Development of Sterile Insect Technique for Navel Orangeworm

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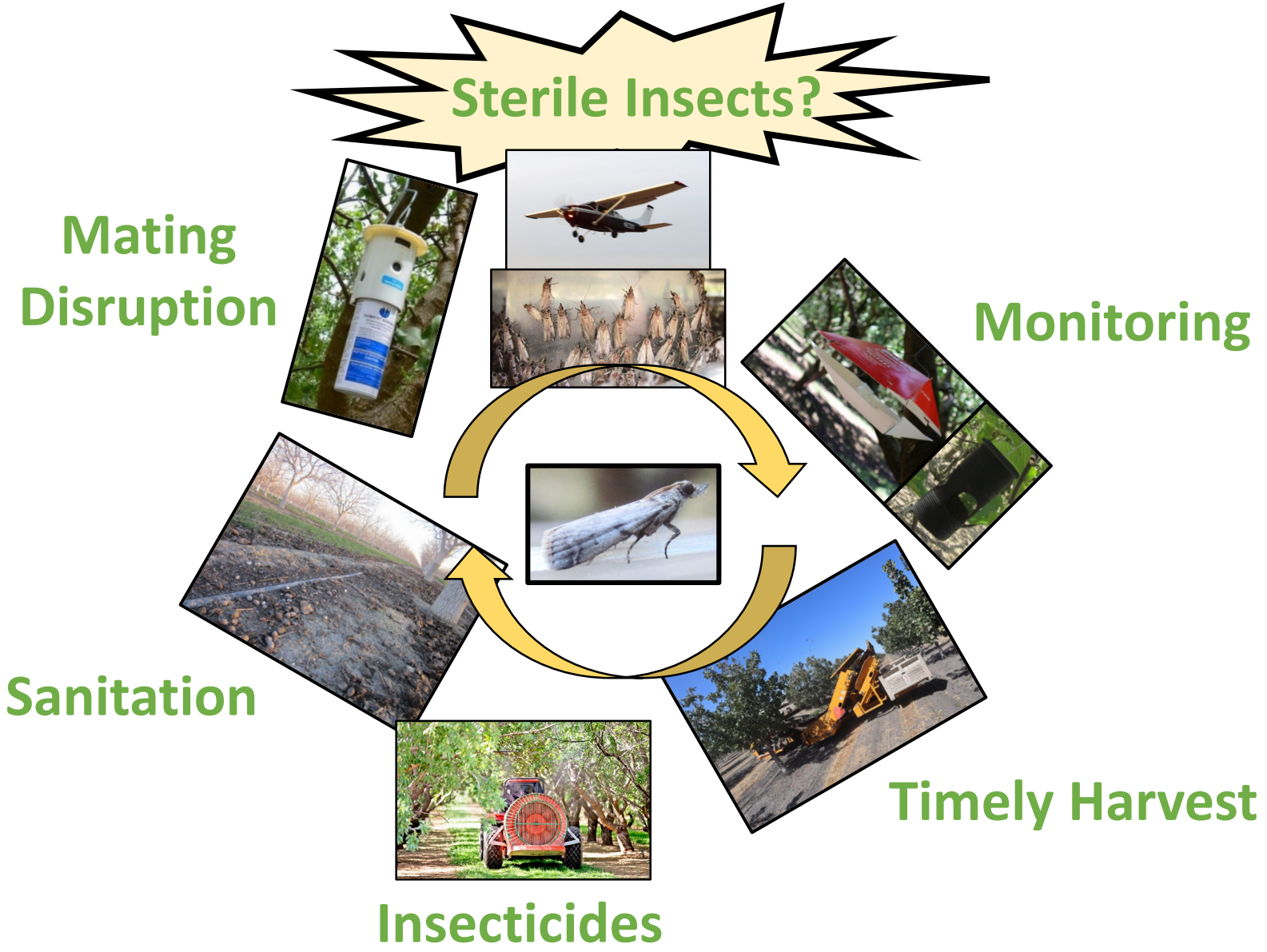
NOW Management in Pistachio/Almond

Use of Multiple Approaches is Key



SIT for NOW - Background

Moth Production/Transportation Process

When? Where? How Many?

Lots of moths…

- **~2,000,000 NOW/day**

…but also lots of crops.

- **1.2M almonds, 300k pistachio, 250k walnuts**
- **Plus alternate hosts**

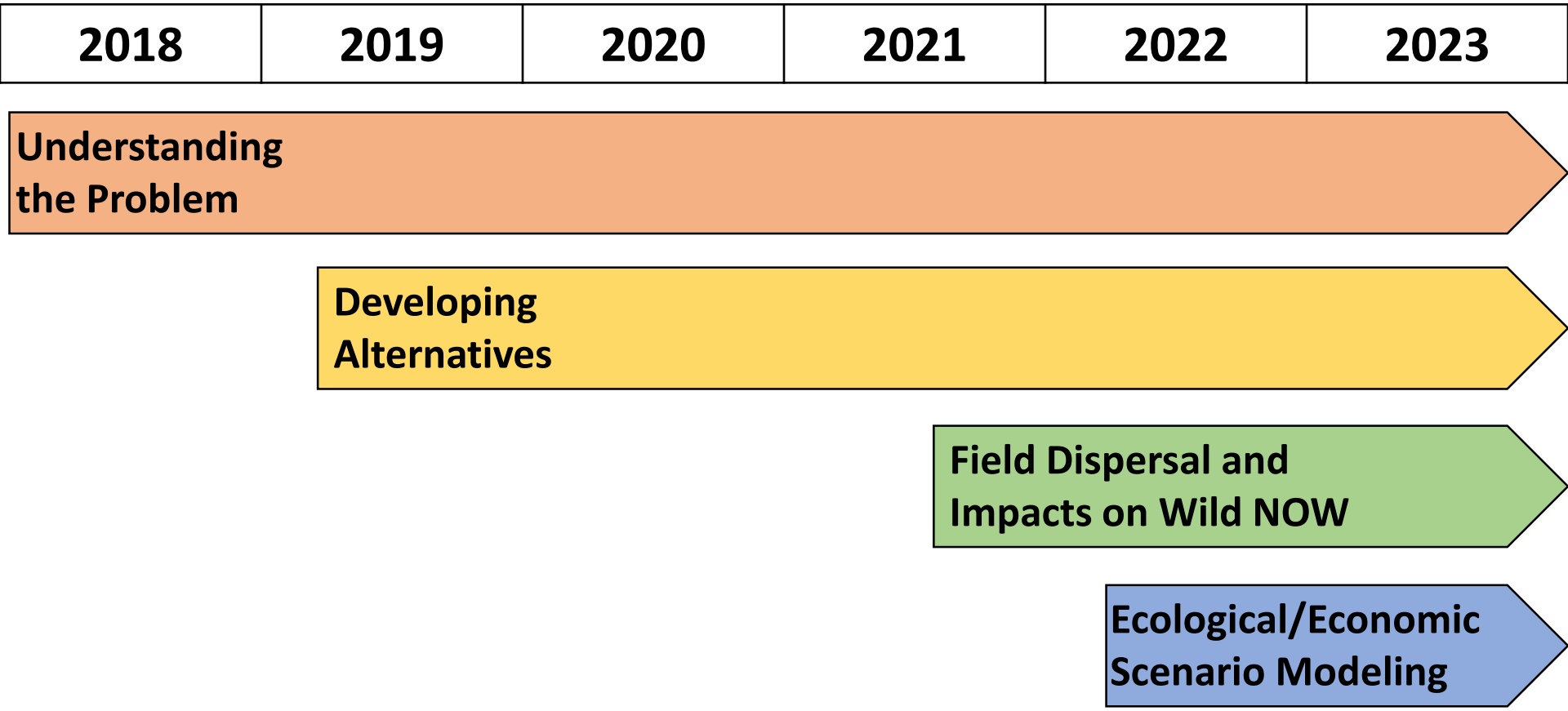
Where to deliver moths? When? How many?

- **Overflooding ratio**
- **Delivery method, timing and location**
- **Integration with existing IPM tools**

Goal = develop a competitive sterile moth, and figure out how to best use it.

Sterile Insect Technique for NOW Project

Project Summary 2018-2023



Research Summary: 2018-2021

Monitoring Techniques and Assays

Pheromone Traps

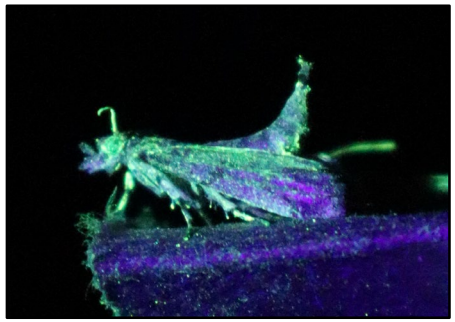
- Synthetic pheromone lure
- Attracts males
- Large trapping radius (captures lots of moths)

Ovibait Traps

- Pistachio/almond bait
- Attracts mated females
- Smaller trapping radius (captures fewer moths)

Research Summary: 2018-2021

Monitoring Techniques and Assays



Female calling (emitting pheromone) at night

NOW mating

Mating Tables

- Sentinel virgin female with wings clipped
- Exposed overnight
- Check at dawn for paired male
- Dissect moths to determine…
  - Male is sterile vs wild
  - Female is mated

