Navel Orangeworm
Ecology, Monitoring and Management



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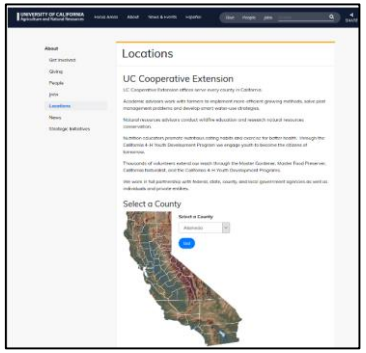
Key Additional Resources

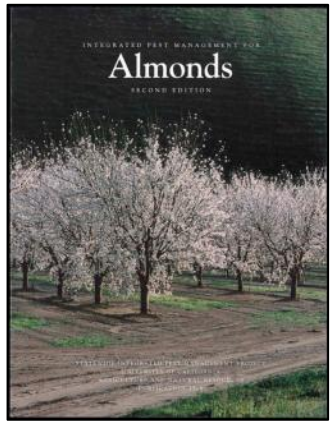


Local Farm/IPM Advisor

- https://ucanr.edu/About/Locations/

UC Statewide IPM Program Website (most current info)

- ALMOND - https://www2.ipm.ucanr.edu/agriculture/almond/Navel-Orangeworm/
- PISTACHIO - https://www2.ipm.ucanr.edu/agriculture/pistachio/Leaffooted-Bugs/
- WALNUT - https://ipm.ucanr.edu/agriculture/walnut/

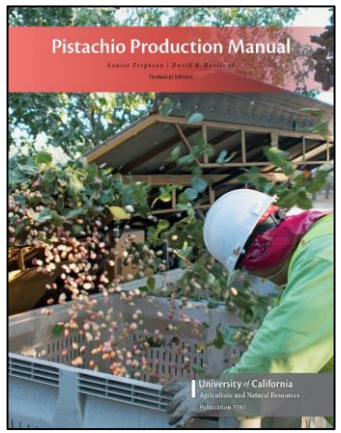


Integrated Pest Management for Almonds (2002)

- UC ANR Publication #3308
- http://ipm.ucanr.edu/IPMPROJECT/ADS/manual_almonds.html

Pistachio Production Manual (2016)

- UC ANR Publication #3545
- https://anrcatalog.ucanr.edu/Details.aspx?itemNo=3545



Integrated Pest Management for Walnuts (2003)

- UC ANR Publication #3270
- https://ucdavisstores.com/merchdetail?MerchID=747104

Navel Orangeworm

Origins, Arrival in CA, Current Pest Status

Navel Orangeworm

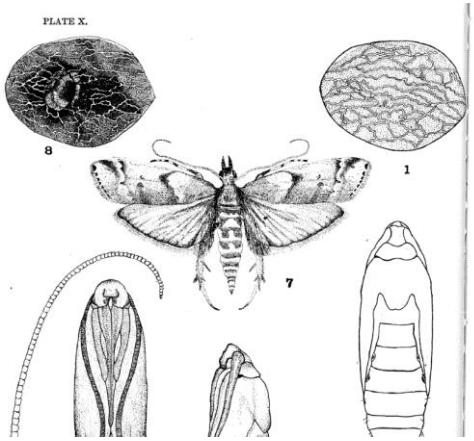
Origins + Arrival in CA

Species Name

Order: Lepidoptera

Family: Pyralidae

Species: *Amyelois transitella*



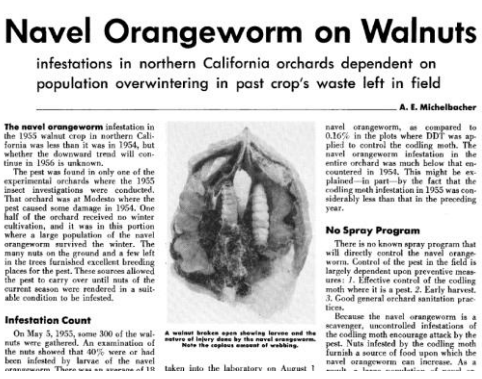
Arrival in California

1800s – Reported in Mexico, Caribbean, Central America, South America

1900s – Reported on citrus in AZ ("navel orange worm")

1940s – Reported on walnuts and almonds in CA

1970s – Reported on pistachio in CA



Navel Orangeworm on Walnuts

infestations in northern California orchards dependent on population overwintering in past crop's waste left in field

A. E. Michelbacher

The navel orangeworm infestation in the 1955 walnut crop in northern California was less than it was in 1954, but whether the downward trend will continue in 1956 is unknown.

The pest was found in only one of the experimental orchards where the 1955 insect investigations were conducted. That orchard was at Modesto where the pest caused some damage in 1954. One half of the orchard received no winter cultivation, and it was in this portion where a large population of the navel orangeworm survived the winter. The many nuts on the ground and a few left in the trees furnished excellent breeding places for the pest. These sources allowed the pest to carry over until nuts of the current season were rendered in a suitable condition to be infested.

Infestation Count

On May 5, 1955, some 300 of the walnuts were gathered. An examination of the nuts showed that 80% were or had been infested by larvae of the navel

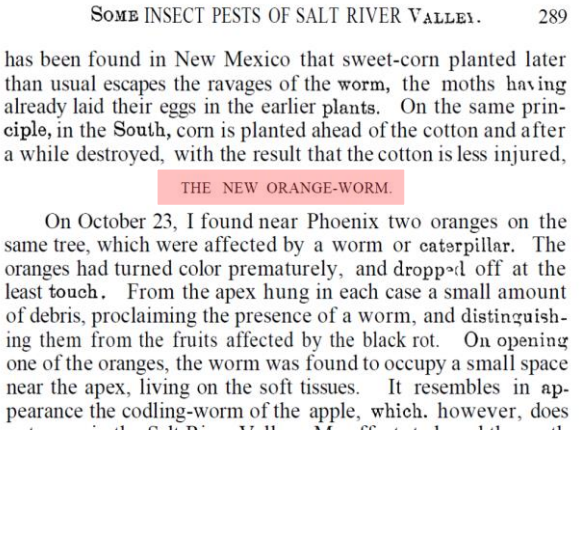
A walnut broken open showing larvae and the nature of injury done by the navel orangeworm. Note the copious amount of webbing.

navel orangeworm, as compared to 0.16% in the plots where DDT was applied to control the codling moth. The navel orangeworm infestation in the entire orchard was much below that encountered in 1954. This might be explained—in part—by the fact that the codling moth infestation in 1955 was considerably less than that in the preceding year.

No Spray Program

There is no known spray program that will directly control the navel orangeworm. Control of the pest in the field is largely dependent upon preventive measures: *1.* Effective control of the codling moth where it is a pest. *2.* Early harvest. *3.* Good general orchard sanitation practices.

Because the navel orangeworm is a scavenger, uncontrolled infestations of the codling moth encourage attack by the pest. Nuts infested by the codling moth furnish a source of food upon which the navel orangeworm can increase. As a



SOME INSECT PESTS OF SALT RIVER VALLEY. 289

has been found in New Mexico that sweet-corn planted later than usual escapes the ravages of the worm, the moths having already laid their eggs in the earlier plants. On the same principle, in the South, corn is planted ahead of the cotton and after a while destroyed, with the result that the cotton is less injured,

THE NEW ORANGE-WORM.

On October 23, I found near Phoenix two oranges on the same tree, which were affected by a worm or caterpillar. The oranges had turned color prematurely, and dropped off at the least touch. From the apex hung in each case a small amount of debris, proclaiming the presence of a worm, and distinguishing them from the fruits affected by the black rot. On opening one of the oranges, the worm was found to occupy a small space near the apex, living on the soft tissues. It resembles in appearance the codling-worm of the apple, which, however, does

Navel Orangeworm

Current Pest Status

Extremely Low Tolerance for Damage (<2%)

High Crop Value

- **Yield/quality x price – of course…**
- **Infestation leads to increased processing time/costs**
- **Carryover of infested remnant/mummy nuts to following year**

Navel Orangeworm

Current Pest Status

Extremely Low Tolerance for Damage (<2%)

Aflatoxin

- **Known human carcinogen, regulated in domestic/foreign markets**
- ***Aspergillus flavus* fungi produce aflatoxin**
- **NOW adults move *Aspergillus* around**
- **Larval feeding create opportunities for fungal growth on nuts**

Spread of *Aspergillus flavus* by Navel Orangeworm (*Amyelois transitella*) on Almond

Jeffrey D. Palumbo, Noreen E. Mahoney, and **Douglas M. Light,** Plant Mycotoxin Research Unit, Western Regional Research Center, United States Department of Agriculture–Agricultural Research Service (USDA-ARS) Albany, CA 94710; **Joel Siegel,** USDA-ARS, San Joaquin Valley Agricultural Sciences Center, Parlier CA 93648-9757; and **Ryan D. Puckett** and **Themis J. Michailides,** University of California–Davis, Kearney Agricultural Research and Extension Center, Parlier 93648

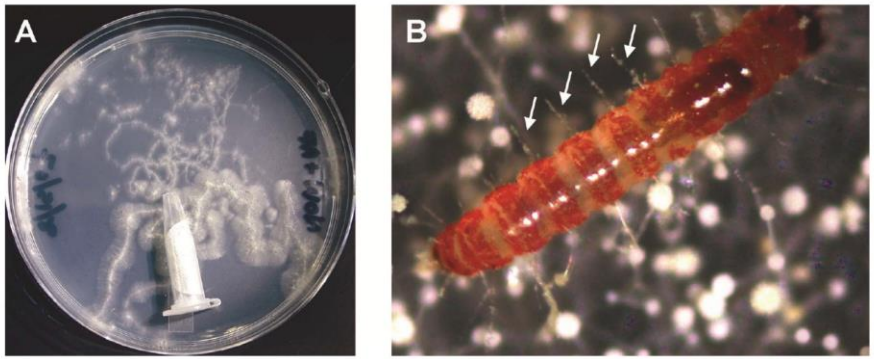


Fig. 1. A, Trails of *Aspergillus flavus* colonies, resulting from navel orangeworm (NOW) transport of conidia from microcentrifuge tube to potato dextrose agar medium. **B,** Accumulation of *A. flavus* conidia on setae (arrows) of NOW larva after crawling across plates containing sporulating *A. flavus* colonies.

