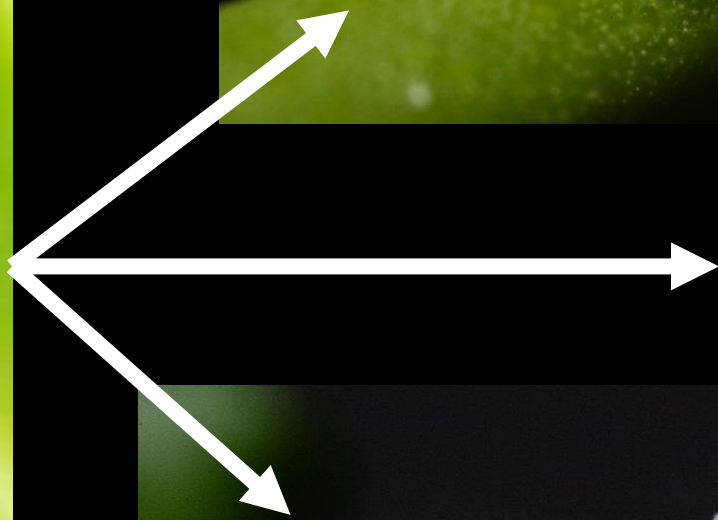


Crushing the Curve: Biological Control of Asian Citrus Psyllid in California



Mark S. Hoddle, University of
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Diaphorina citri Life Cycle



Adults can live for several months

Average number eggs laid at 28°C is 748



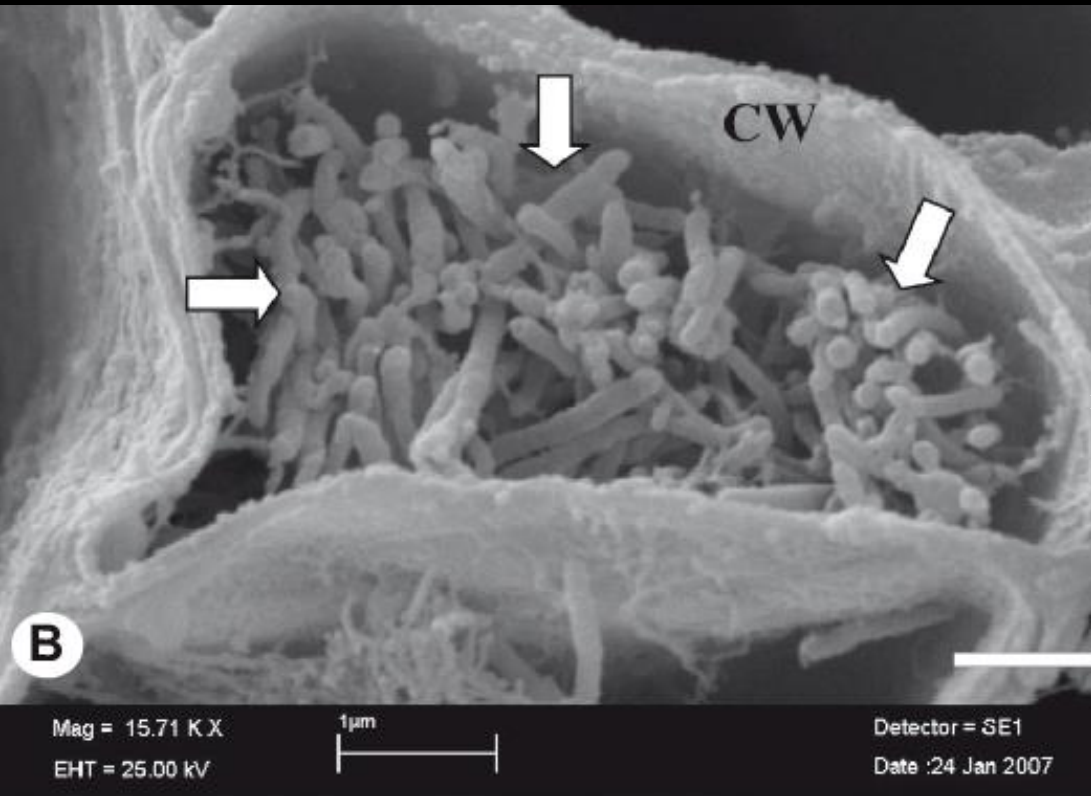
Eggs hatch in 2–4 days

Optimal Temperature for Development is 25-28°C



Five nymphal instars complete development in 11-15 days





The ACP-HLB Problem in Florida

Florida's citrus industry valued at US\$9.3 billion

ACP first found in 1998

HLB detected in 2005

Now infects all 32 citrus producing counties in FL

~621,000 acres of citrus in Florida

> 60,000 acres of trees destroyed by 2009

>\$330 million/yr in losses

8,257 jobs lost (Hodges & Spreen 2016 UFL pub.)

