools and limitations

Adult trapping systems

Image via Trece


Image via Michigan State U


Image via Scentry

Homemade baits
Yeast/sugar water
Wine + apple cider vinegar (ACV)
Fermenting slurries
Not ACV alone!

Synthetic lures
Based on fermentation odors
Available from Trece, Scentry, Biobest


Image via Biobest

- **Traps indicate presence/absence of adult flies**
- **Traps may be useful for timing the start of treatments in some crops**
- **<u>No</u> adult trapping system has been demonstrated to correlate well with fruit infestation**
- **Some homemade baits and synthetic lures have similar trap captures**

Monitoring tools and limitations

Adult trapping systems

Range of attraction for Scentry attractant in cherry orchards post harvest <u>120 m</u> with 1.2% recapture rate

Important to note that traps perform differently in the presence of host fruit

Comparisons in multiple hosts planned for 2017

Kirkpatrick and Gut, Michigan State University

Naturally occurring biological control & exploration

Occur naturally in US

Pteromalidae

Pachycrepoideus vindemiae

Generalist pupal parasitoids

Field parasitism:

California: 0-10%

North Carolina: 0-2.5%

Diapriidae

Trichopria drosophilae

Figitidae

Leptopilina heterotoma

Leptopilina boulardi

Ganaspis sp.

Generalist larval parasitoid that attacks drosophilids in fruit, but did not attack *D. suzukii* in laboratory screening

Wang & Daane, UC Berkeley and Hoelmer, USDA ARS

Naturally occurring biological control & exploration

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Pteromalidae

Pachycre

Diapriida

Trichopri

Figitidae

Leptopili

Leptopilina boulardi

Ganaspis sp.

Wang, Daane, and Hoelmer

Generalist pupal parasitoid
Field parasitism 0-10%.

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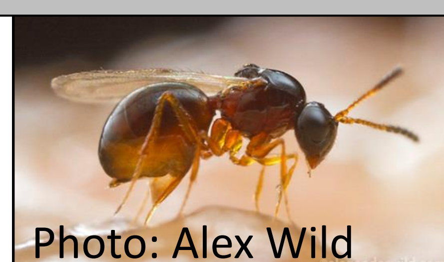
Exploration in native range:

South Korea (2014): 10-19% parasitism

China (2016): 3-73% parasitism

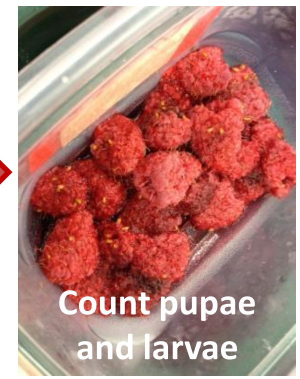


Generalist larval parasitoid that attacks drosophilids in fruit, but did not attack *D. suzukii* in laboratory screening