Navel Orangeworm

Biology, Behavior and Ecology

Basic Biological Parameters

Life Stages

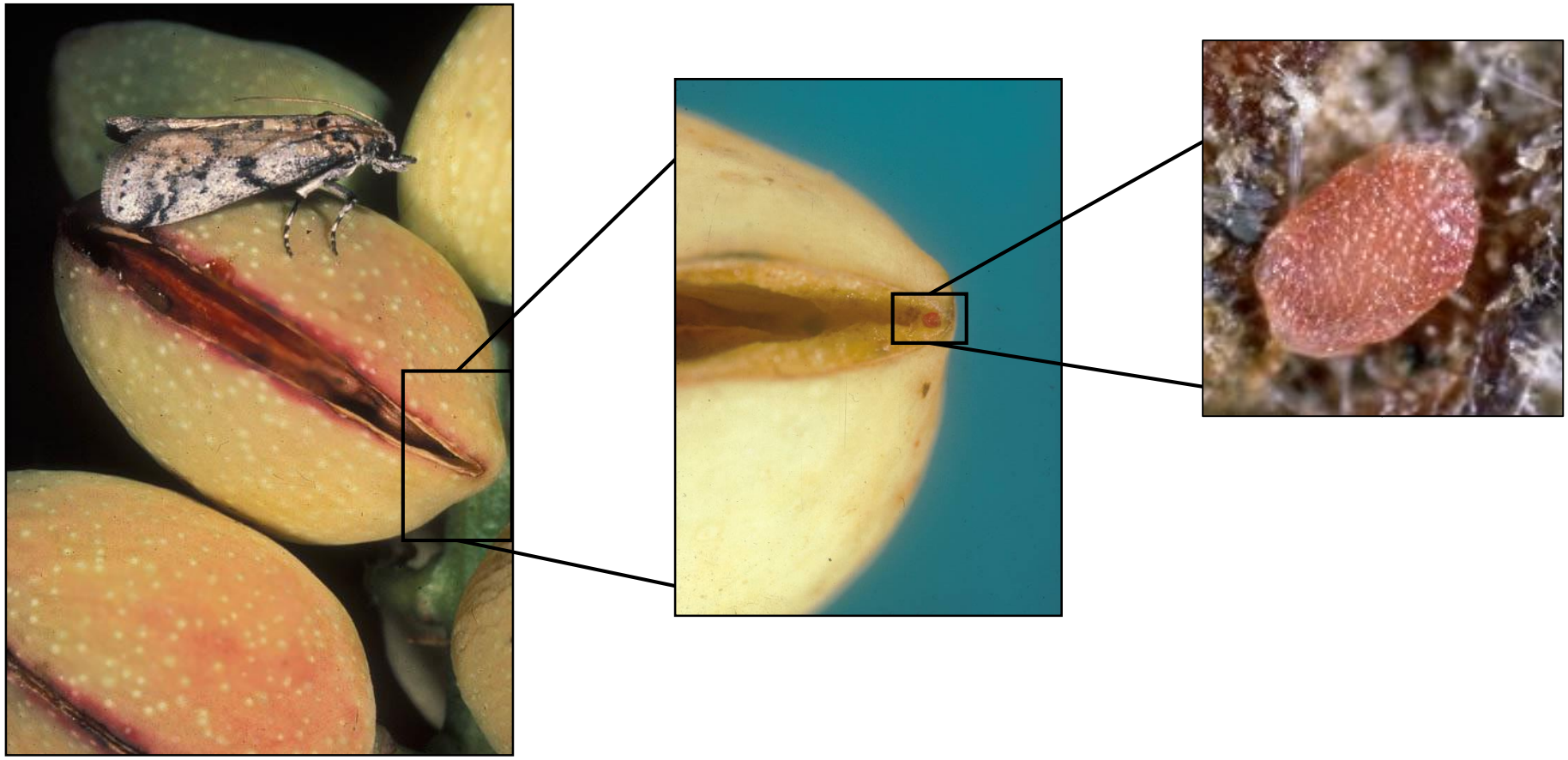
Egg → Larva → Pupa → Adult




Basic Biological Parameters

Eggs Deposited Directly onto the Nuts

Pistachio for scale, note proximity to suture



Basic Biological Parameters

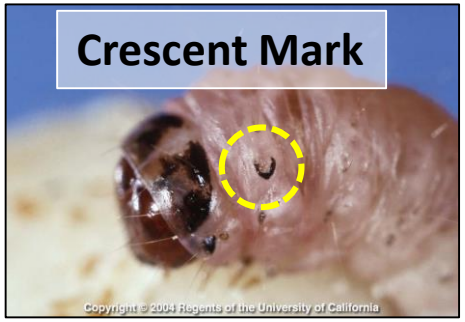
Life Stages

Eggs

- Deposited directly onto nuts

Larvae

- Crescent-shaped mark
- Pass through 5-6 stages (instars)
- Frass and webbing as they feed



Pupae

- Spins a silk coccoon

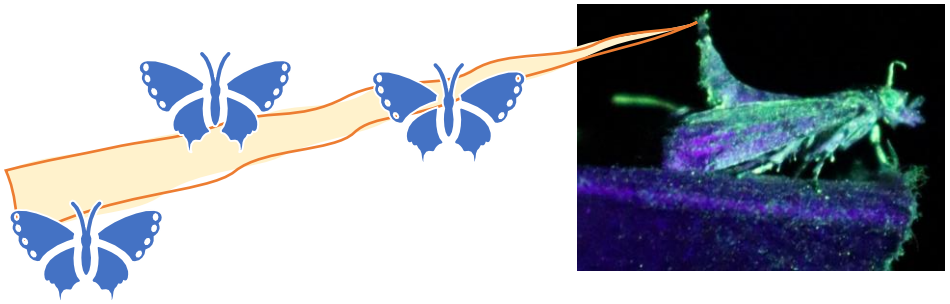
Adults

- Has a pronounced “snout”

Mating and Reproduction

Summary, Timing and Role of Pheromones

- NOW is active at night (nocturnal)
- Adults emerge (eclose) from pupae at dusk
- Females emit pheromone that males use to locate them
- Mate during the last few hours of the night / early morning
- Mated females will start to deposit eggs the following night



Female NOW with abdomen in the air ~3am emitting pheromone ('calling')

NOW mating ('in copula')

Seasonal Phenology

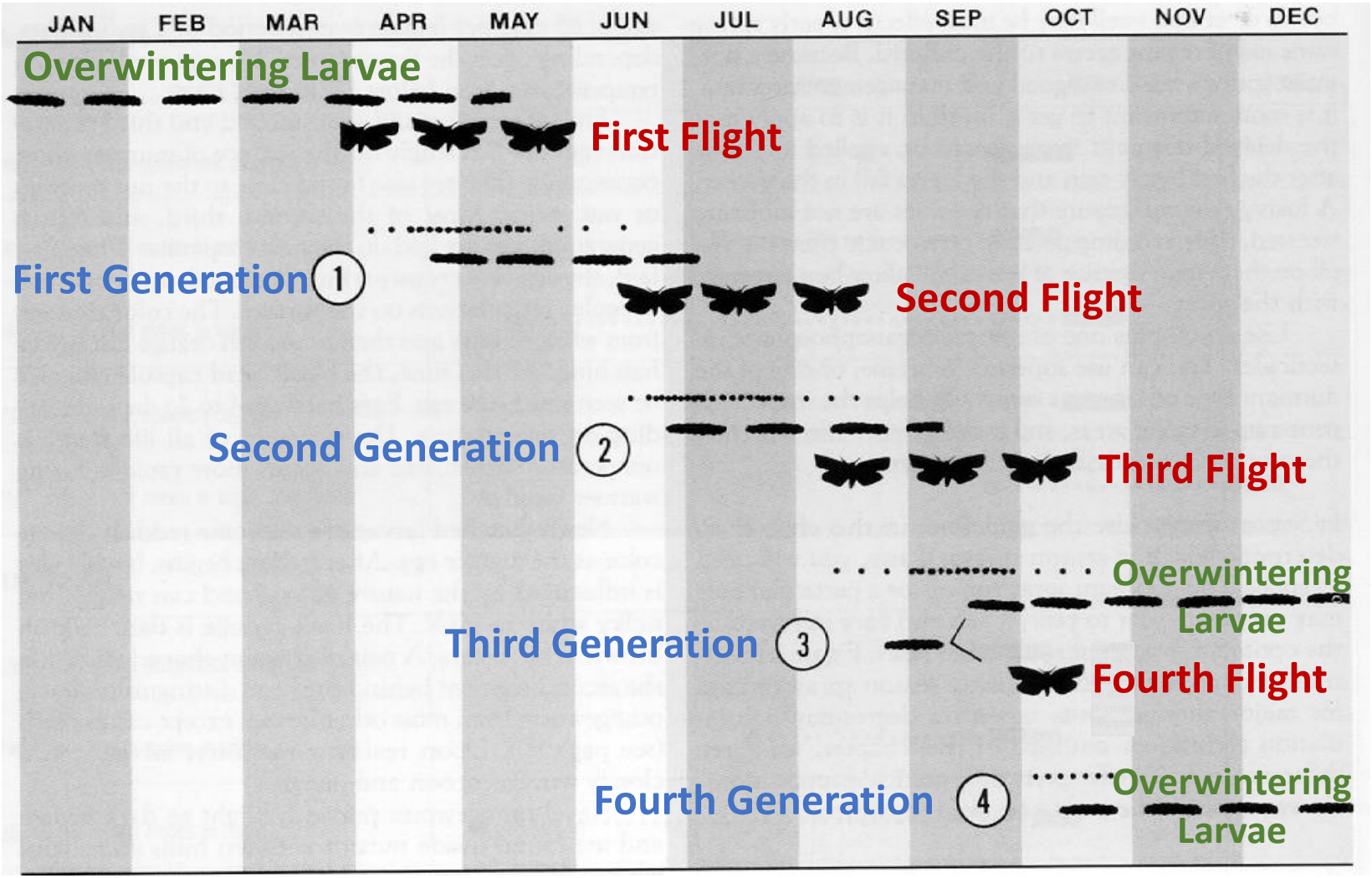
- **Overview**
  - Overwinter as larvae/pupae in remnant “mummy” nuts
  - Adults emerge in the spring
  - 3-4 generations per year, depending on weather and host quality
- **Populations develop more rapidly as the season progresses**
  - Warmer weather
  - Develop more rapidly on new crop vs. mummy nuts
  - Increased host availability (hull split / hull slip)