2022: ~75% decline in acreage (ESA 2022)

Why has Florida failed while Brazil has succeeded?

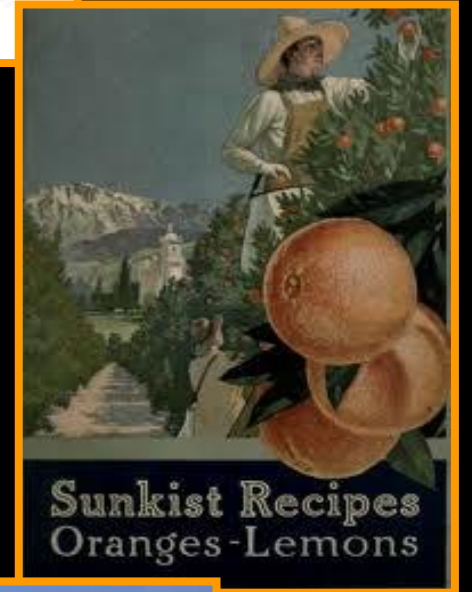
Poor "collective action" for "public good"

(Singerman & Rogers 2020. J. IPM)



The Threat ACP-HLB Poses to California

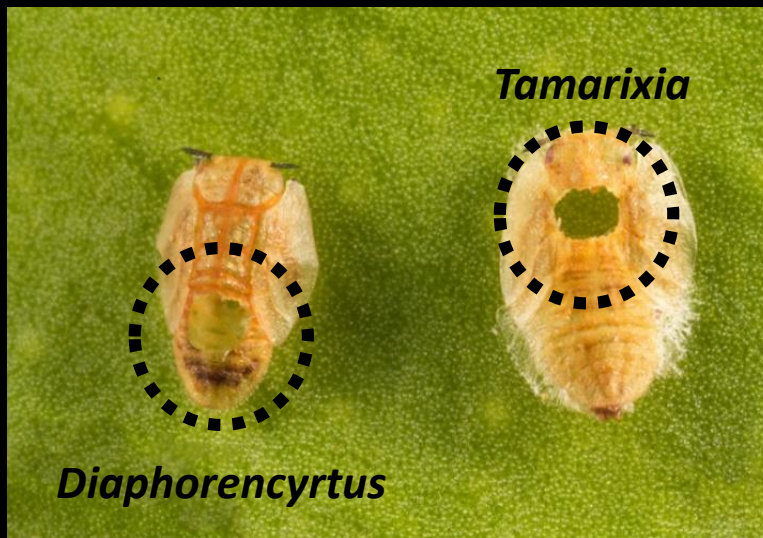
- CA second largest citrus producer in USA after FL
 - Oranges 66% of crop
 - Lemons = 25% of crop
 - Grapefruit = 6%; tangerines = 3%
 - ~5,000 growers farming ~250,000 acres
 - All CA citrus is worth ~\$3.3 billion/yr
 - Total economic impact \$7.1 billion/yr (Babcock 2018)
- ACP found in 2008 – San Diego County
- HLB detected 2012 – LA County
- **IMPACT?????**
 - \$\$ tens of millions expended so far in mitigation and research
 - ACP and HLB almost exclusively found in urban citrus