Monitoring tools and limitations

Larval sampling

Hold at 20°C for 7-14 days or dissect individual fruit



Rearing allows visual species ID

Can enumerate all surviving eggs, larvae, pupae at time of collection

Soak in salt solution

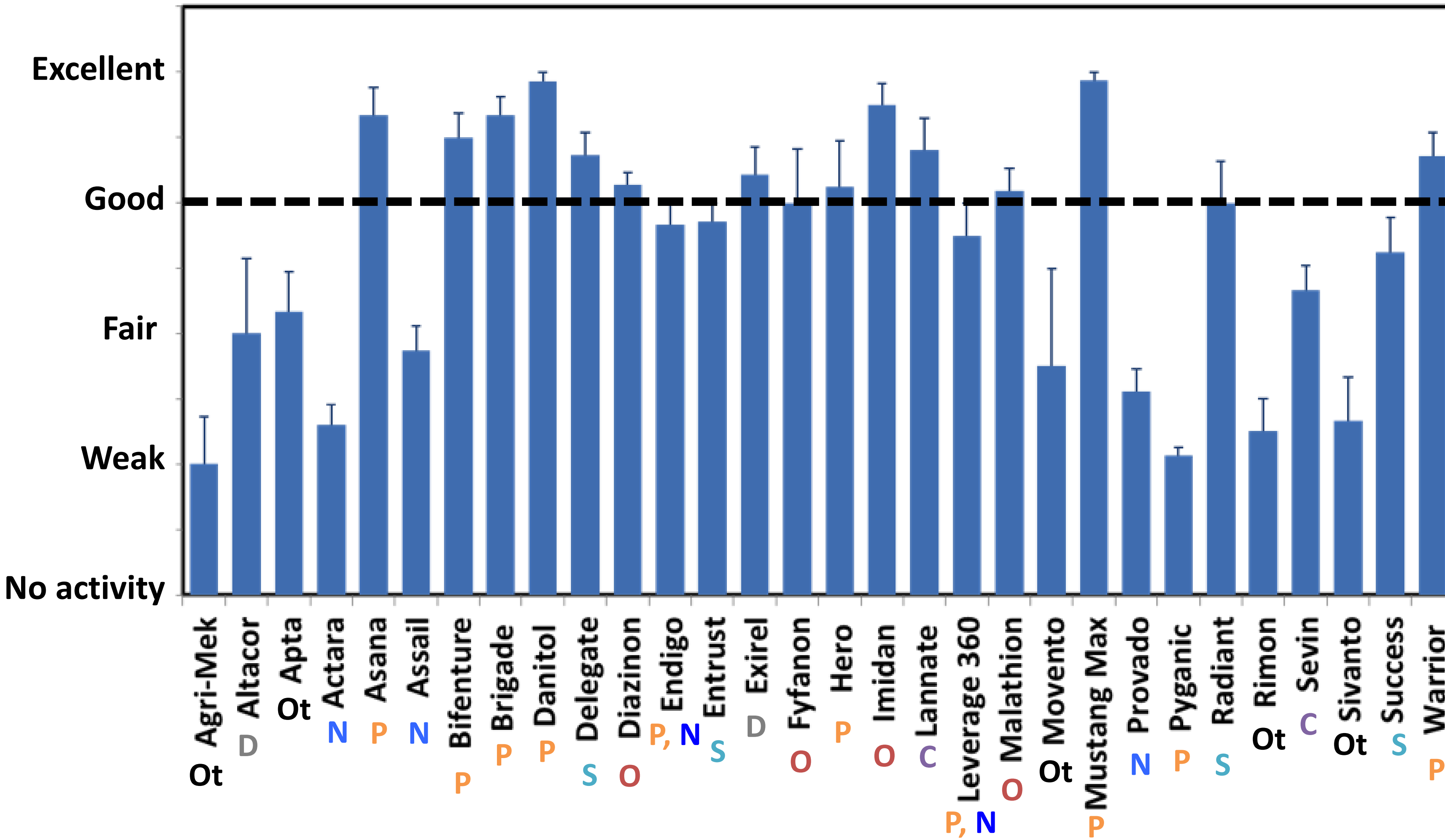
Cannot easily ID larvae to species

Can only enumerate (large) larvae

Summary rankings of insecticide efficacy against *D. suzukii*

10 states, 20 state x crop combinations

CA, OR, WA, MI, ME, NY, NJ, NC, GA, FL



O = organophophate P = pyrethroid S = spinosyn C = carbamate N = neonicotinoid D = diamide Ot = other

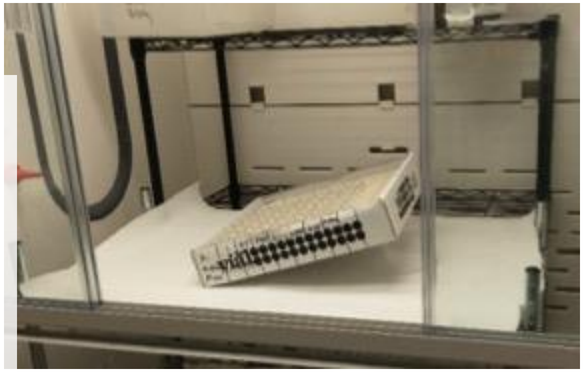
Spotted wing drosophila
Efficacy of currently used insecticide tools

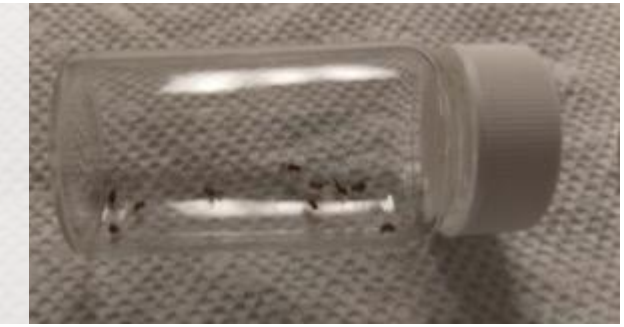
Rufus Isaacs
MSU

Ash Sial
U of GA

Glass vial assays

- Field collected populations from areas in Michigan and Georgia treated with target pesticides
- Assessed mortality of 5 male, 5 female *D. suzukii* after 6 h
- Will expand to additional regions in 2017





Efficacy of currently used insecticide tools


Rufus Isaacs
MSU

Ash Sial
U of GA

Material	Location (# of populations	Estimated LC90	Field rate (50 gpa)
Zeta-cypermethrin	Michigan (12)	0.4-1 ppm	60 ppm
Zeta-cypermethrin	Georgia (4)	0.25-4 ppm	60 ppm
Malathion	Michigan (14)	5-10 ppm	2996 ppm
Malathion	Georgia (5)	5-10 ppm	2996 ppm
Spinetoram	Michigan (14)	30-130 ppm	225 ppm
Spinetoram	Georgia (4)	2.5-30 ppm	225 ppm