Mummy vs. New Crop Nuts

Increasing host availability as hull integrity declines

Seasonal Phenology

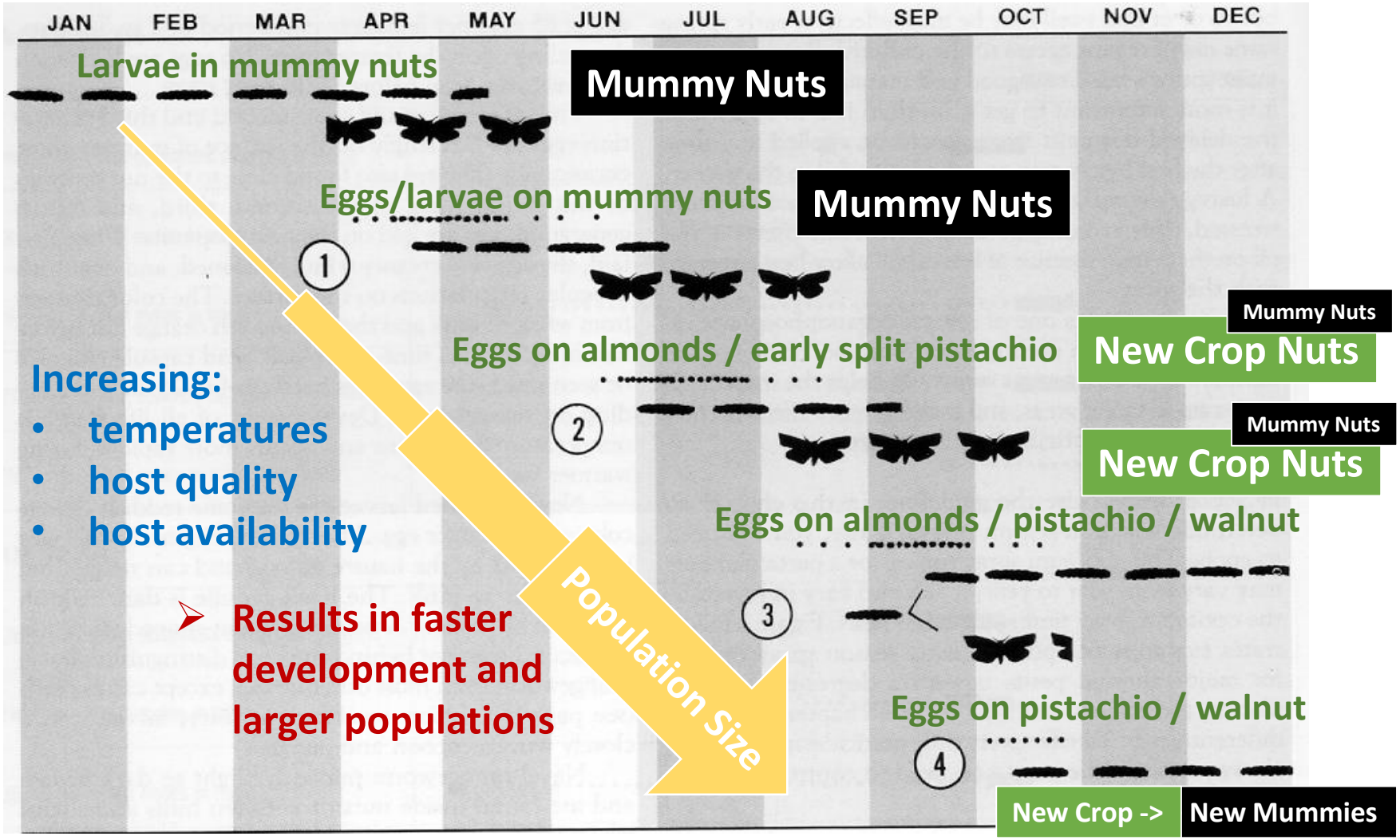
Overview



IPM for Almonds, UC ANR Publication #3308

Seasonal Phenology

Increasing Populations Over Time



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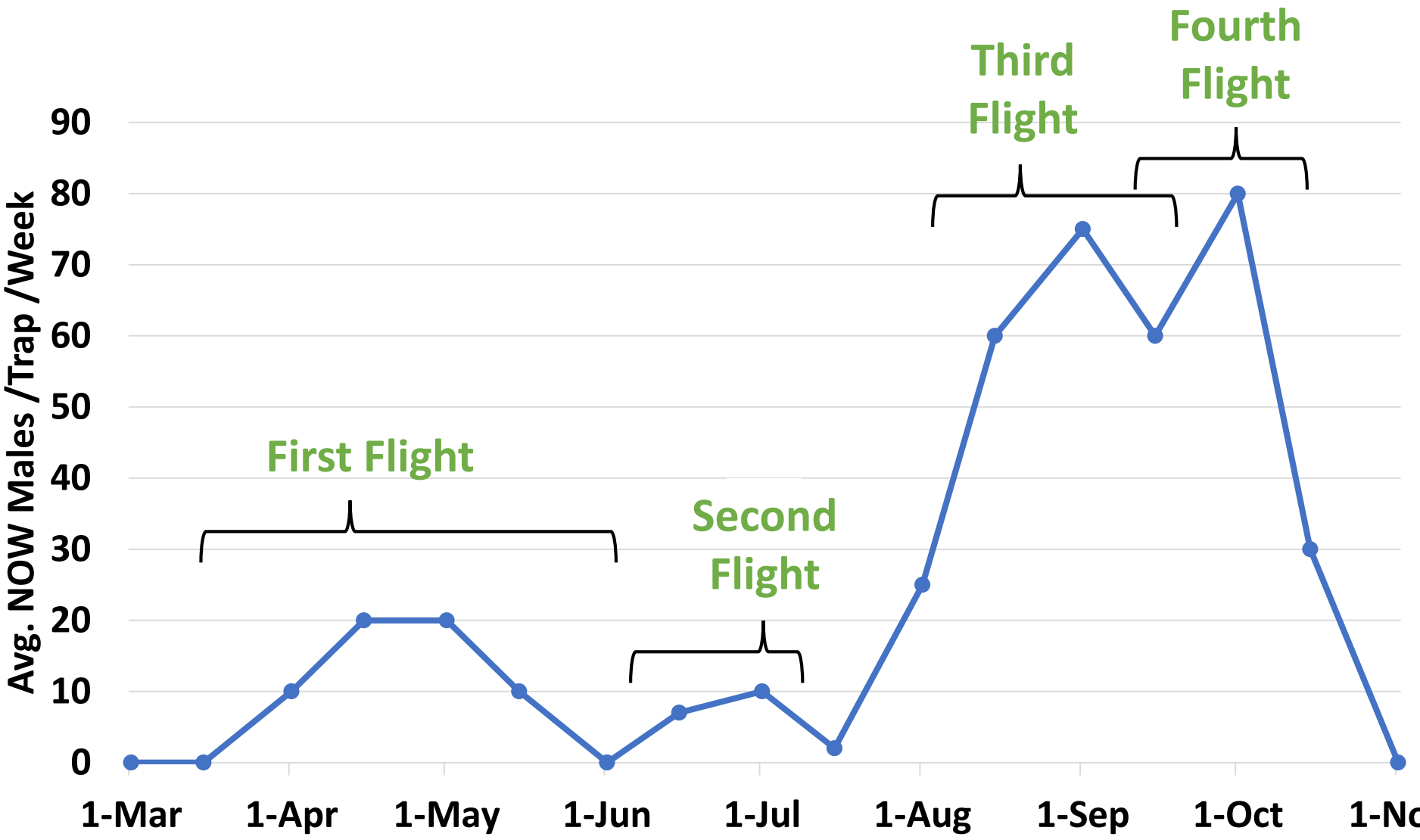