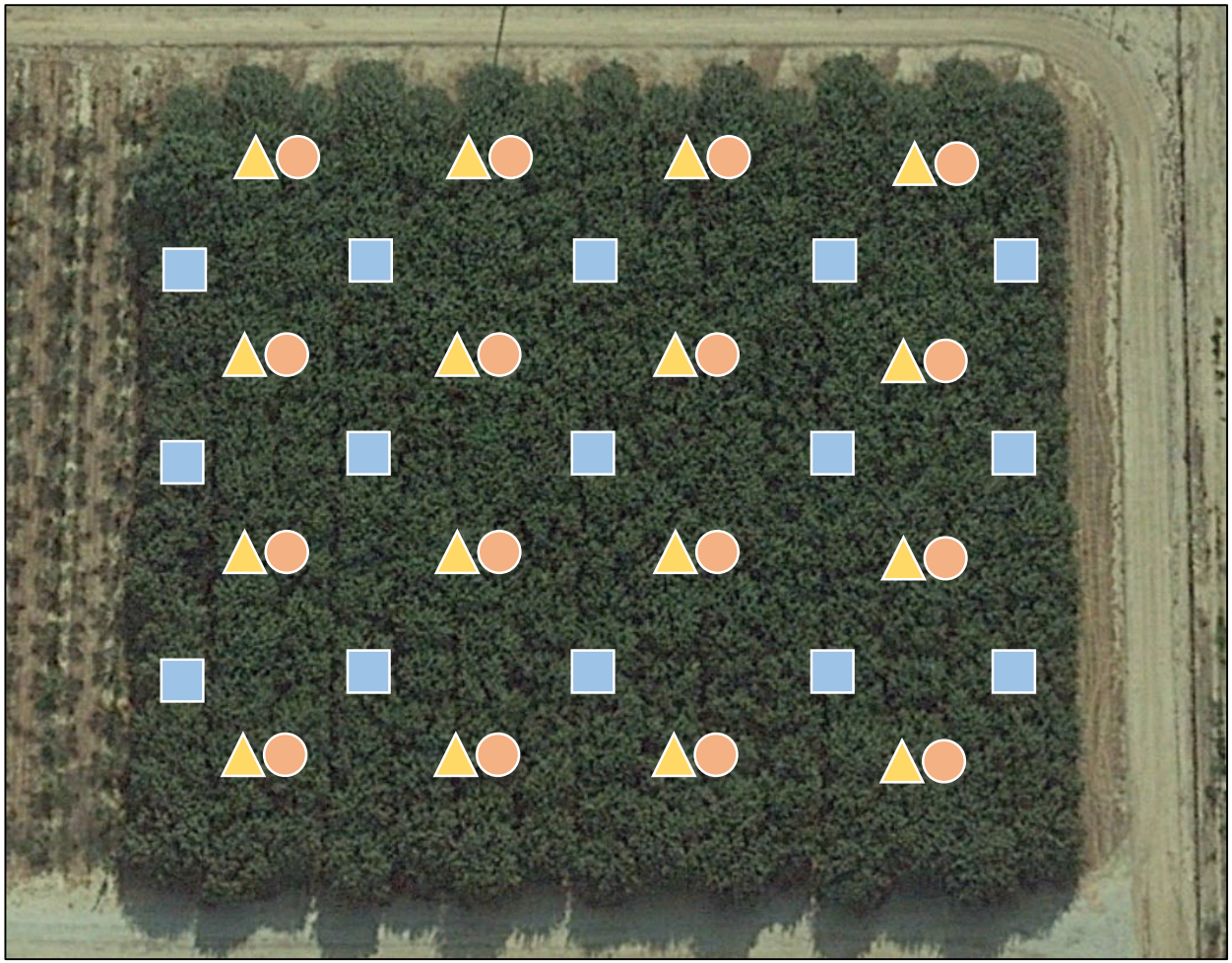
Sentinel Females Used

- Mendota Colony = control moth
  - Can sterile males locate females?
- Phoenix Facility
  - Can sterile females attract wild males?

Research Summary: 2018-2021

Field Release Sites – Two Small Pistachio/Almond Orchards

Grid of Traps and Mating Tables



Pheromone

Ovibait

Mating Table

1-3 acre blocks

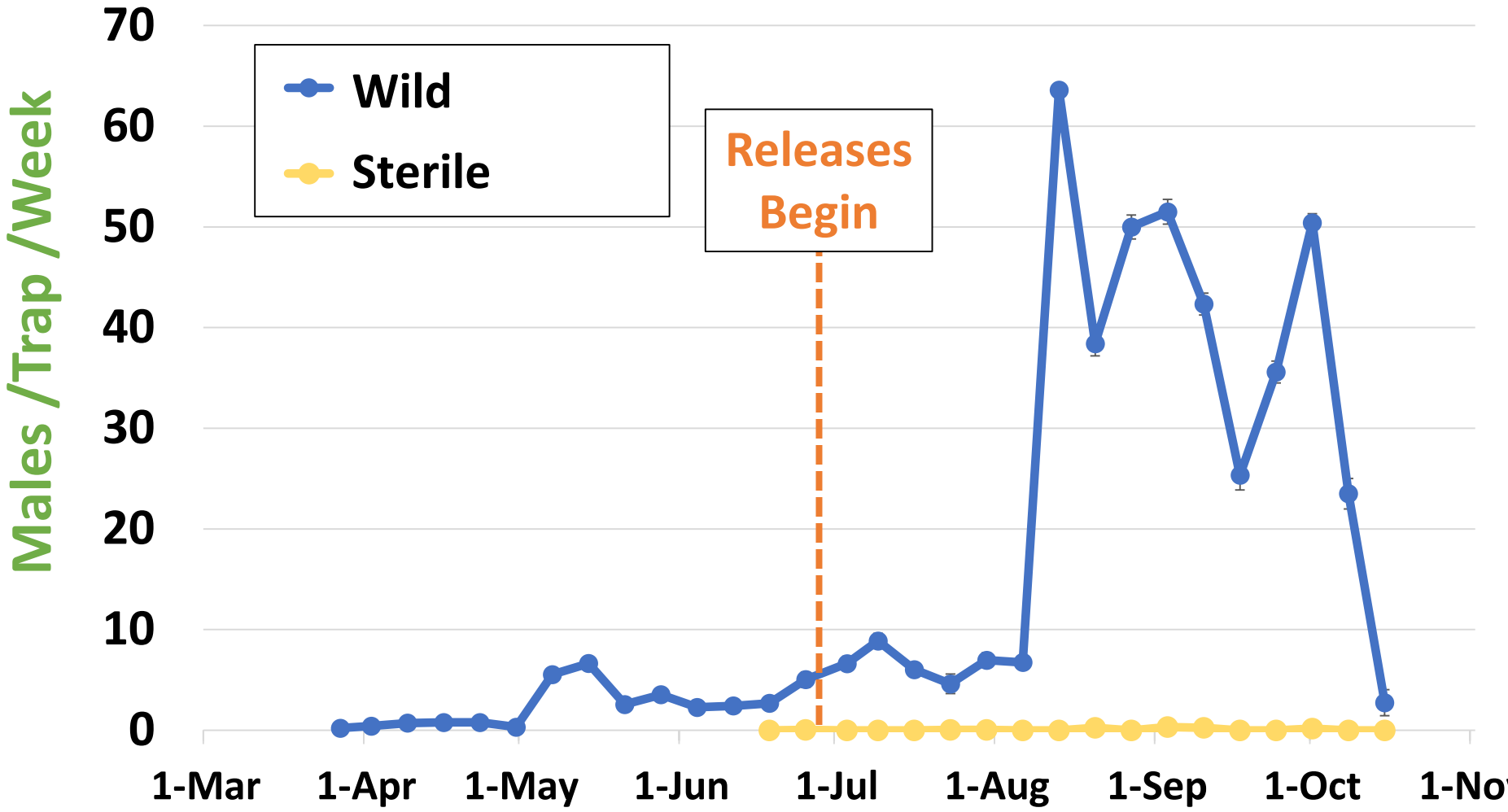
Crop Year 2018

What does moth recapture rate look like?

Crop Year 2018

Poor Recovery of Sterile Males

Flight Traps at Kearney



Crop Year 2019

Poor recovery in 2018

Can males even fly and respond to pheromone?

Crop Year 2019

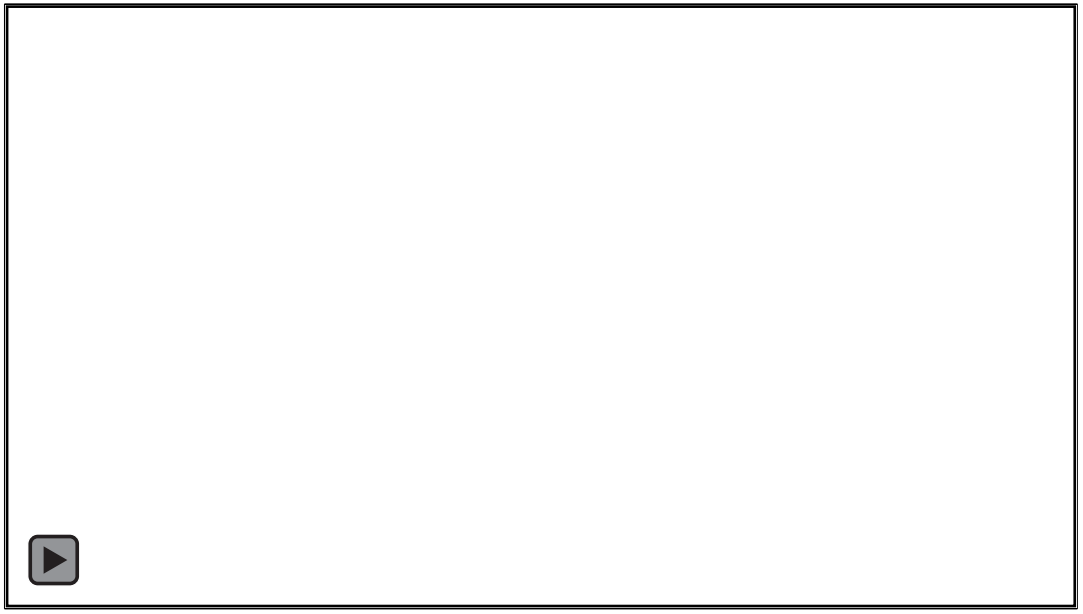
Why Such Poor Recovery of Males?

Can they even fly?

- **Flight mill assays**

Do they respond to pheromone?