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Area wide management tactics under consideration

Mass trapping

Limitations include attractants, range of attraction, and trap longevity

Traditional SIT and via conditional lethal strains

Limitations include strain development, high populations sizes, large host range, extensive distribution, unclear infrastructure, and public/regulatory approvals

Gene drive mediated population suppression and/or replacement

Limitations include strain development, large host range, and public/regulatory vacuum

DsRed *D. suzukii*

Photo: Matt Bertone

Acknowledgements

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www.SWDManagement.org

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- North Carolina Blueberry Council, Inc.
- Georgia Blueberry Growers Association
- Southern Region Small Fruit Consortium
- NC Agricultural Foundation, Inc.
- Project GREEEN
- MBG Marketing
- Michigan Blueberry Advisory Council
- Georgia Blueberry Commission
- Georgia Department of Agriculture

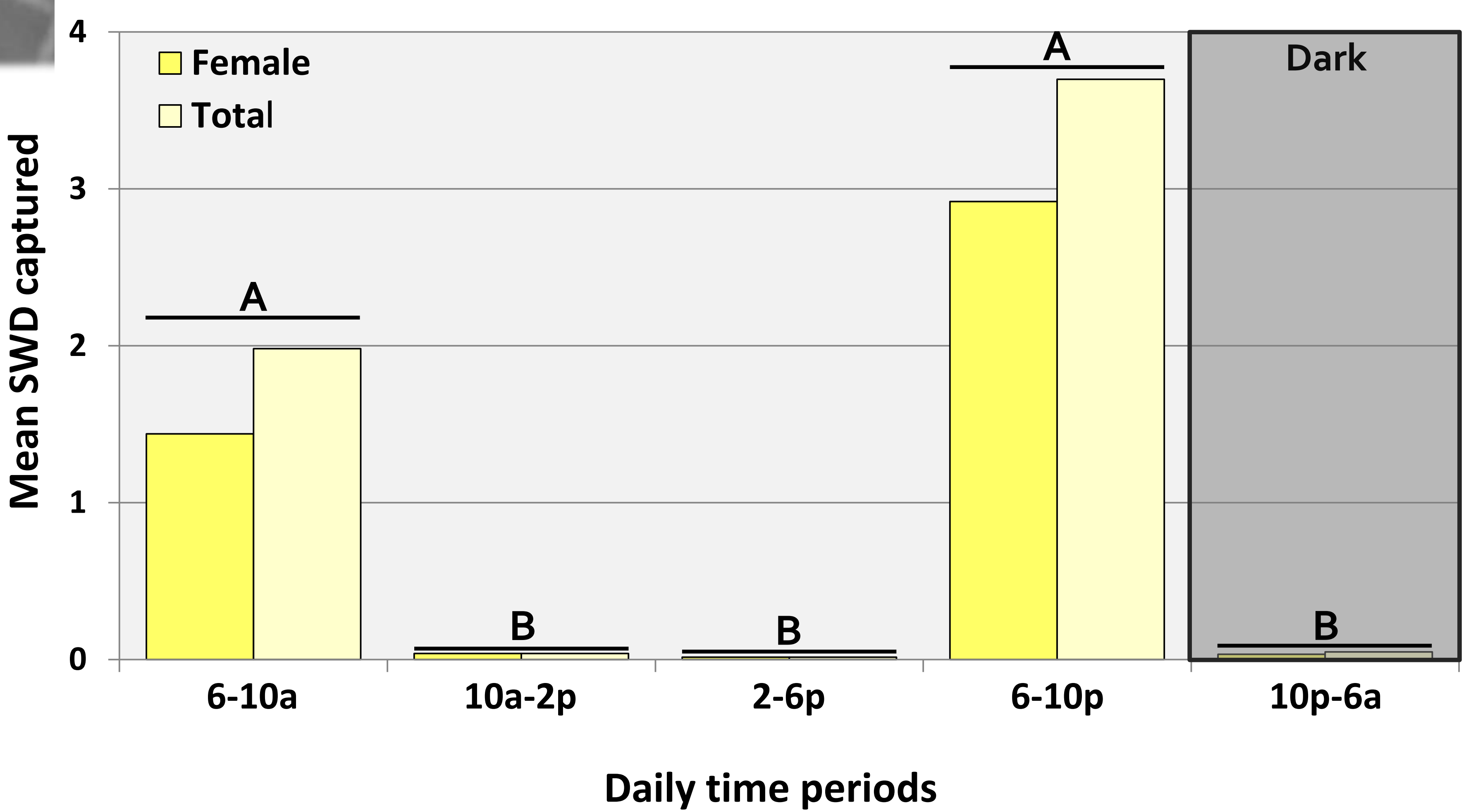
Diurnal activity patterns of *D. suzukii*