Seasonal Phenology

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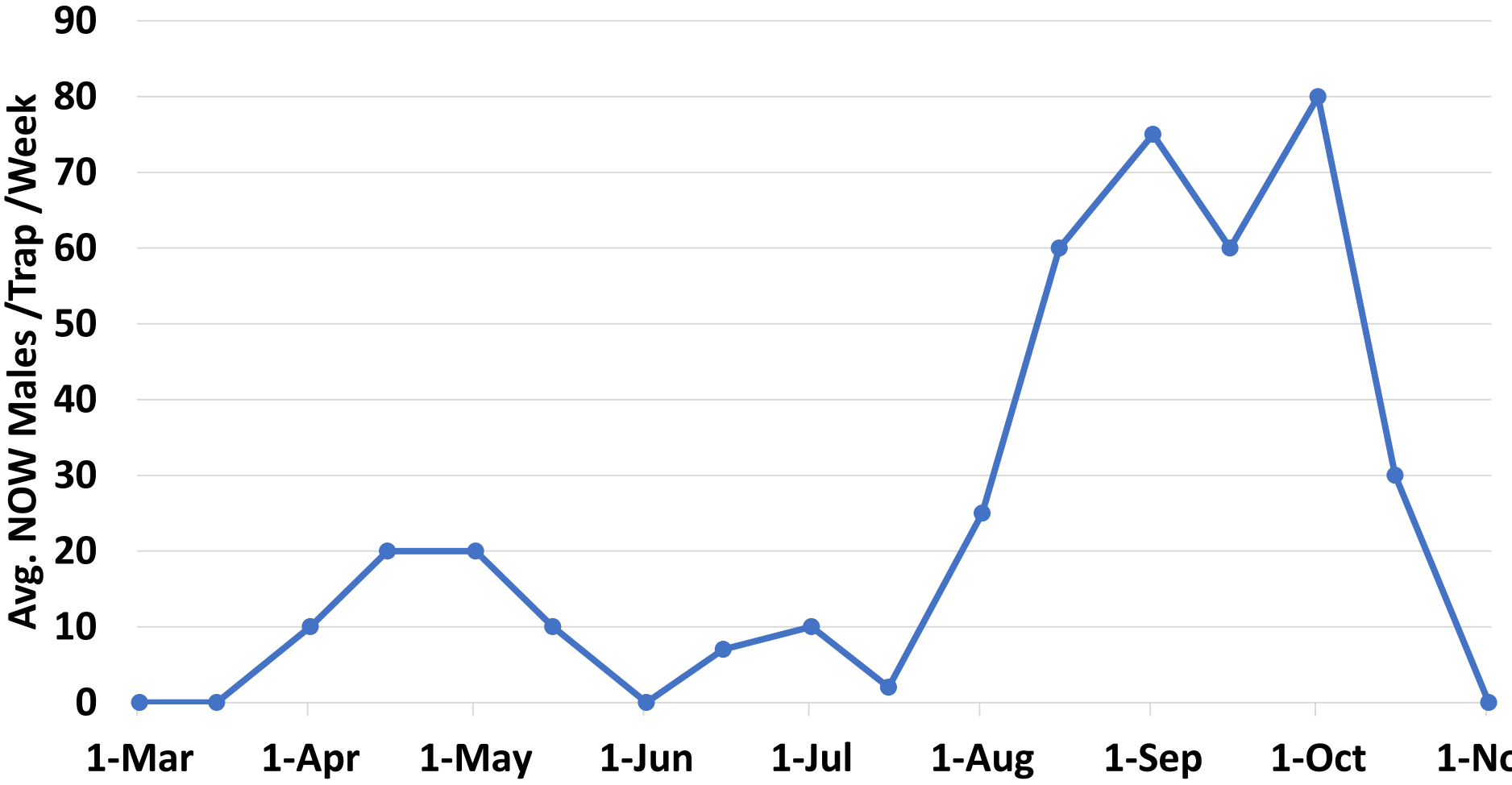
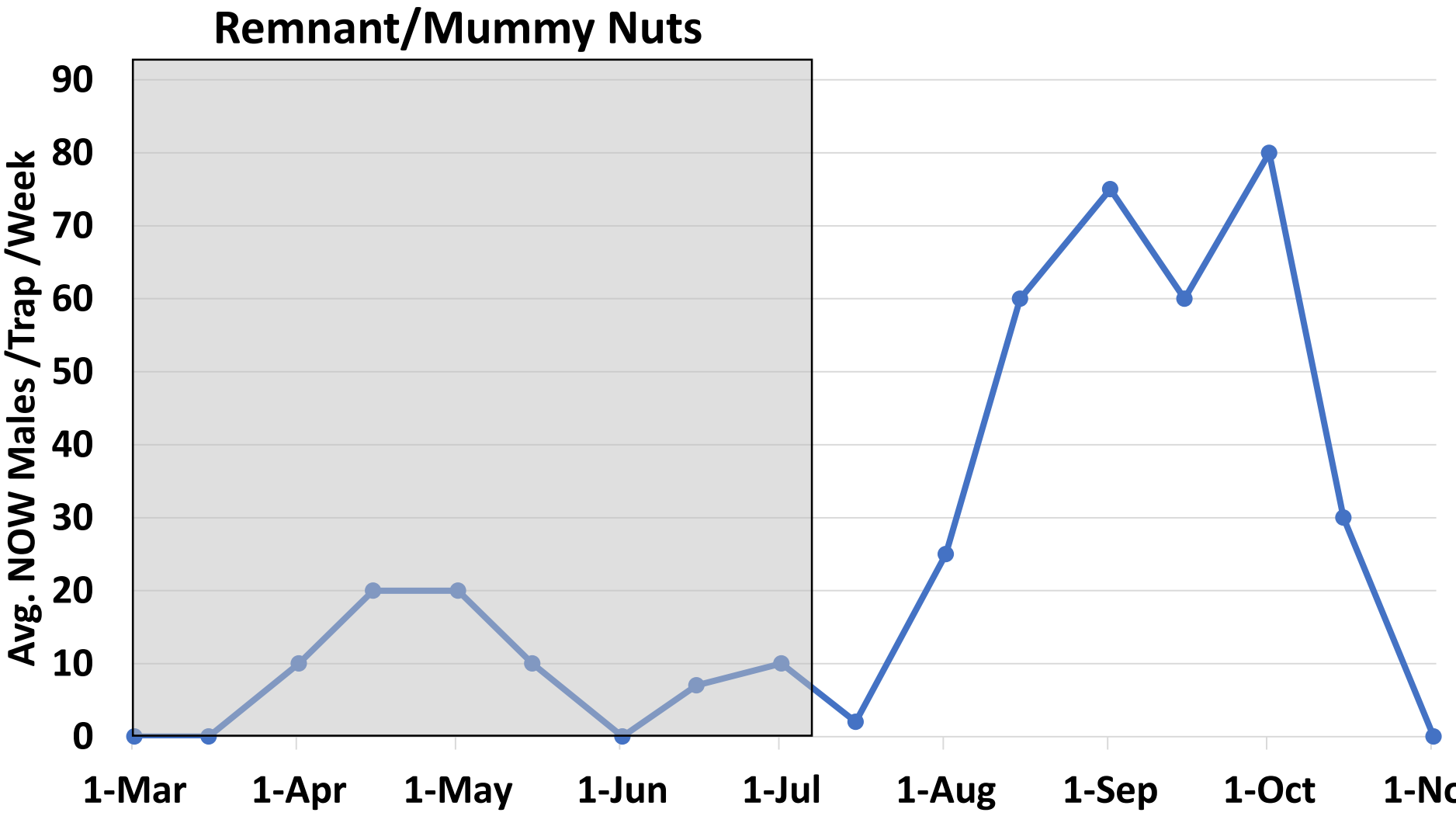