- **Wind tunnel assays**



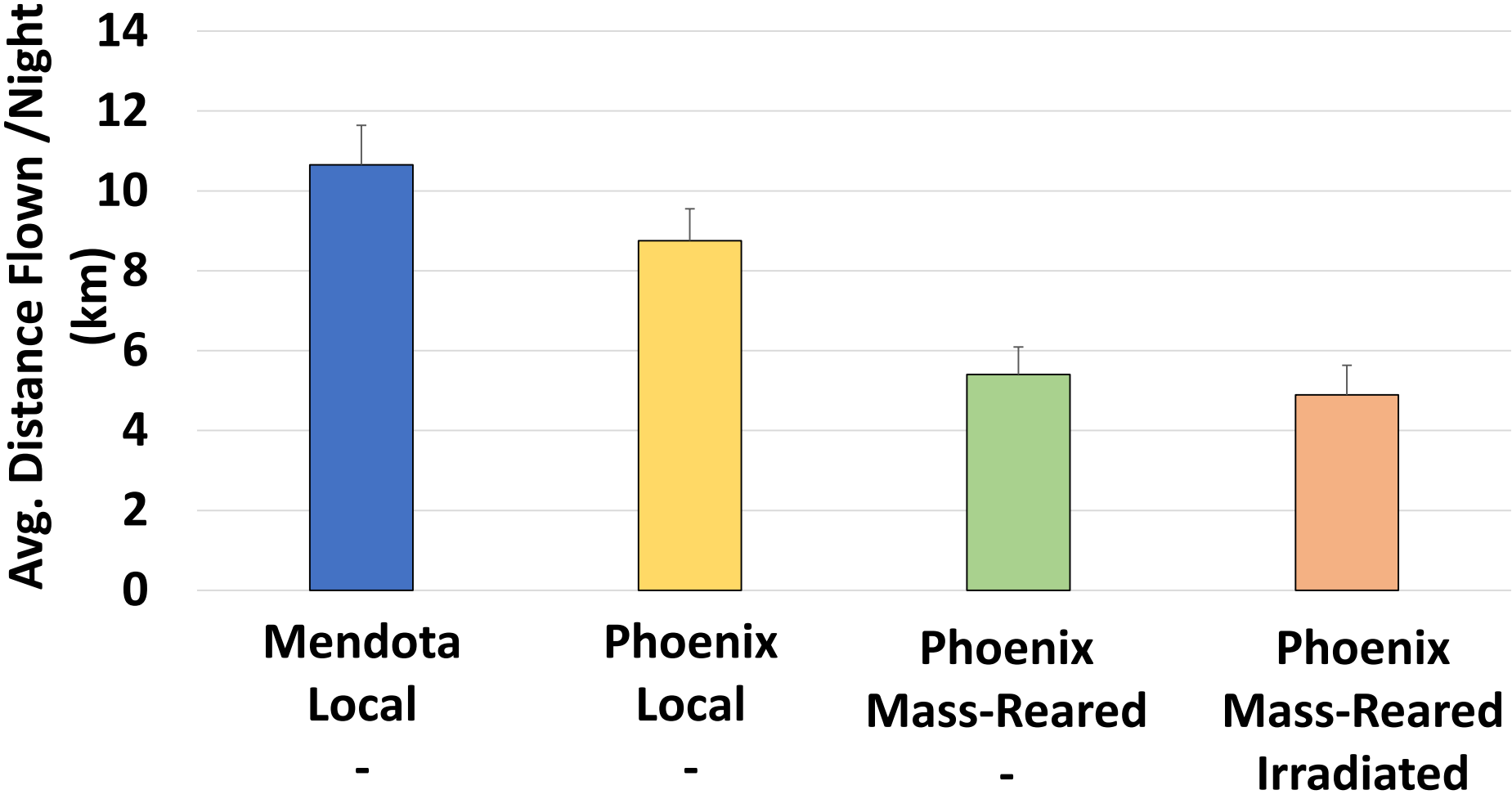
Tandem NOW on a flight mill

Video courtesy of
Joshua Reger, Ph.D. Student
Dept. Entomology, UC Riverside

Crop Year 2019

Evaluating the Phoenix Strain Males

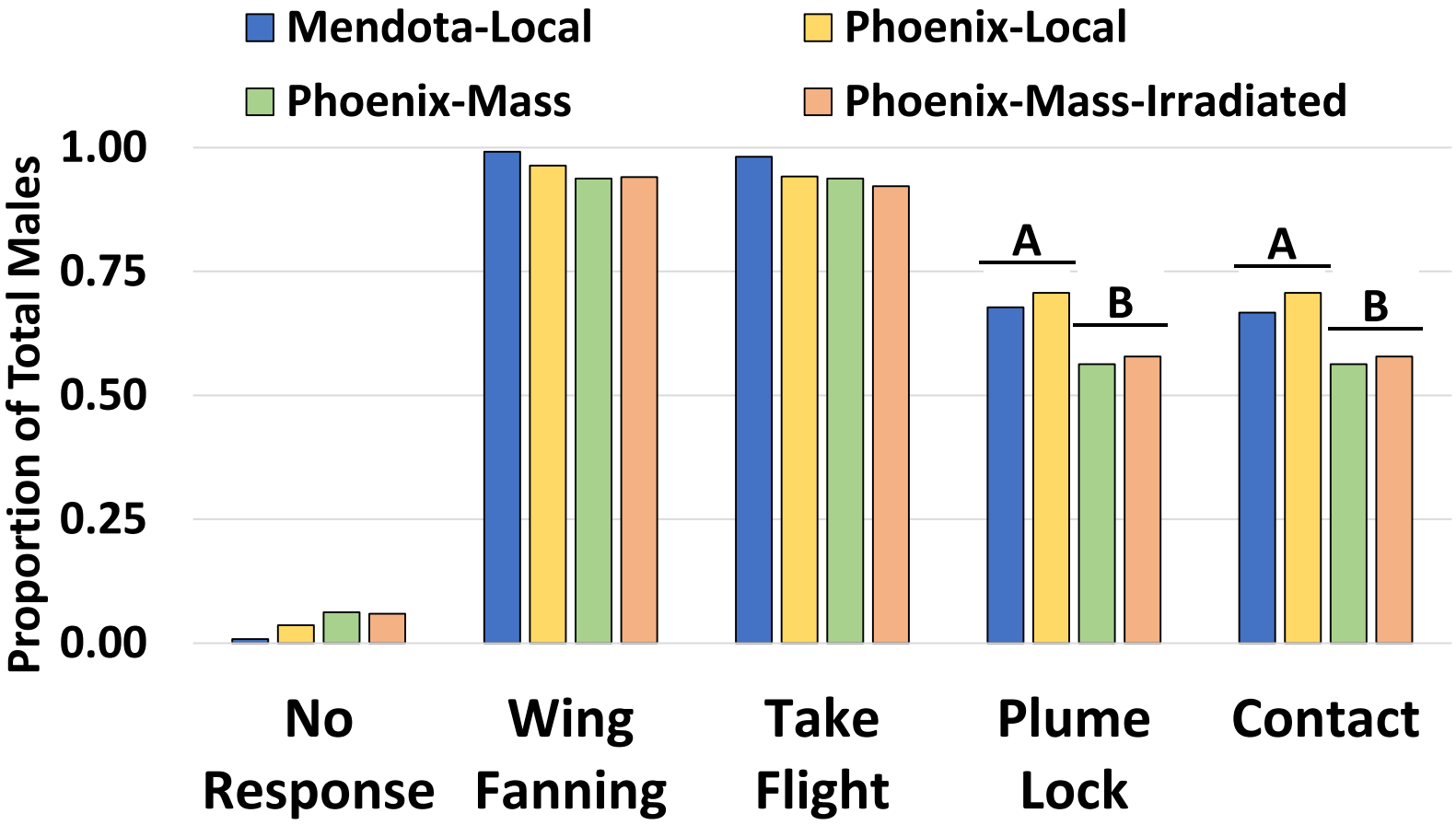
Males can fly – but not as well



Crop Year 2019

Evaluating the Phoenix Strain Males

Males do respond to pheromone



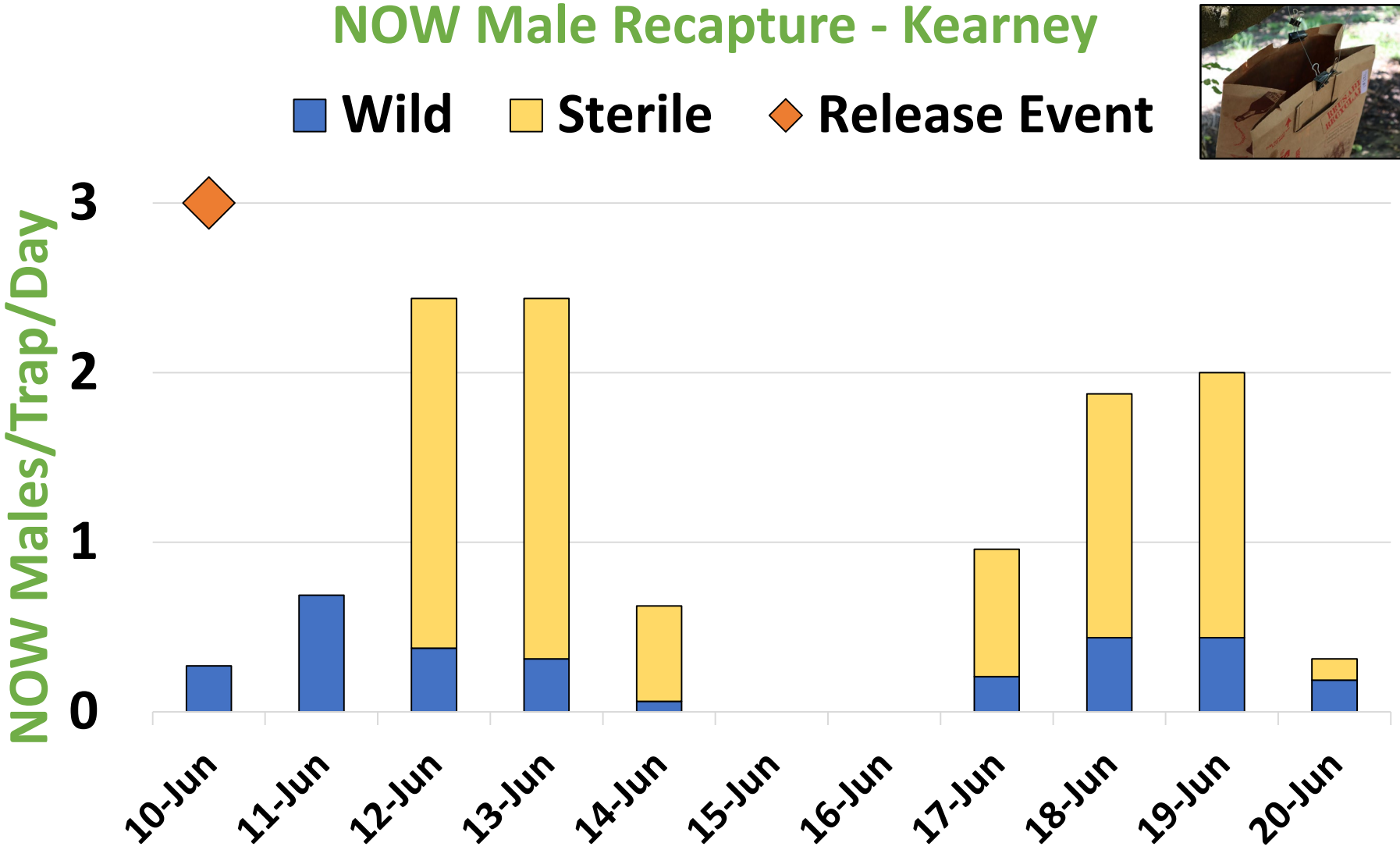
Crop Year 2019

New Release System Provisions Vertical Space

Grocery Bags with Paper Tubes

Crop Year 2019

Recovery Dramatically Increased!