Parasitoid Development – An Overview





The Urban Focus of the ACP Biocontrol Program

Tamarixia released Dec. 2011

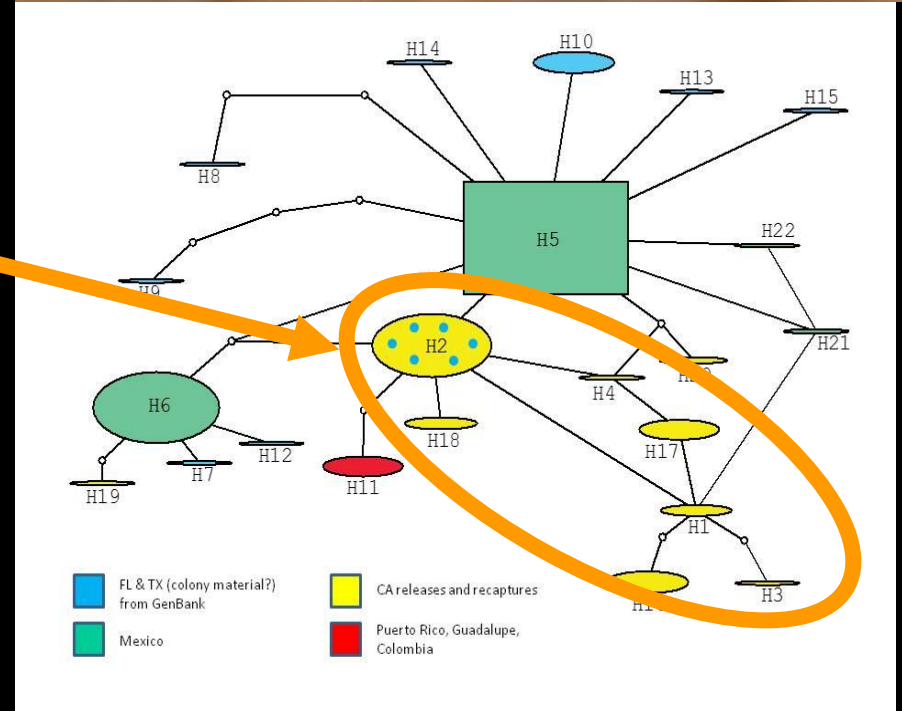
Immediate establishment

Rapid spread (5-8 miles into non release areas)

Molecular work confirmed field recoveries were of Pakistan origin

> 23 million *Tamarixia* released by CDFA as of 2022

IMPACTS???