Seasonal Phenology

Increasing Populations Over Time



Seasonal Phenology

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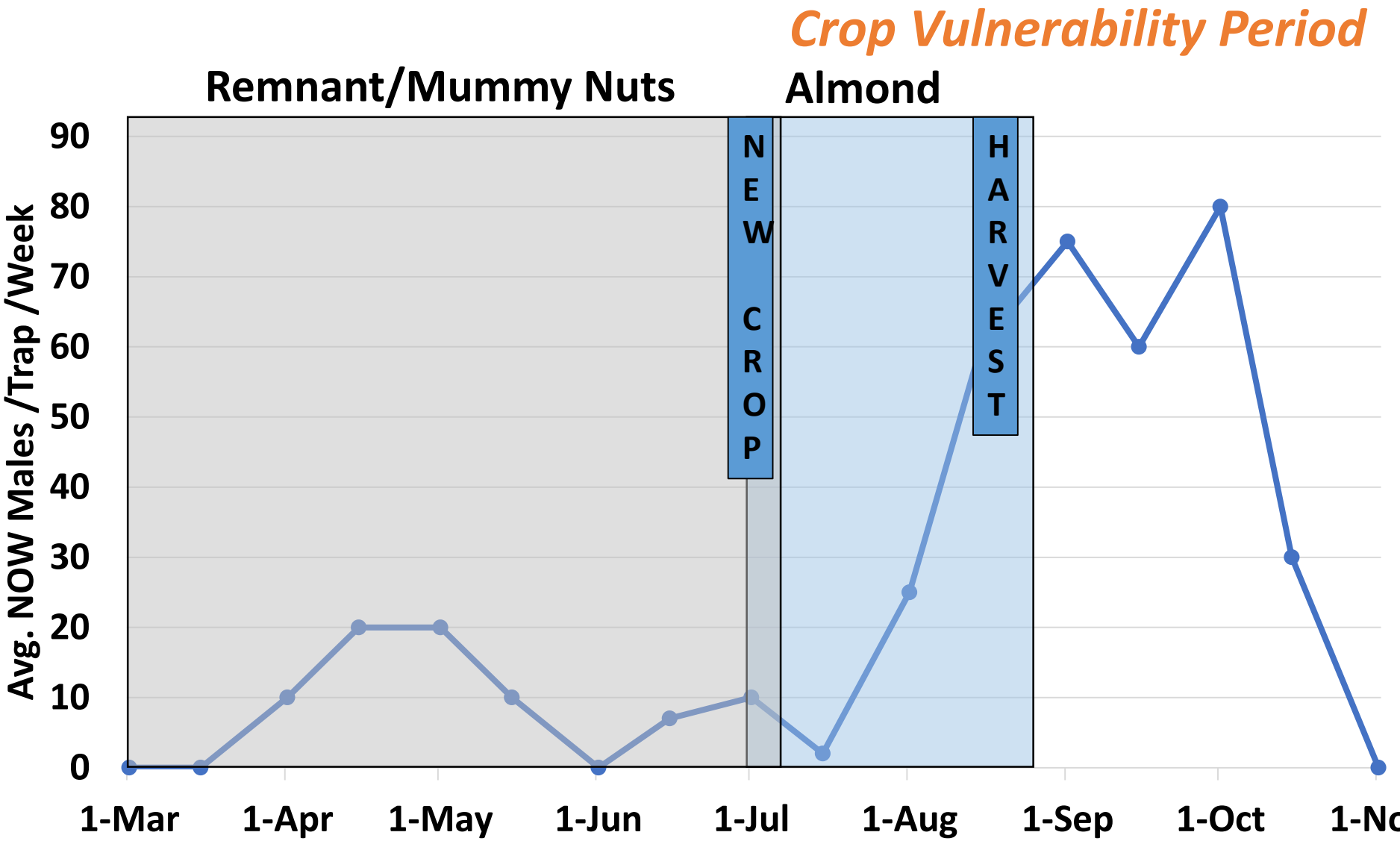
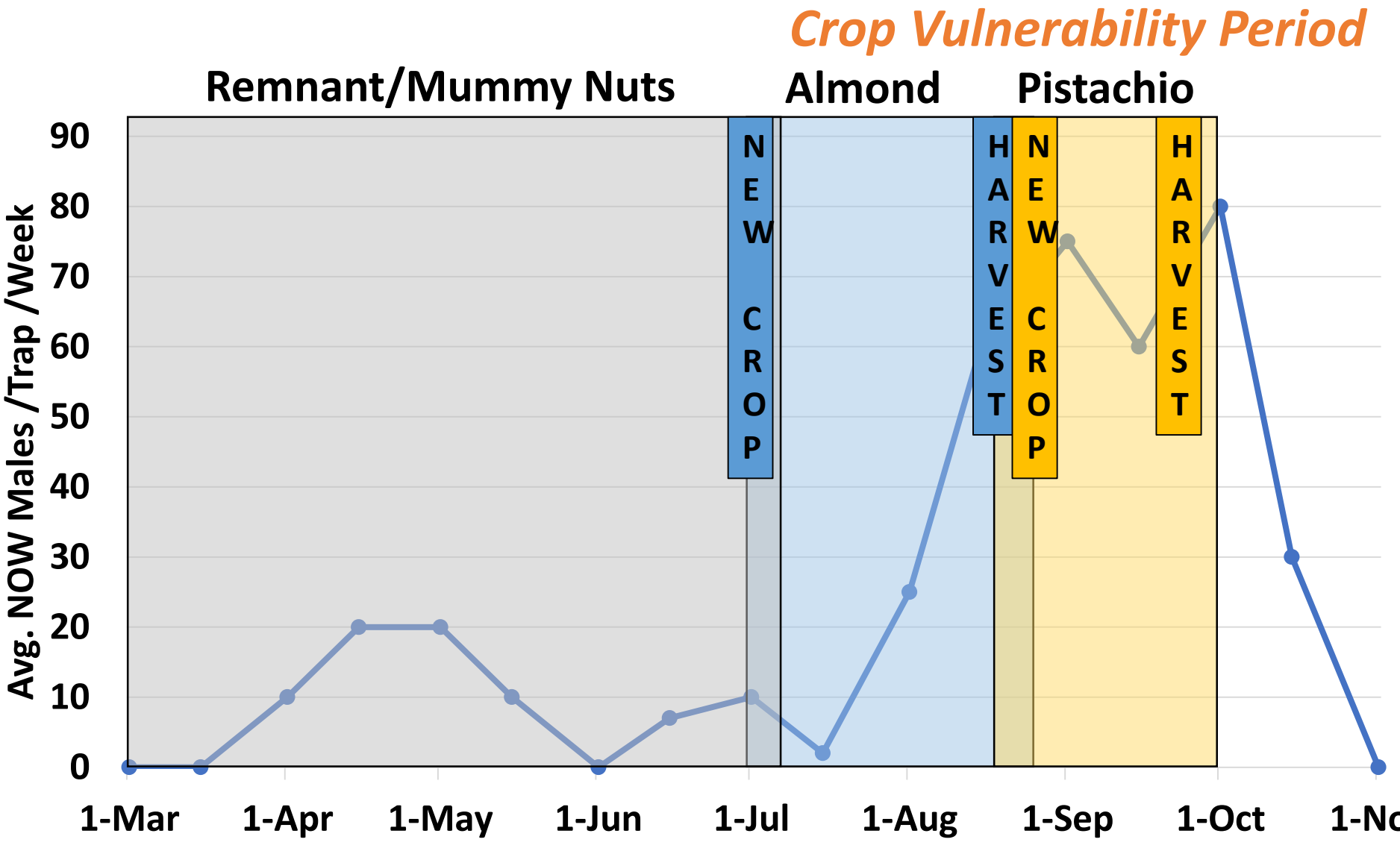


Seasonal Phenology

Increasing Populations Over Time



Seasonal Phenology

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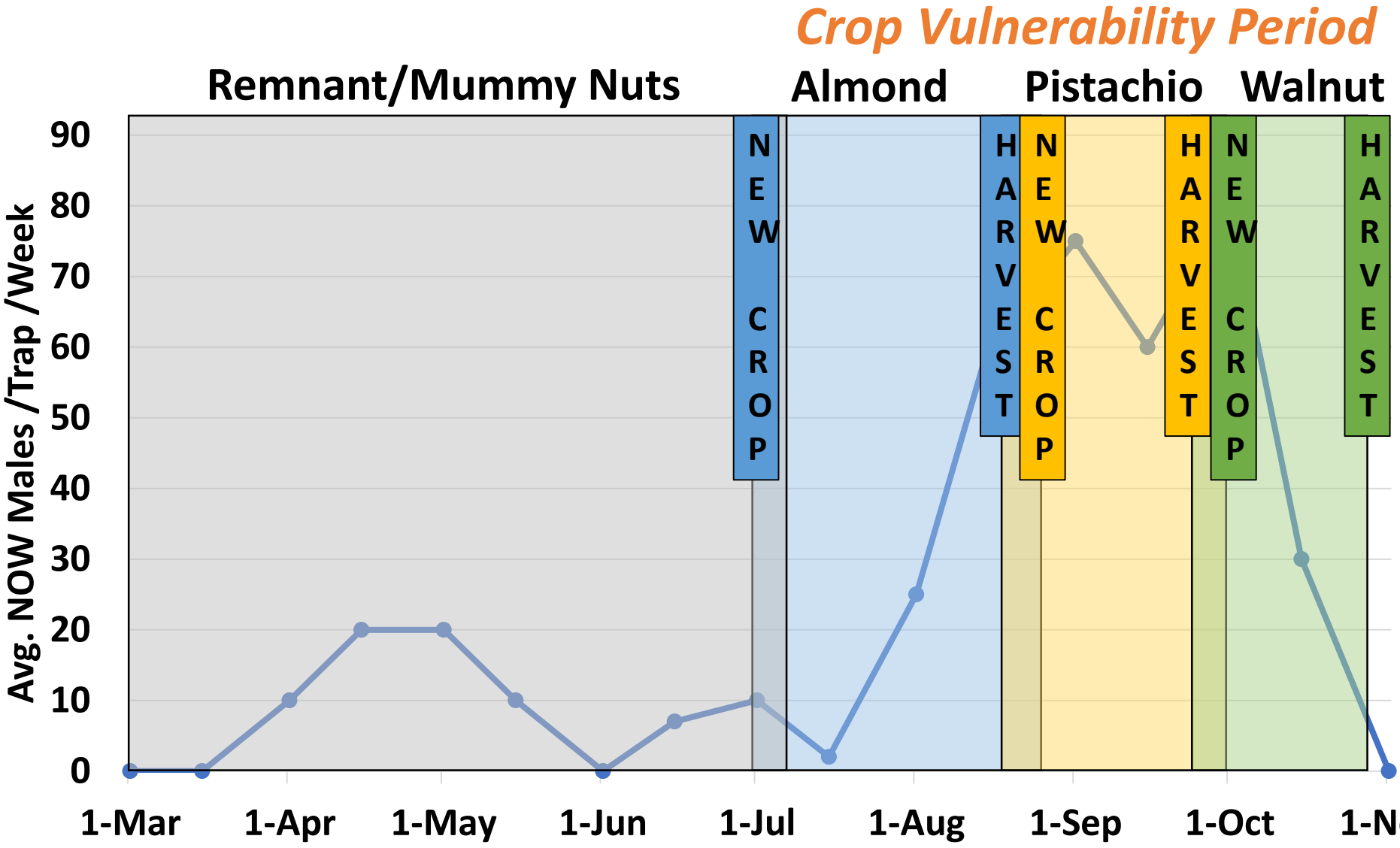
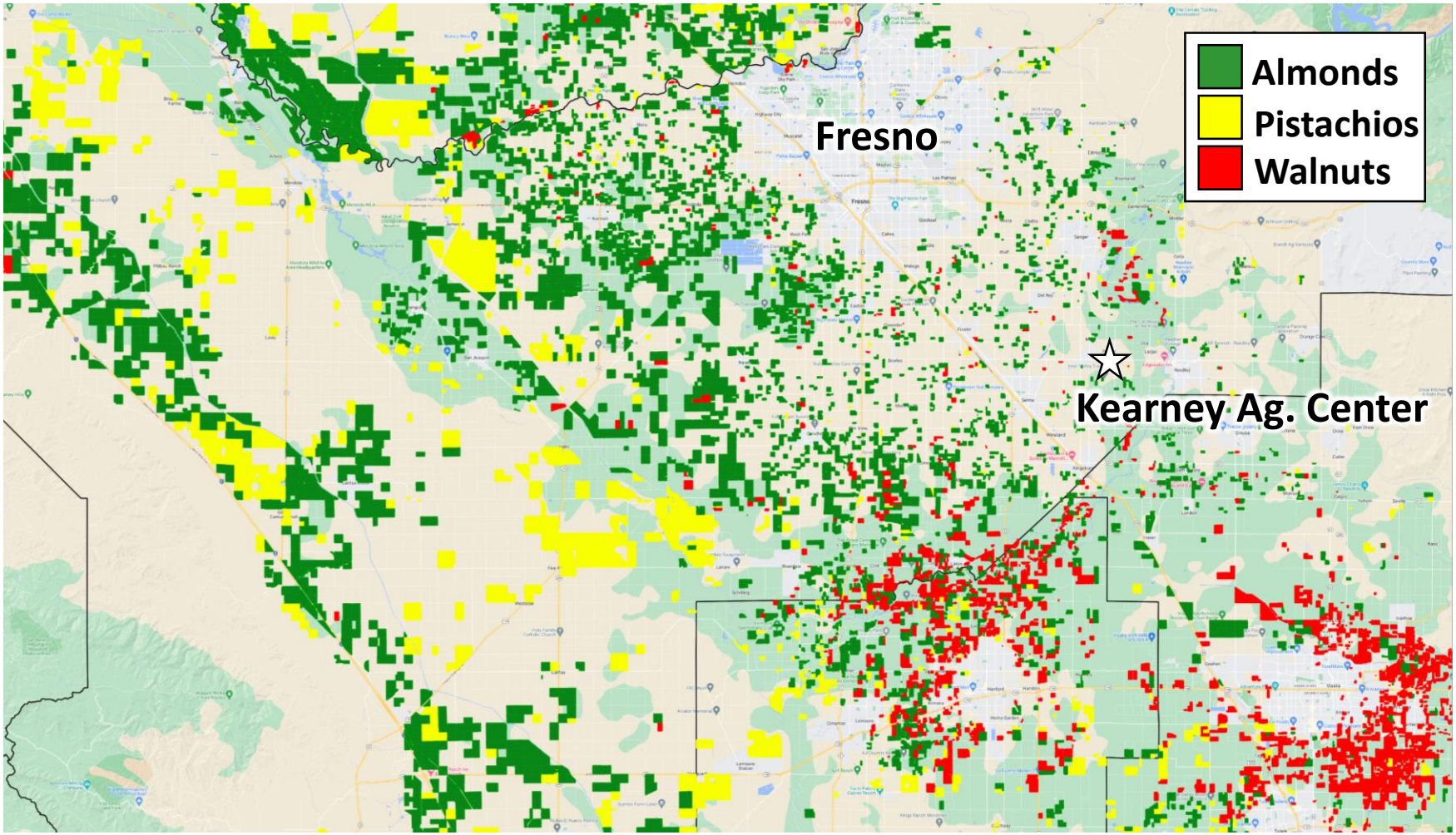