Crop Year 2020-2021

YES - males fly and respond to pheromone

BUT – can they mate in the wild?

ALSO - release system is important

SO - can we improve it further?

Crop Year 2020-2021

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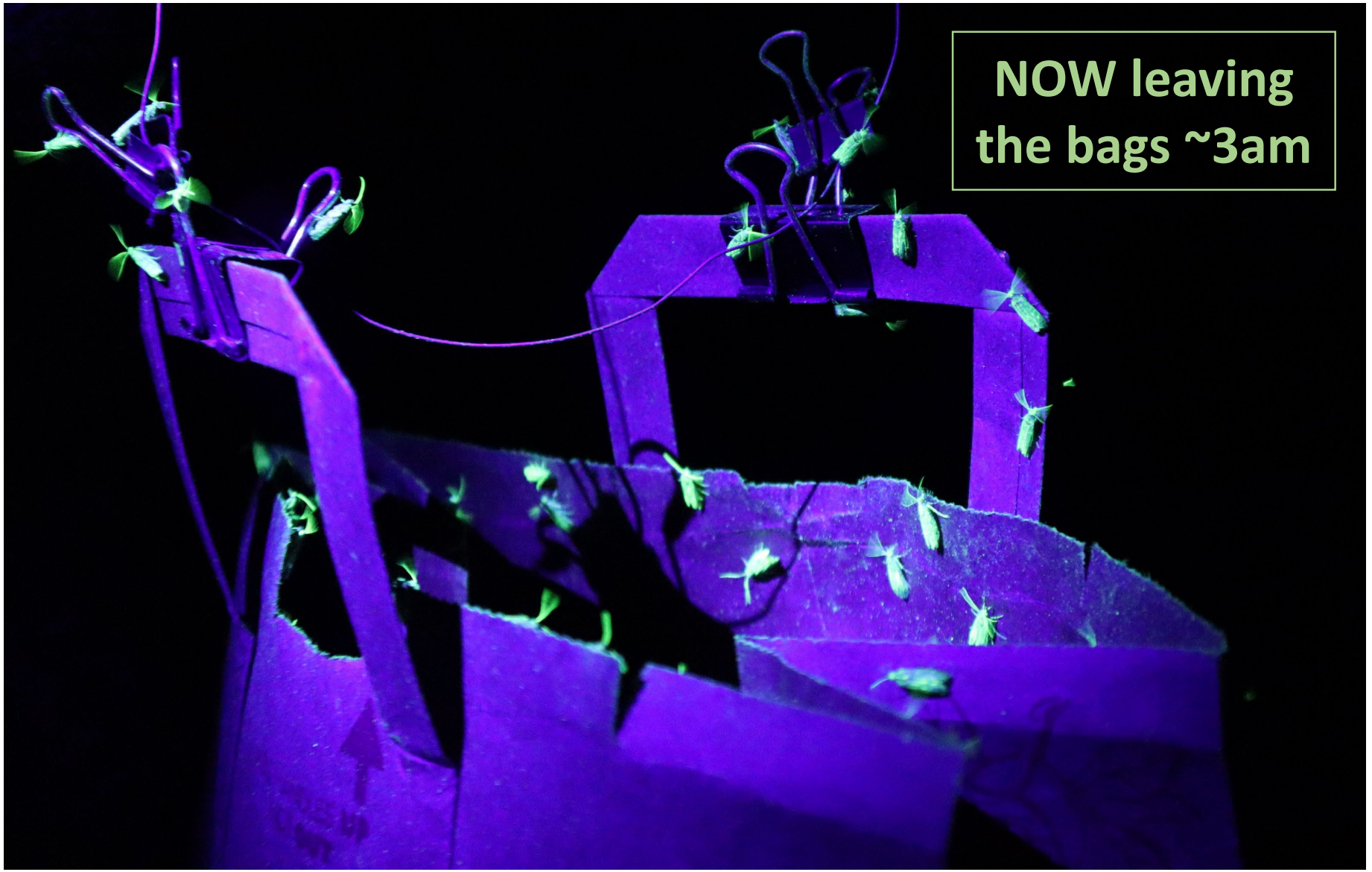
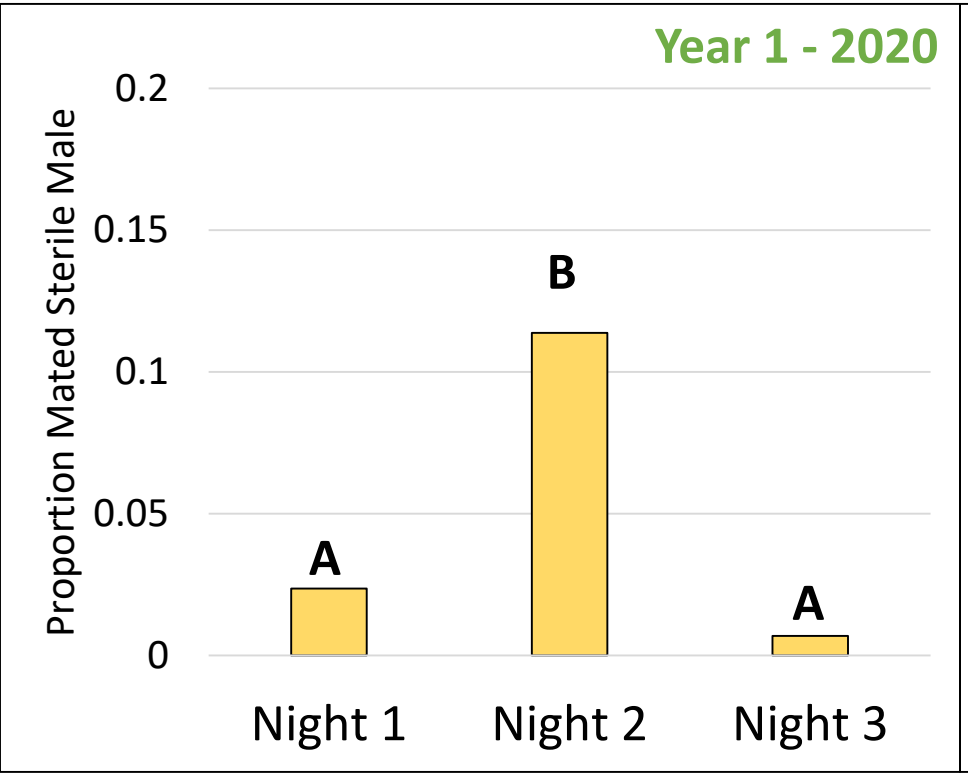
Crop Year 2020-2021

Recovery Improved – But Can They Mate?