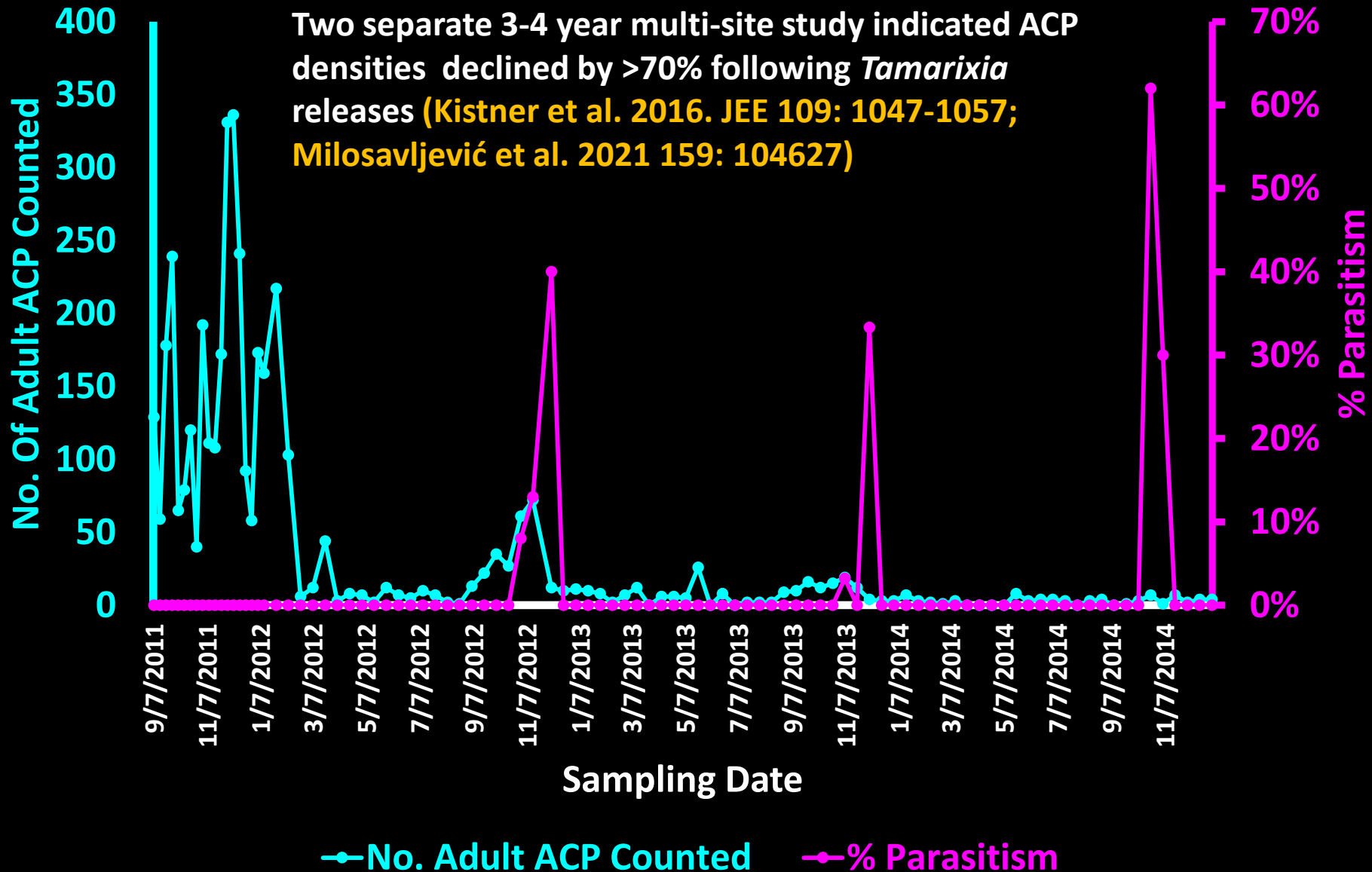
Pop Up Quiz Question - 1

- Asian citrus psyllid is native to
- **a) Indian subcontinent**
- b) Oceania
- c) Central America
- d) South America



Assessing Impacts: ACP Counts

Two separate 3-4 year multi-site study indicated ACP densities declined by >70% following *Tamarixia* releases (Kistner et al. 2016. JEE 109: 1047-1057; Milosavljević et al. 2021 159: 104627)



Assessing Impacts: More Evidence of ACP Population Declines Based on Count Data

- **Milosavljević et al. 2021** (Biol. Contr. 159: 104627)
 - 4 year study (1 Jan. 2015 – 31 Dec. 2018), 28 sites, and 55 trees spanned a transect from the coast (cool), inland (moderate) to desert (hot)
 - **Egg densities** declined by 92% (ants present eggs 3x greater in density)
 - **Small nymphs** (1st – 3rd instars) declined by 81% (ants present eggs 3x greater in density)
 - **Large nymphs** (4th – 5th instars) declined by 94% (ants present eggs 3x greater in density)
 - **Adults** declined by 75% (ants had no effect on adult densities)
 - **Average % parasitism** by *Tamarixia* ranged ~20-25%, often exceeding 60% during peak ACP densities (ants present average parasitism declined by 50%)
 - Impacts of *Tamarixia* likely underestimated as mortality from host feeding, unsuccessful parasitism, and intraguild predation of parasitized nymphs unknown
 - Density dependent lag of 12 months best predictor of ACP densities the following year

Videography Studies: Who is Doing the Killing?

- Raspberry Pi cameras set up to film insect activity on ACP cohorts
- Recording time ~ 5 days
- IR capabilities for night recording
- 5 mp image resolution





Argentine ants are almost always present on ACP cohorts when they have access to them

Sanitation



R. J. Baker

Increased development rate & reproduction



Dr. Dong-Hwan Choe; UC Riverside

Mike Lewis

Transportation



Natural enemy interference





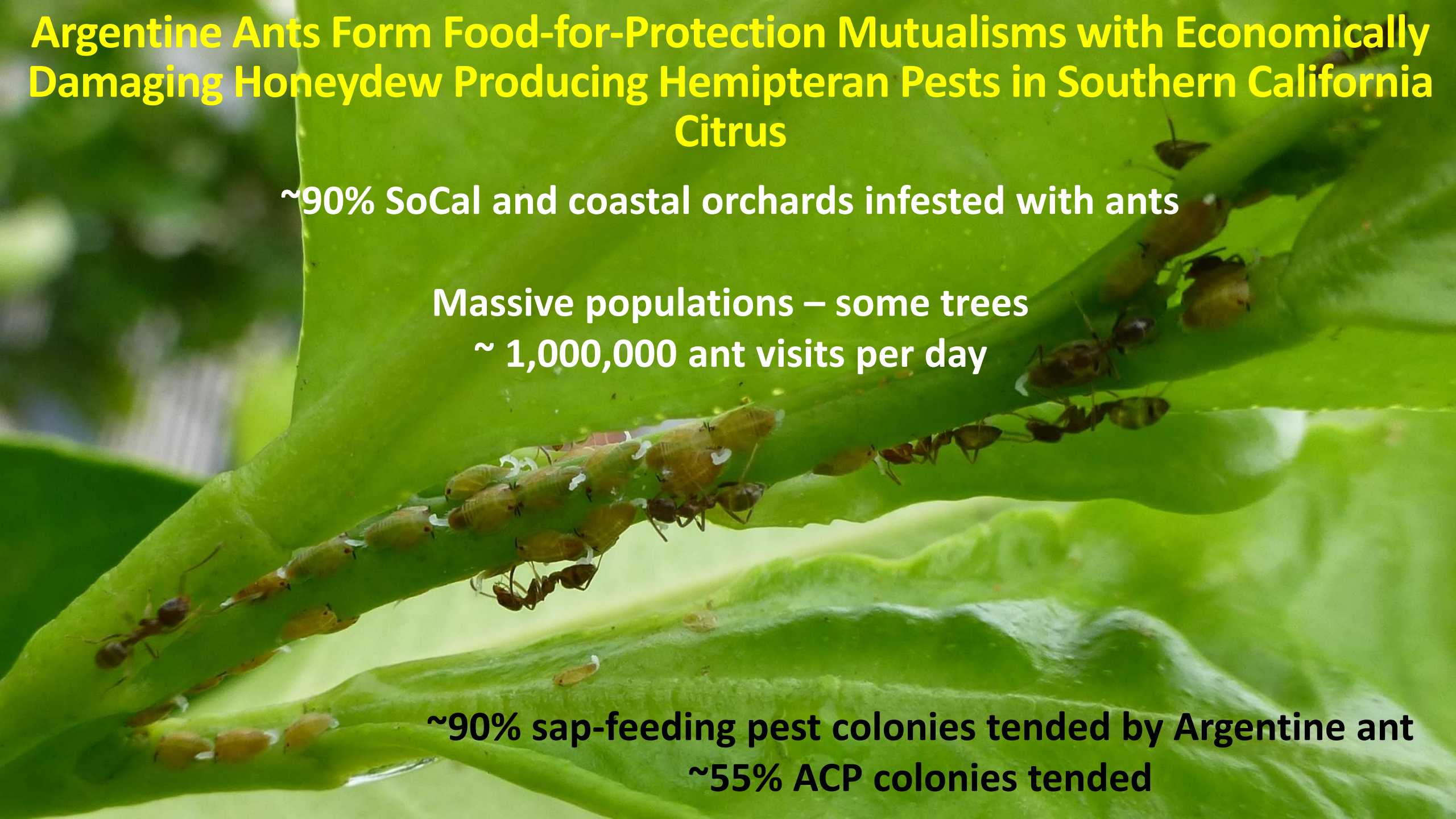
Video courtesy of Josh Cassidy and Gabriela Quiros,
KQED's Deep Look Team