Seasonal Phenology

Crop Composition x Phenology x NOW

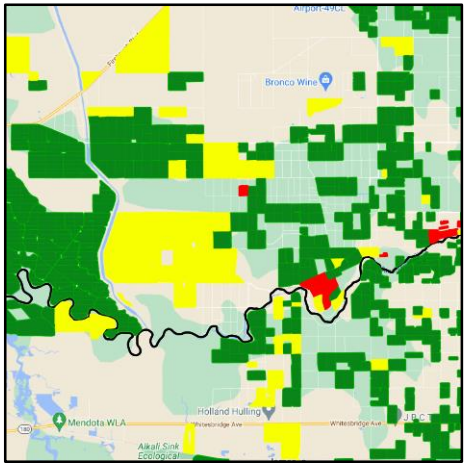
Acreage vs. Availability

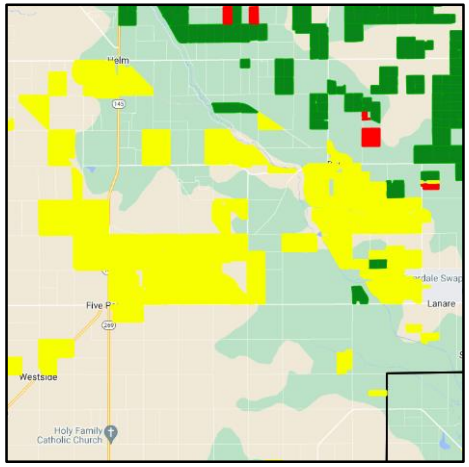


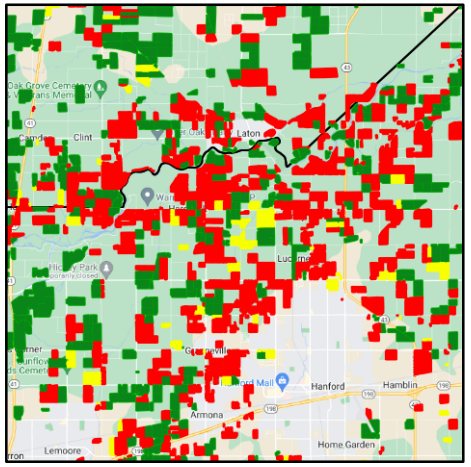
Seasonal Phenology

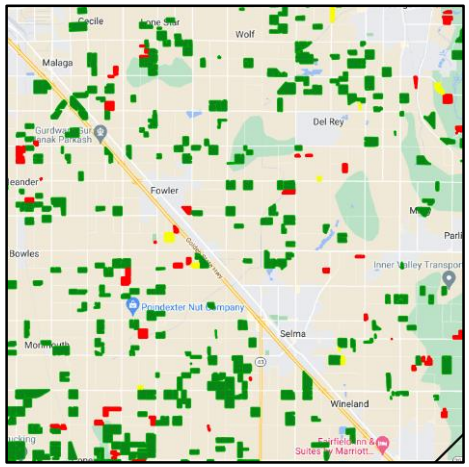
Crop Composition x Phenology x NOW

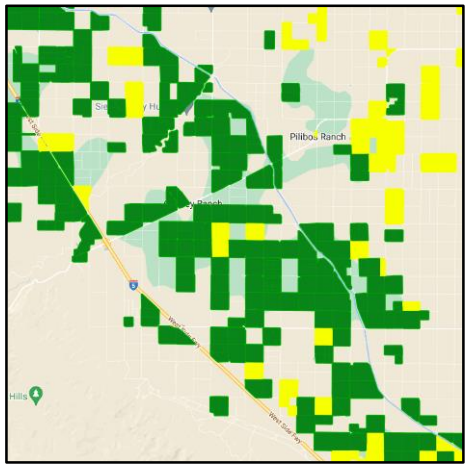
How does landscape composition influence this?











Pop Quiz Question #1

What are the primary hosts of navel orangeworm?

(a) almonds, pistachios and walnuts
(b) stone fruit
(c) figs and pomegranates
(d) tomatoes and melons

Navel Orangeworm
Integrated Pest Management

Modern NOW Management in Pistachio

Integrated Pest Management

Key Tools

1. **Sanitation** – Destroy mummy nuts
2. **Biological Control** – Natural enemies predate/parasitize
3. **Mating Disruption** – Reduce mating/reproduction
4. **Monitoring** – Egg traps, flight traps, biofix, degree days
5. **Spray Timing** – Maximize impacts
6. **Early/Timely Harvest** – Logistics

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The Key to Success is Using Multiple Points of Attack!

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Winter Sanitation / Crop Sanitation

Key Points

- **NOW overwinter as larvae in remnant "mummy" nuts**
  - **Base population for the coming year**
  - **Reproductive substrate for first flight moths**

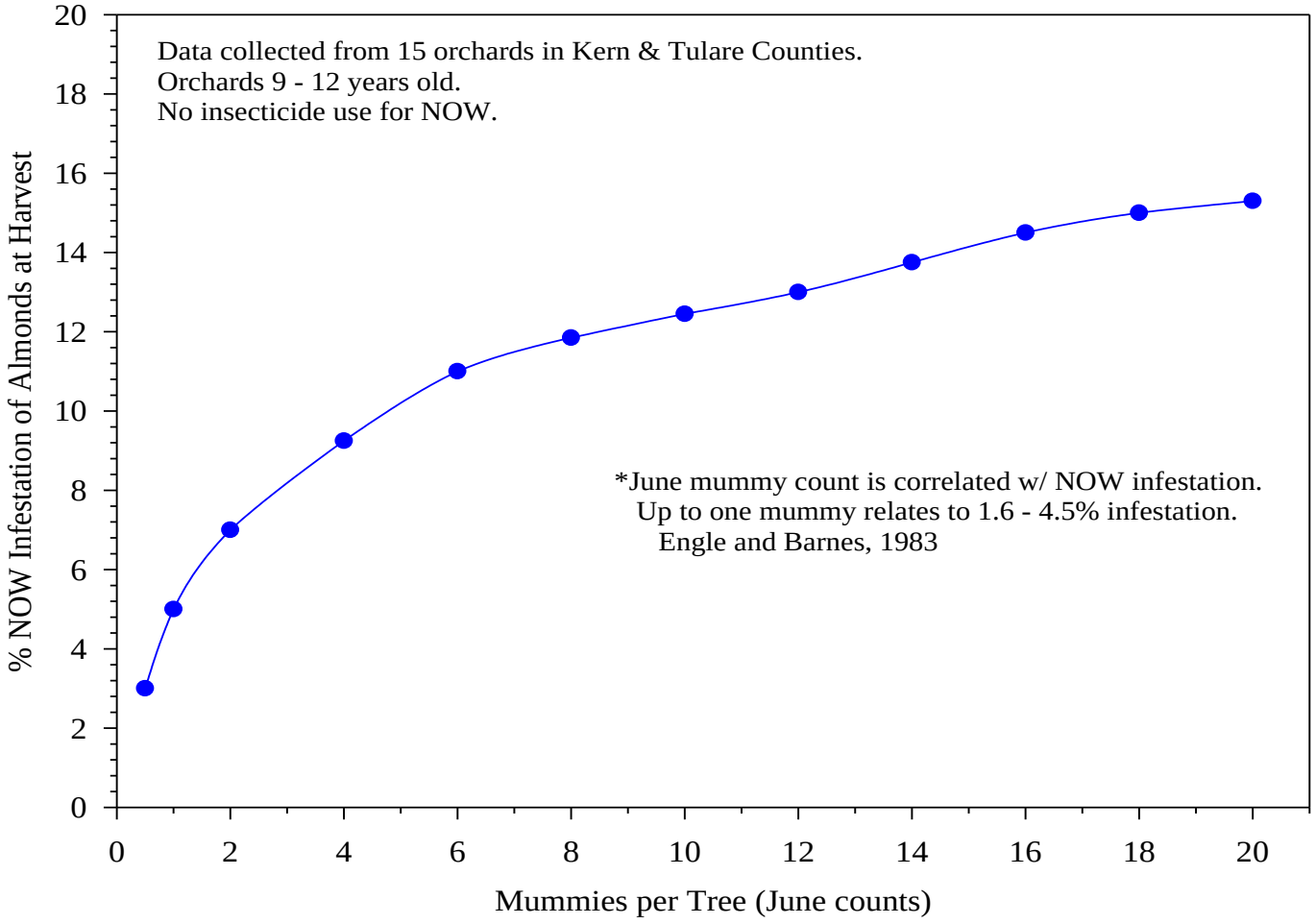
Winter Sanitation / Crop Sanitation

Procedures

- **Harvest in a timely manner!**
  - The longer nuts are exposed, the higher infestation rate of mummies
- **After harvest – get all mummies onto the orchard floor**
  - Shake or pole trees to remove mummies from canopy, tree crotches etc.
- **Blow/sweep burms to aggregate mummies in the row middles**
- **Mow/disc the mummies to destroy them**

Winter Sanitation / Crop Sanitation

Fewer Mummies = Lower Damage



Data: Engle and Barnes 1983 | Figure: D. Haviland

Winter Sanitation / Crop Sanitation

Take Note

- **Sanitize ASAP before orchard access becomes difficult**
- **Weather (cold, moisture) can cause some NOW mortality**
- **For instance, mummies…**
  - **on the ground – fair worse than in the tree canopy**
  - **in ground covers – fair worse than on bare soil**
  - **on moist bare soil – fair worse than on dry bare soil**

REGARDLESS → Don't leave it up to chance!