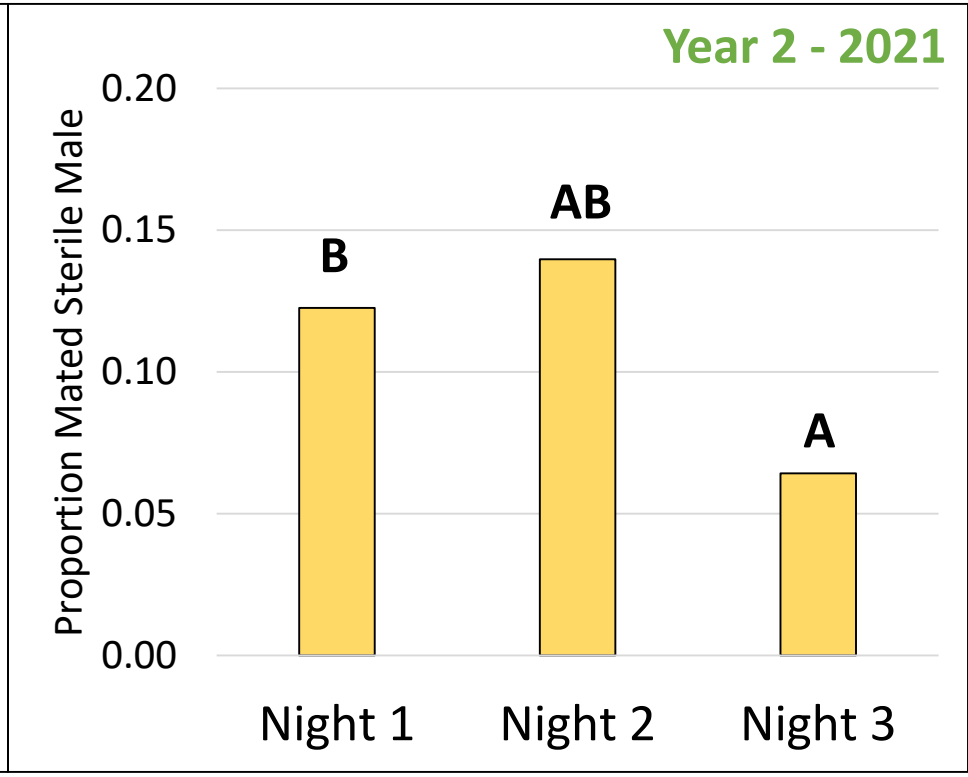


Crop Years 2020-2021

Mass/Sterile Males Can Locate Sentinel Females



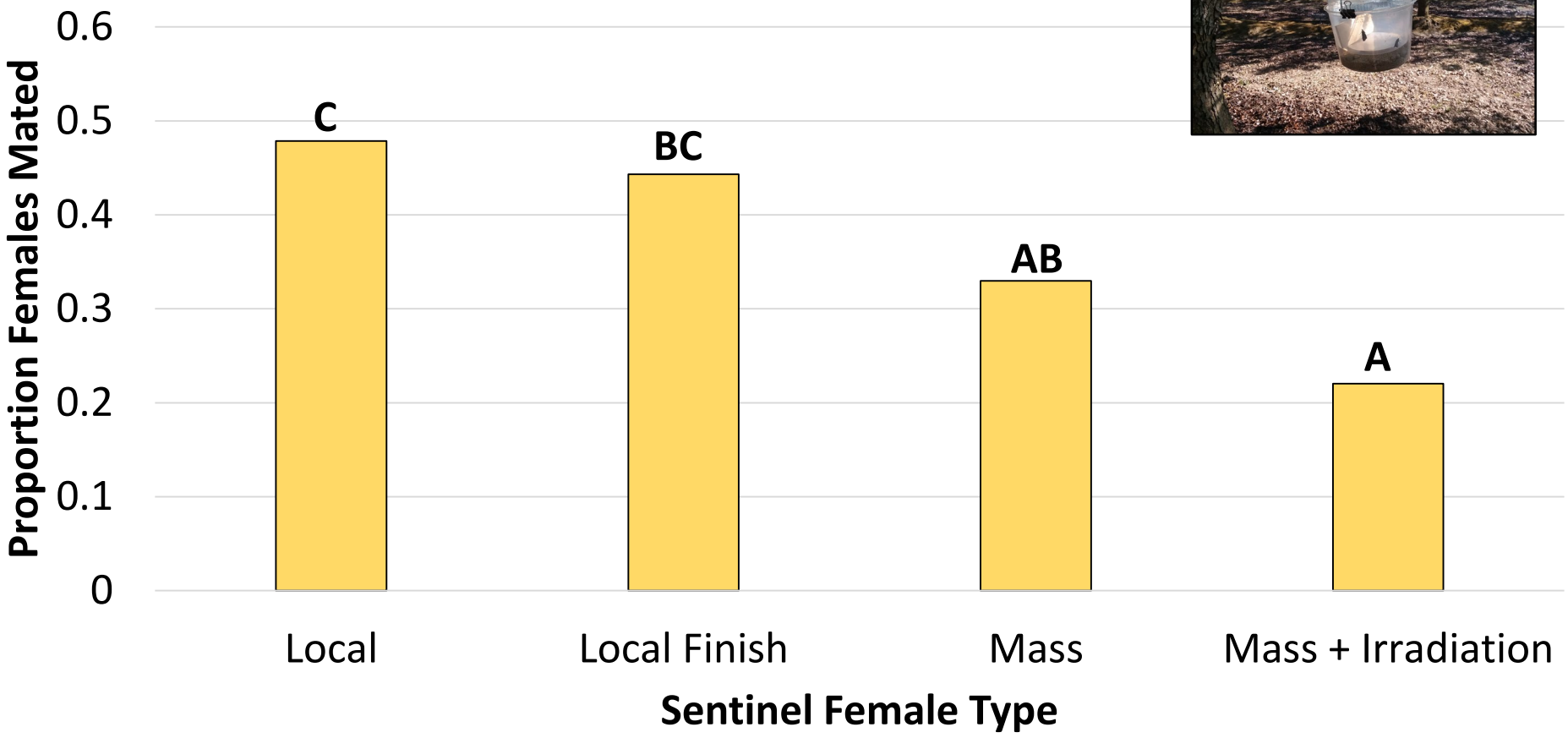
χ^2=21.9, n=524, *P*<0.001



χ^2=10.6, n=541, *P*<0.01

Crop Years 2020-2021

Mass/Sterile Females Can Attract Wild Males



χ^2=44.0, n=1,115, *P*<0.001

Crop Year 2020-2021

YES - males fly and respond to pheromone

BUT – can they mate in the wild?

ALSO - release system is important

SO - can we improve it further?

Crop Year 2020-2021

Primary Focus on Transport/Release Methods

Transport

Shipped via UPS

Driven in refrigerated cooler

Vehicle: M3 Agriculture

Release

Paper Bag + Tubes

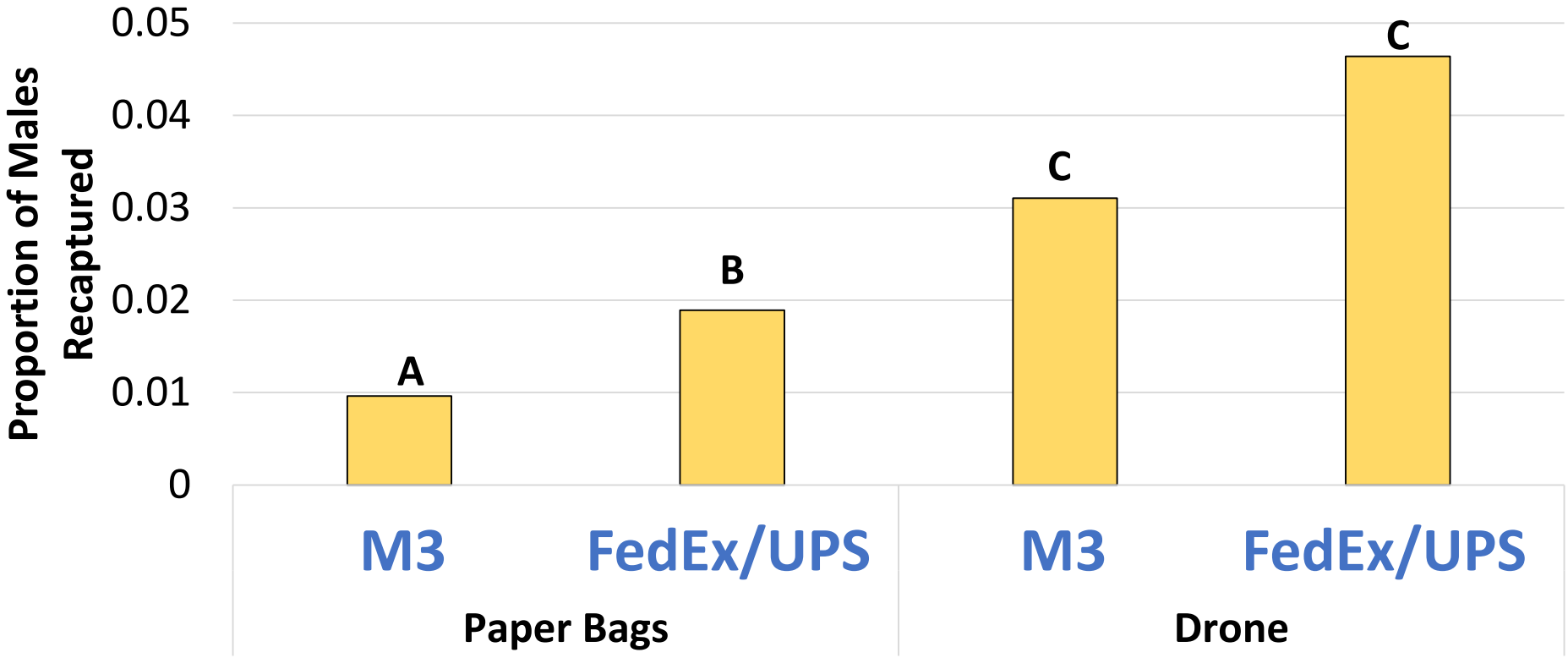
UAV/ Drone

Drone: M3 Agriculture

Crop Years 2020-2021

Transport and Release Does Influence Performance

Mass-Rear Moths Only

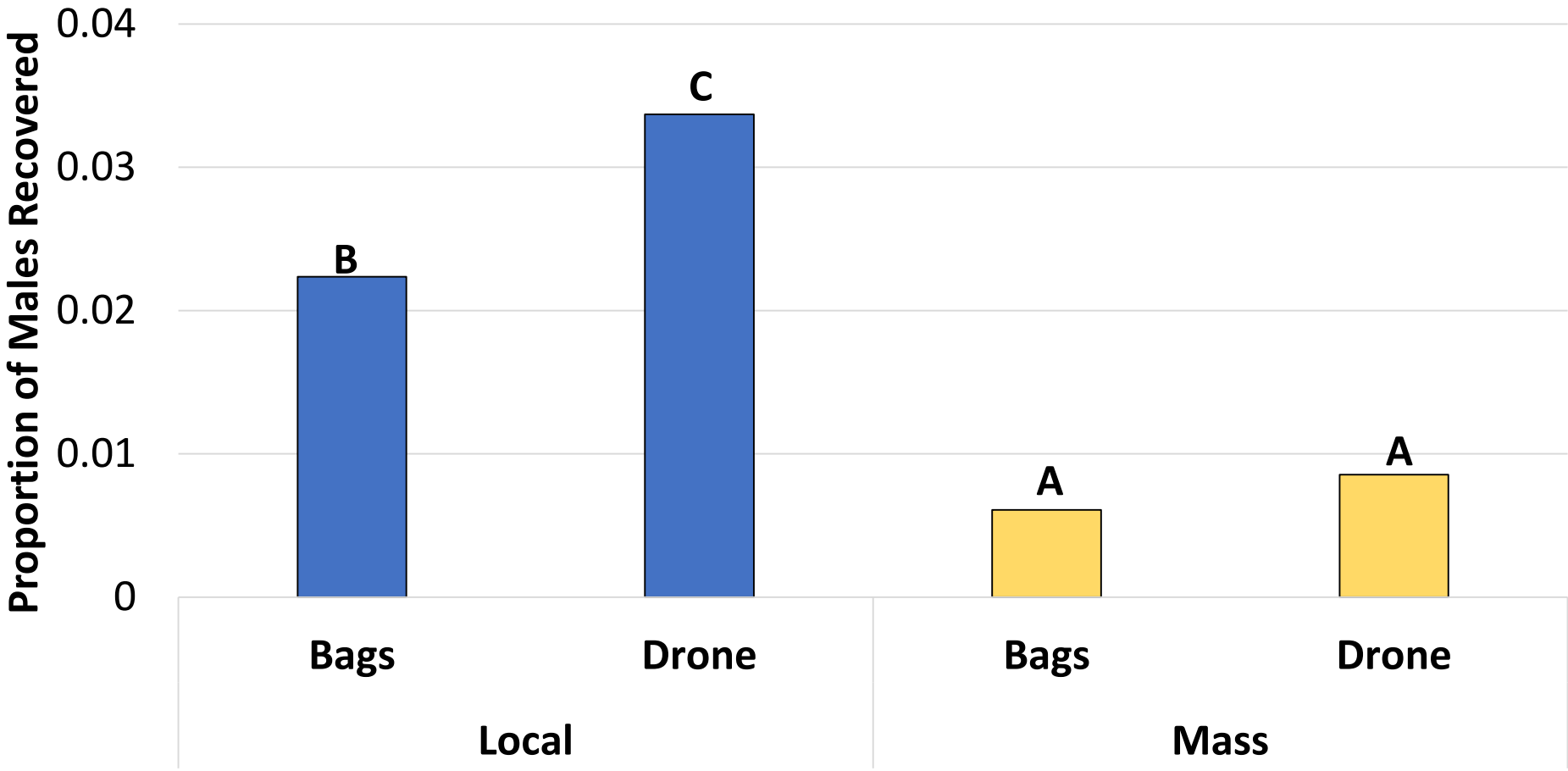


χ^2=9.7, n=19, *P*<0.01

Crop Years 2020-2021

Mass Rearing Negatively Impacts Field Performance

Regardless of Release Device or Transport



χ^2=352.2, n=40, *P*<0.01

Crop Year 2021-2022

Improved Recovery from the Airplane

How do they disperse in large blocks?