Argentine Ants Form Food-for-Protection Mutualisms with Economically Damaging Honeydew Producing Hemipteran Pests in Southern California Citrus

~90% SoCal and coastal orchards infested with ants

Massive populations – some trees
~ 1,000,000 ant visits per day

~90% sap-feeding pest colonies tended by Argentine ant
~55% ACP colonies tended





**Natural enemies have killed more
ACP than any other management
program**



**ACP biocontrol agents are working for you
24/7/365**

Working now to make impacts even greater!



Pop Up Quiz Question – 2

- Why are Argentine ants a problem in citrus?
- a) They make nests underground that weaken roots
- b) They eat honeydew excreted by sap sucking pests
- c) They disrupt biological control agents
- d) They herd pests and move them to other trees



How Can We Improve Biocontrol of Citrus Pests When Ants are Present?









Take Home Messages

- Repeated field evaluations across replicated sites over several years spanning the coast, inland, and desert areas, clearly showed a massive decline (>70%) in ACP densities since the inception of the classical biological control program
- **Eleven years on from the initial CLas detection in LA County, it is highly unlikely CA citrus will be destroyed by ACP-CLas**
- ACP biocontrol program, in part, has contributed to this outcome as vector densities are now very low. So low in fact, that CDFA is considering discontinuing ACP population density monitoring as many of their study sites have been ACP-free for ≥ 2 yrs
- **Natural enemies have achieved far greater levels of suppression over much vaster areas far more cheaply and sustainably than was ever possible with the USDA-CDFA urban spray programs**
- Consequently, because of such low vector densities, of the millions of citrus trees grown in urban areas, only $\sim 6,000$ citrus trees have succumbed to HLB, a miniscule fraction

Acknowledgements

The background of the slide features a close-up photograph of several ants. The ants are dark brown or black, with their segmented bodies and long antennae clearly visible. They are positioned on a bright blue, textured surface that resembles a plastic or fabric material with a fine, repeating pattern. The lighting is bright, creating some highlights and shadows on the ants' bodies.

- **People**

- Friends and colleagues at the University of Agriculture, Faisalabad Pakistan
- Erica Kistner, Kelsey McCalla, Nic Irvin, Ivan Milosavljević, Mike Lewis, Ruth Amrich, Christina Hoddle
- Numerous students and field assistants too many to mention by name
- Cooperating growers – unlimited access to orchards
- UCR Computer Science Engineers, Shailendra Singh and Eamonn Keogh

- **Funding Agencies**

- Citrus Research Board
- California Department of Food and Agriculture Specialty Crops Program
- California Department of Pesticide Regulations
- USDA-APHIS-CPHST-MAC
- Donations to the lab from growers



SCAN ME