Methods

- 2-headed Malaise traps
- Monitoring traps with a fermentation-based bait
- Two farms in western NC in 2014 & 2015
- Biweekly samples at each farm
- 24 hours except when dark

K. Swoboda-Bhattarai, NC State University

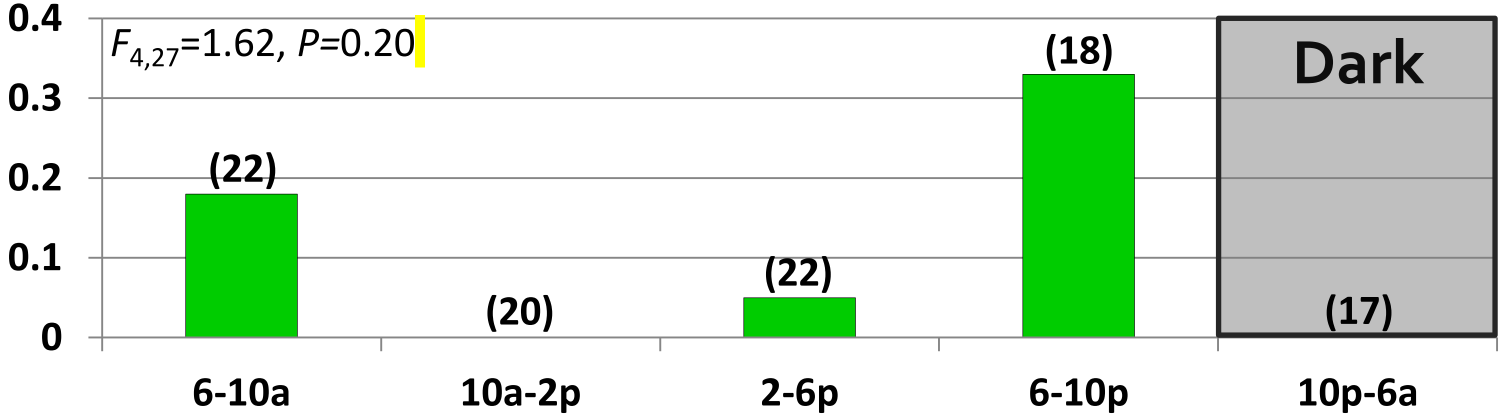
D. suzukii are caught in monitoring traps during the morning & evening hours



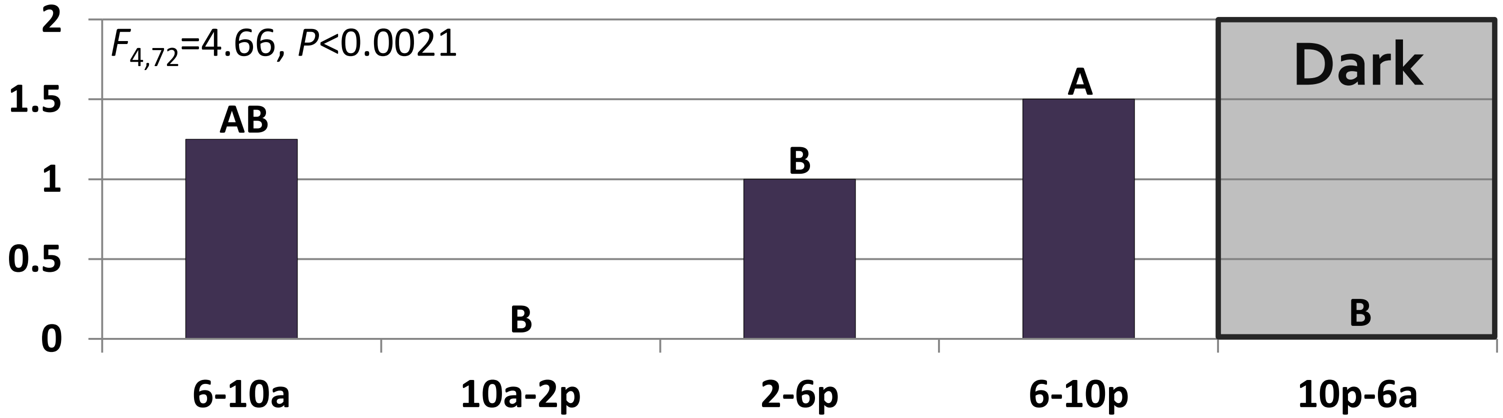
K. Swoboda-Bhattarai, NC State University

D. suzukii infest berries during the morning & evening hours

Proportion of infested berries (# berries exposed)



Mean SWD per berry



K. Swoboda-Bhattarai, NC State University