Can they impact wild NOW?

Mass-rearing/handling impacts

SO - new "MCS" strain

Where should moths be allocated?

Ecological-economic scenario modeling

Crop Year 2021-2022

Improved Recovery from the Airplane
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Crop Years 2021/2022

Dispersal in Large Block Setting - Pistachios

Weekly Release with Grid of Traps

Crop Years 2021/2022

Dispersal in Large Block Setting - Pistachios

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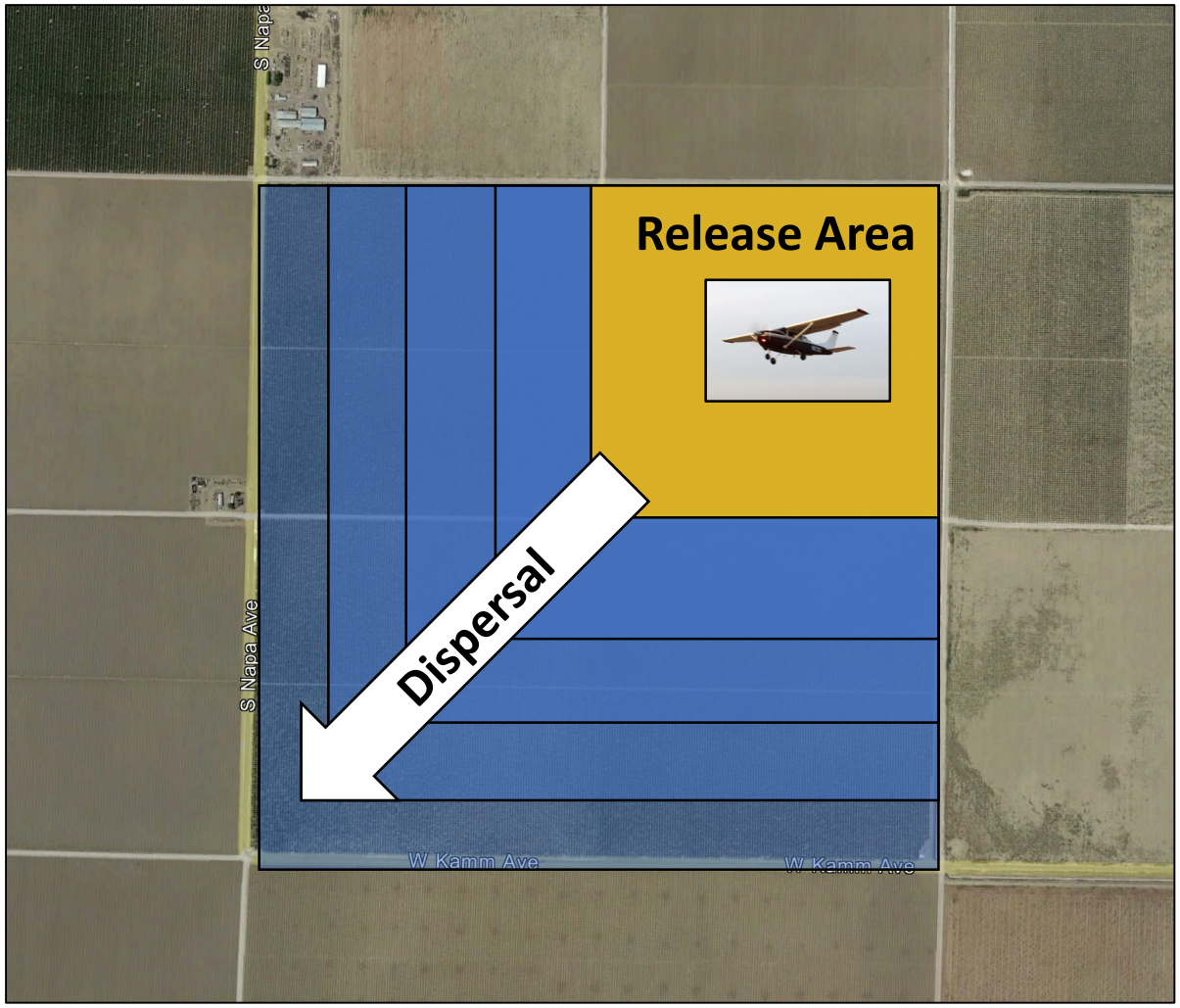
Crop Years 2021/2022