Aggregate and Destroy Mummies!

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Biological Control

Natural Enemies of NOW

Parasitoids

- *Goniozus legneri* – attack larvae
- *Copidosoma plethorica* – attack eggs
- Not very effective at low NOW densities

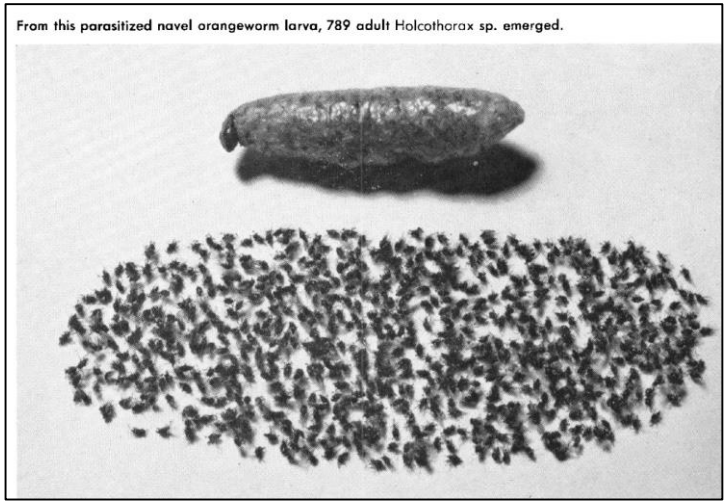
Goniozus legneri

Vertebrates

- Some birds/mice eat mummy nuts or knock them to the ground
- Impacts/tradeoffs are unclear

Green lacewing with Goniozus

(Photo: Kent Daane)



Copidosoma plethorica

"Polyembryonic"

Modern NOW Management in Pistachio

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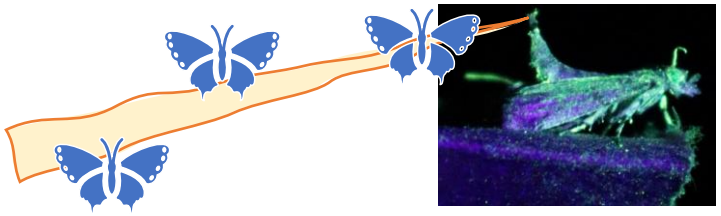
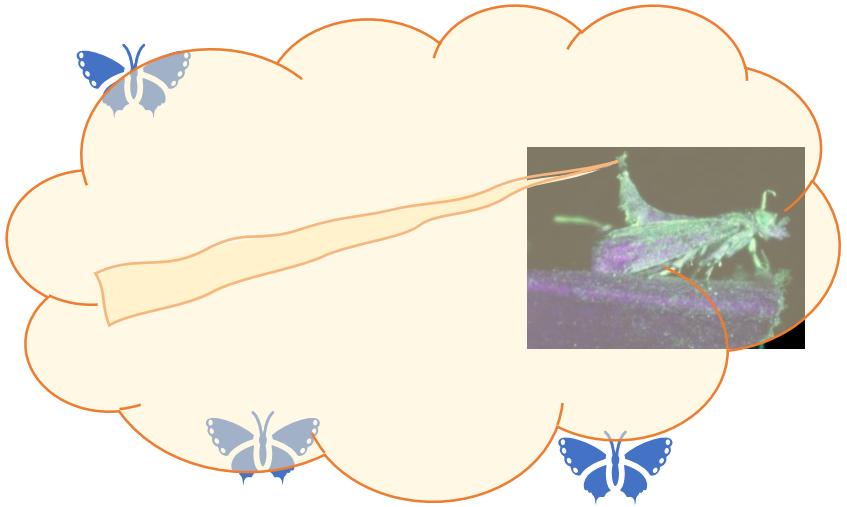
Mating Disruption

Basic Concept

- Synthetic pheromone ‘disrupts’ male ability to locate females
- Emitters go out in the spring and run all season



Males follow pheromone plume to locate females



Mating disruption interferes with male ability to locate and track the real pheromone plume

Mating Disruption

Commercial Products Available

Multiple Types of Emitters

Aerosol Emitter
"Puffer"

Polymeric Emitter

Flowable
Microencapsulated Spray

TRÉCÉ INCORPORATED

semios

Pacific Biocontrol

Suterra®

- Four companies
- Same pheromone
- Different systems

Mating Disruption

Active and Passive Emissions

Active Emitters

- **Aerosol "Puffers"**
  - Pressurize aerosol cannister
  - 1-2 cannisters/acre, spray frequently over the night

- **Microencapsulated "Flowable"**
  - Liquid that you apply like a pesticide
  - Applied multiple times, 30-day activity period

Passive Emitters

- **Polymeric Strips**
  - Plastic material impregnated with pheromone
  - 15-20 emitters/acre, passively emit all the time

Mating Disruption

Key Considerations

- **Mated female NOW can still migrate into your blocks**
  - **Best used in large contiguous areas**
  - **Square blocks >40 acres, ideally >100 acres**

- **It will shut down your pheromone traps**
  - **Phenyl-proprionate (PPO) lures will remain attractive**
  - **Egg traps will remain attractive, at least early season**

- **Background NOW population is important**
  - **Works best with lower populations of NOW**
  - **Get them down, and then keep them down**

Pop Quiz Question #2

Where do navel orangeworm overwinter?

(a) within remnant “mummy” nuts
(b) in the soil
(c) under the bark
(d) on alternate winter crops like wheat

Modern NOW Management in Pistachio

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Monitoring

Key Points

- With 2% damage tolerance, economic thresholds don't exist
- Monitoring is to track insect phenology to determine spray timing
- No singular method is perfect, use multiple trap types
- Populations are highly variable, so more traps is better than fewer

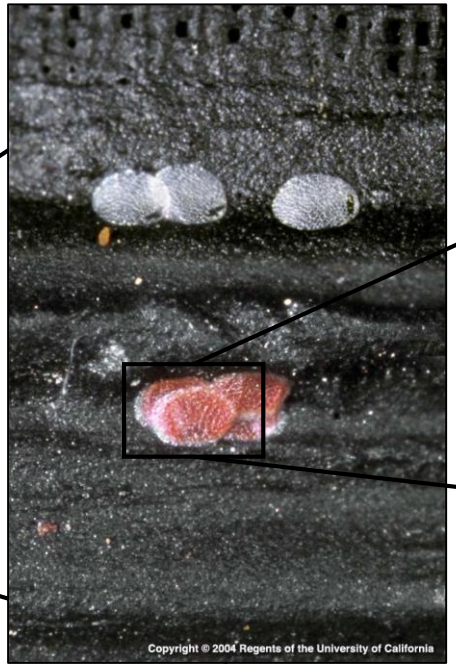
Monitoring

Monitor Mummies - Overwintering Larvae

- Examine mummy nuts around 20 trees/block
  - Do this before Jan. 15
  - Make sure to check each variety
- Count total mummies (tree + ground)
  - Crack out to inspect for NOW larvae
- Provides info on relative mummy abundance and infestation rate
- Do you have a lot of mummies and/or NOW larvae in your blocks?

Monitoring

Egg Traps



Monitoring

Egg Traps

- Start by March 15, 1 trap/10 acres (at least 4 traps per block)
- Count eggs 1-2x/week, replace bait every 4-6 weeks
- Most effective during first flight in well-sanitized orchard
- Used to determine biofix for degree-day models

Monitoring

Flight Traps

Wing Traps

Delta Traps

Pheromone Lures

Oviposition Baits

Sticky Liners

PPO Lures

Monitoring

Flight Traps

Trap Types

- **Pheromone trap**
  - Attracts males – pheromone lure

- **Peterson trap**
  - Attracts females – oviposition bait
  - Remains attractive under mating disruption
  - Also marketed for mass-trapping females

- **PPO trap**
  - Attracts males + females – PPO lure
  - Remains attractive under mating disruption

Monitoring

Flight Traps – Pheromone, Peterson, PPO

Timing and Use

- Set out traps in early March
- 1 trap/50 acres (at least 2 per block)
- Hang at 6-8 ft., unobstructed by foliage
- Check 1x/week
- Replace liners every 1-2 weeks
- Replace baits every 4-6 weeks

Modern NOW Management in Pistachio

Integrated Pest Management

Key Tools

1. **Sanitation** – Destroy mummy nuts
2. **Biological Control** – Natural enemies predate/parasitize
3. **Mating Disruption** – Reduce mating/reproduction
4. **Monitoring** – Egg traps, flight traps, biofix, degree days
5. **Spray Timing** – Maximize impacts
6. **Early/Timely Harvest** – Logistics

The Key to Success is Using Multiple Points of Attack!