Dispersal in Large Block Setting - Pistachios

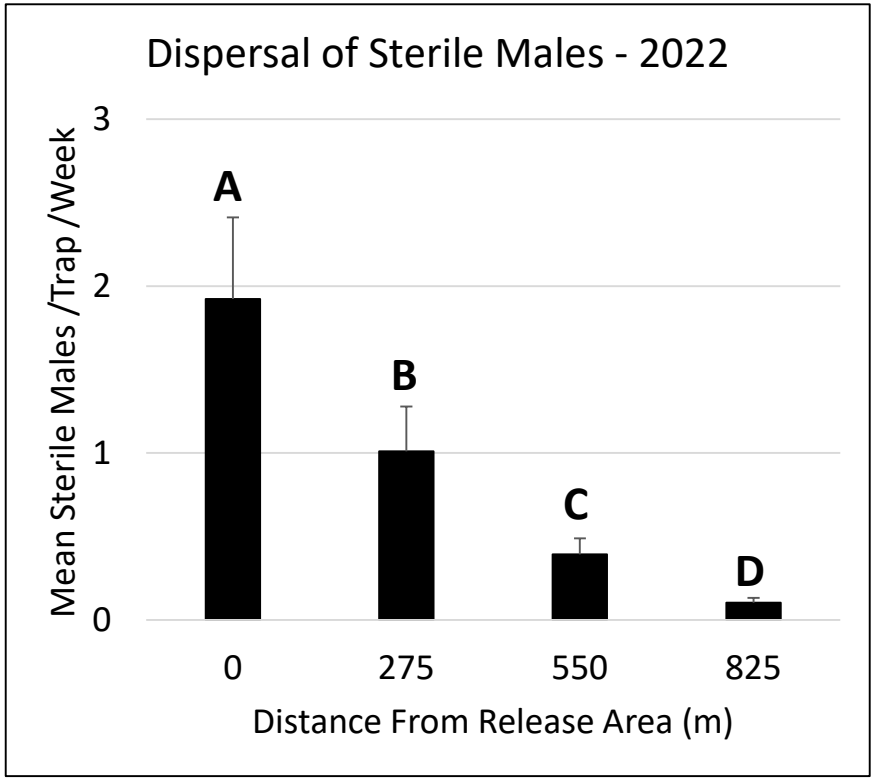
Weekly Release with Grid of Traps

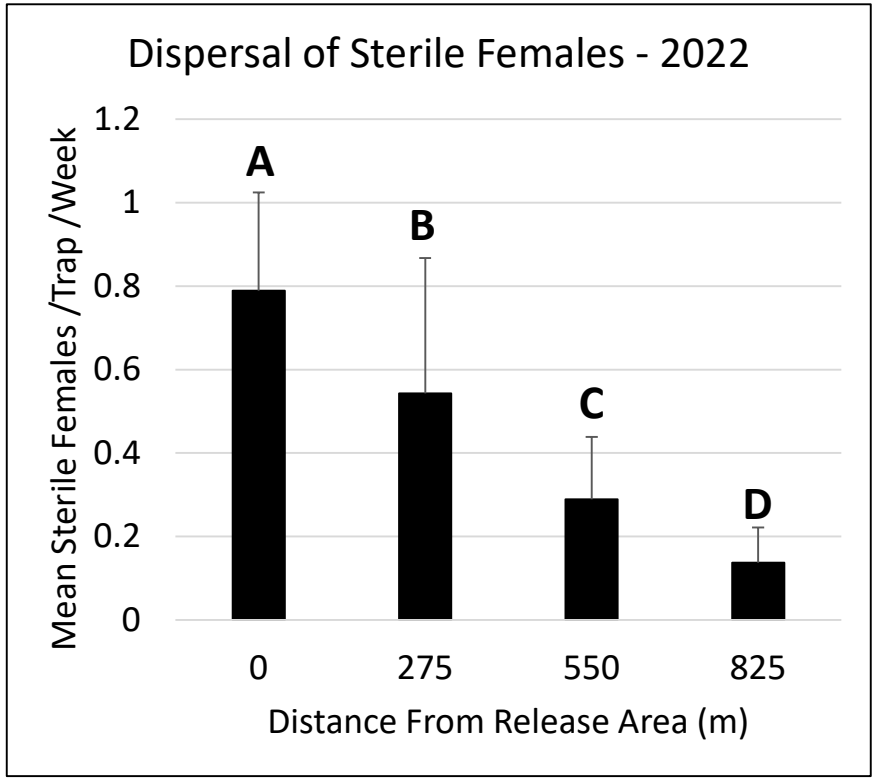


Crop Years 2021/2022

Dispersal in Large Block Setting - Pistachios

Most remain in the release area, 10-20% disperse outward





Crop Years 2021/2022

Impact on Wild Populations – Almonds

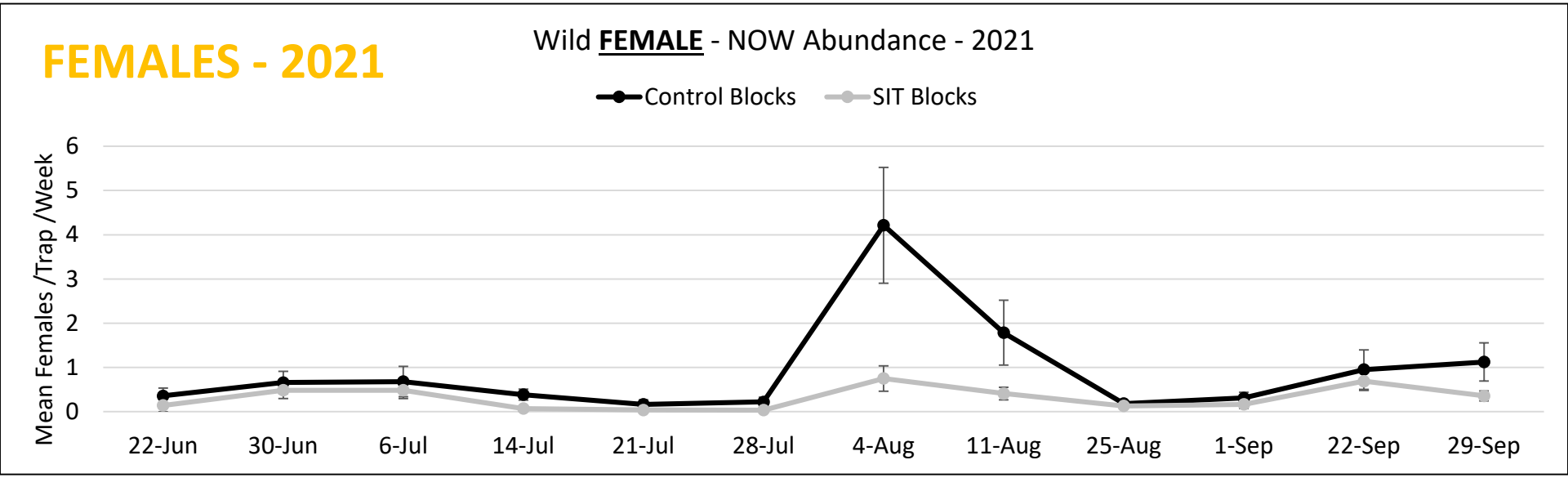
Weekly Release in Paired Plots

Crop Years 2021/2022

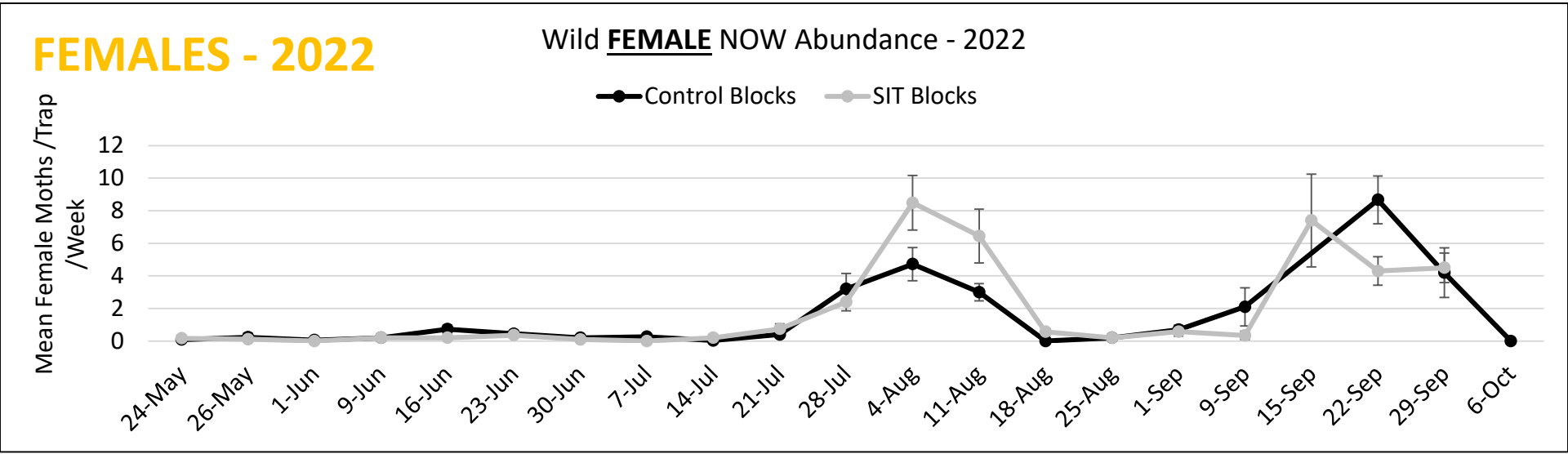
Impact on Wild Populations - Almonds

So Far - Inconsistent Impacts on Wild Populations

FEMALES - 2021



FEMALES - 2022



Crop Year 2021-2022

Improved Recovery from the Airplane

How do they disperse in large blocks?

Can they impact wild NOW?

Mass-rearing/handling impacts

SO - new "MCS" strain

Where should moths be allocated?

Ecological-economic scenario modeling

Crop Year 2022

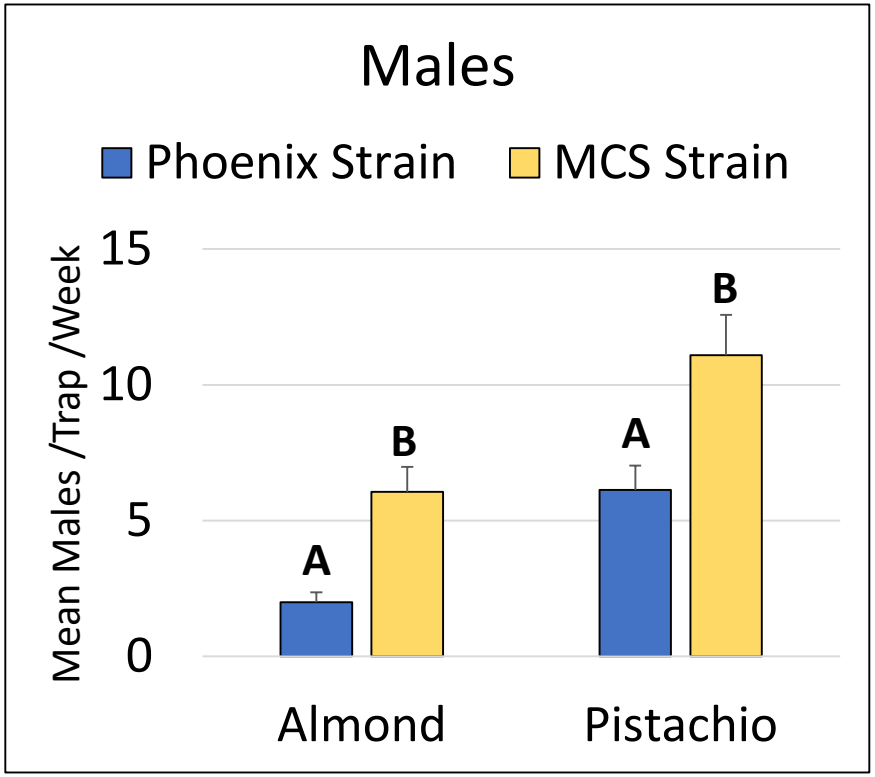
Comparison of Improved Strain for Mass Rearing

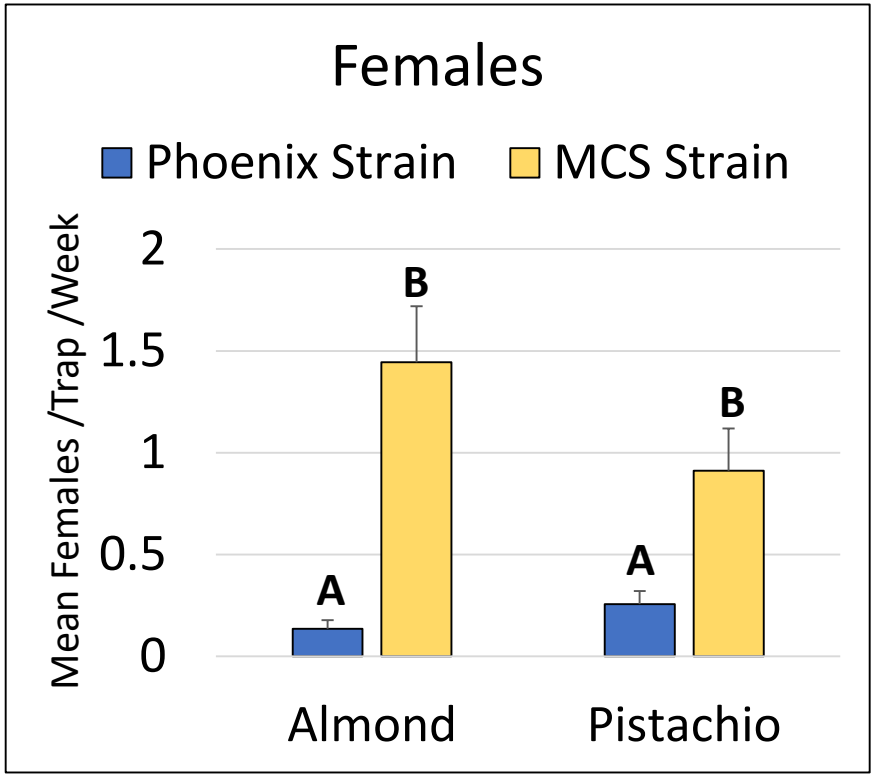
‘MCS’ Strain Selected for Rearing Conditions

Crop Year 2022

Comparison of Improved Strain for Mass Rearing

Small Plot Work - So Far Looks Promising…





Crop Year 2021-2022

Improved Recovery from the Airplane

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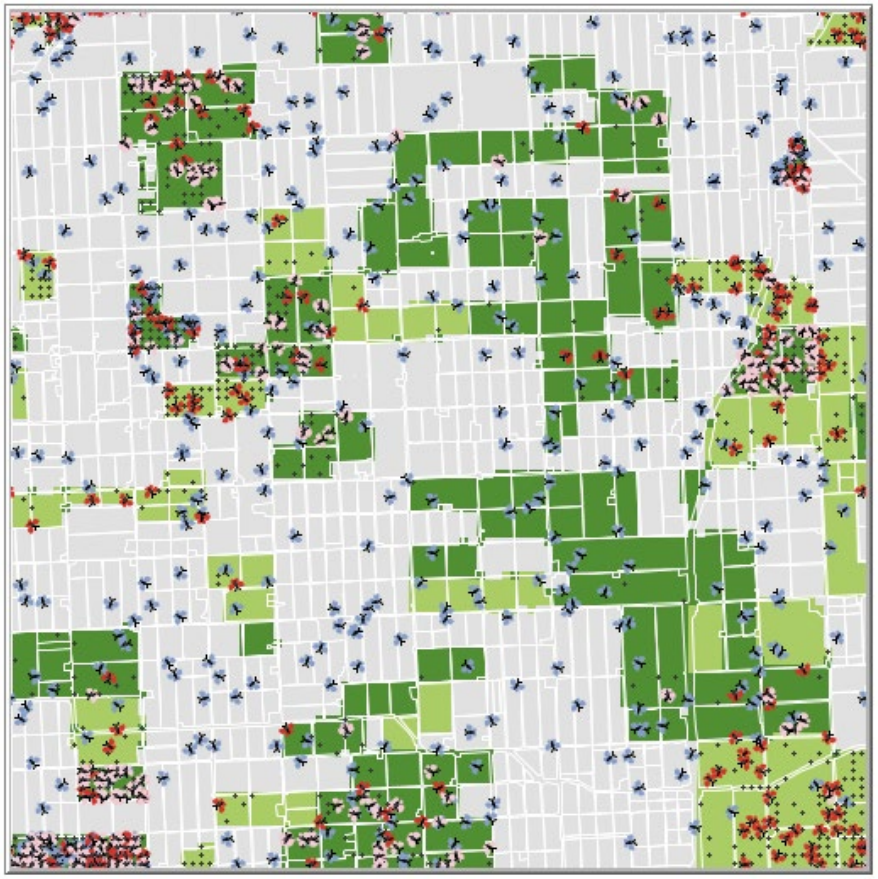
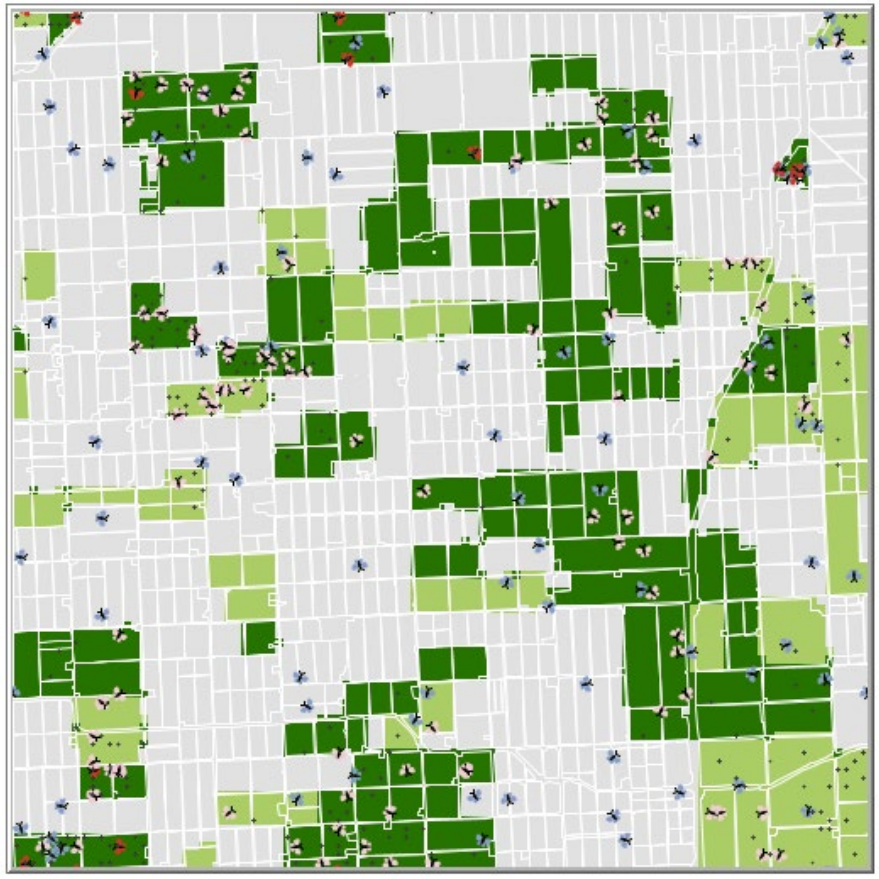
Crop Years 2021/2022

Ecologica/Economic Scenario Modeling

Can we determine if/when/where sterile NOW makes sense?

Models incorporate various features to make them realistic, such as data on the distribution and arrangement of tree nut orchards, pesticide use and tree phenology.





Co-PIs: Dr. Ran Wei (UC Riverside) and Dr. Brittney Goodrich (UC Davis)

Crop Years 2021/2022

Ecologica/Economic Scenario Modeling

General Process

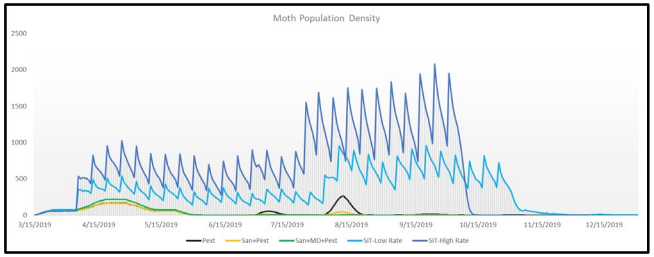
1

Predefined scenarios include different combinations of management practices.

Example Scenarios
1. Pesticides Only
2. Sanitation + Pesticides
3. Sanitation + Mating Disruption (MD) + Pesticides
4. Sanitation + SIT at Low Rate
5. Sanitation + SIT at High Rate

2

Scenarios then generate different population curves for NOW in a given region.



3

Those NOW populations then have differential impacts on crop damage.

% Damage Rate	Almond		Pistachio	
	Nonpareil	Monterey	1st-Harvest	2nd-Harvest
1-Pesticide	0.04	0.04	0.06	0.73
Sanitation + 1-Pesticide	0	0.09	0.01	0.1
Sanitation + MD + 1-Pesticide	0	0	0	0
Sanitation + SIT-Low Rate	1.35	0	1.38	2.42
Sanitation + SIT-High Rate	0	0	0	0

4

Management efforts and crop damage can then be used to estimate economic costs/benefits under each scenario.

IPM	Percent Damage	IPM Cost Per Acre	Revenue Per Acre	Net Benefit Per Acre
Pesticide	0.04	$ 65.46	$ 3,998.50	$ 3,933.04
Sanitation + Pesticide	0	$ 421.00	$ 4,000.10	$ 3,579.10
Sanitation + Pesticide + MD	0	$ 531.00	$ 4,000.10	$ 3,469.10
Sanitation + Low SIT	1.35	$ 355.54	$ 3,902.50	$ 3,546.96
Sanitation + High SIT	0	$ 355.54	$ 4,000.10	$ 3,644.56

Crop Year 2023

Continue evaluation of "MCS" strain

Mating tables and large scale dispersal

Continued focus on large block studies

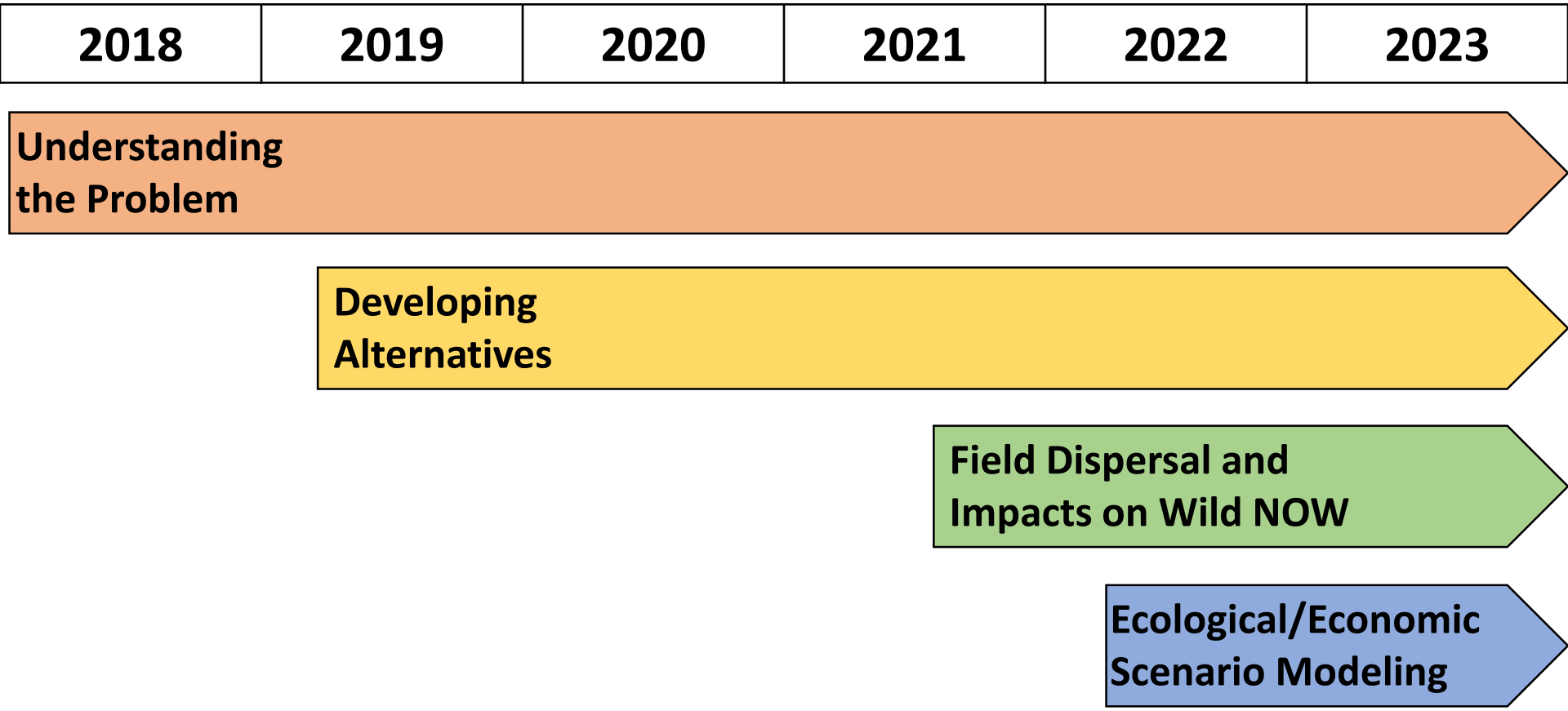
Dispersal and impacts on wild NOW

Where should moths be allocated?

Ecological-economic scenario modeling – Y2

Sterile Insect Technique for NOW Project

Project Summary 2018-2023



Thank You!

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[Postdocs / Grad Students] Dylan Tussey, Jean Liu, Nathalie Baena Bejarano, Kadie Britt, Joshua Reger

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