Chemical Control / Insecticides

Timing = Insect x Crop Phenology

- Hull-split = crop vulnerability
- Spray timing should be based on…
  - Insect phenology – monitoring data
  - Crop phenology – no later than 1% hull-split
  - Current pest pressure

Sacramento Valley Orchard Source

Niederholzer - "Hull Split Timing and Sprayer Practices for Best Pest Control Results"

https://www.sacvalleyorchards.com/almonds/insects-mites/hull-split-timing-and-sprayer-practices/

Chemical Control / Insecticides

Timing = Insect x Crop Phenology

When is hull-split?

- **Stage 2C – before the suture is wide open**
- **First occurs at top southwest quadrant of trees**
- **Blank nuts split 1-2 weeks earlier, don't be confused**

Chemical Control / Insecticides

Timing = Insect x Crop Phenology

When to spray?

1. **At hull-split**
   - Most effective spray timing for NOW in almonds

2. **2-3 weeks after hull-split**
   - If moderate/high NOW pressure
   - Maintains residues, covers pollinizers

3. **Spring/May spray?**
   - Maybe, if high historical NOW or targeting PTB
   - Efficacy not entirely clear, but we see it
   - Difficult to time accurately due to long flight period
   - Best advice is target first generation egg-hatch (100 DD)
   - If you spray pyrethroids it may drive secondary outbreaks

Chemical Control / Insecticides

Make Your Sprays Count

For ANY spray…

- **Spray calibration, drive speed (go slow) and weather conditions are critical**

Consult With…

- **Local Farm/IPM Advisor**
  - **https://ucanr.edu/About/Locations/**
- **UC Statewide IPM Program Website**
  - **https://www2.ipm.ucanr.edu/agriculture/almond/Navel-Orangeworm/**

Spray Training Opportunities Available

- **http://ipm.ucanr.edu/training/**

Modern NOW Management in Pistachio

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The Key to Success is Using Multiple Points of Attack!

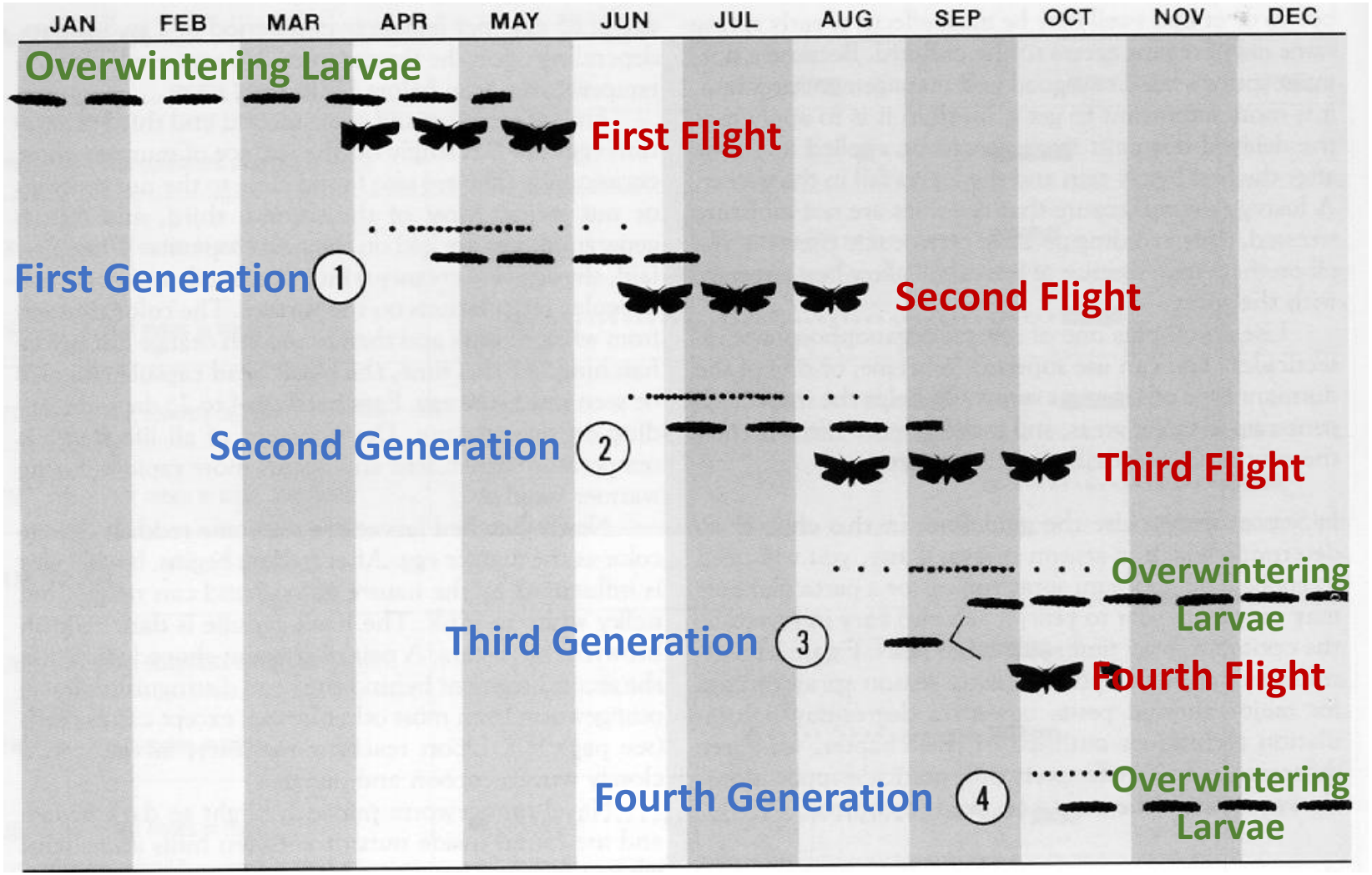
Early/Timely Harvest

Logistics and Management

- NOW populations build exponentially over time
  - Longer crop hangs on the tree = higher probability of infest
    - Higher infest a problem this year = more mummies next year

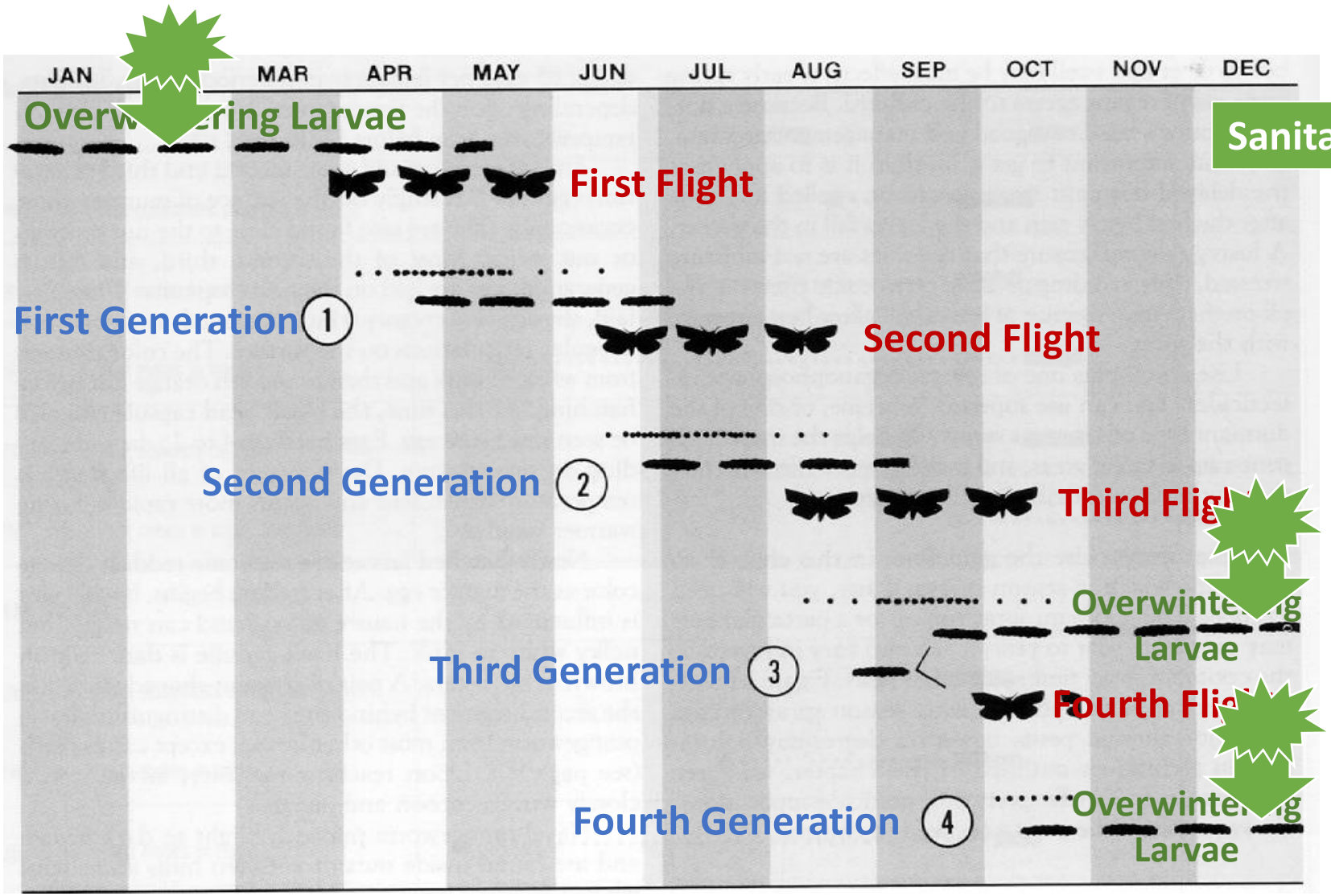
Bringing It All Together

KEEP THEM ON THE RUN!



Bringing It All Together

KEEP THEM ON THE RUN!



Bringing It All Together

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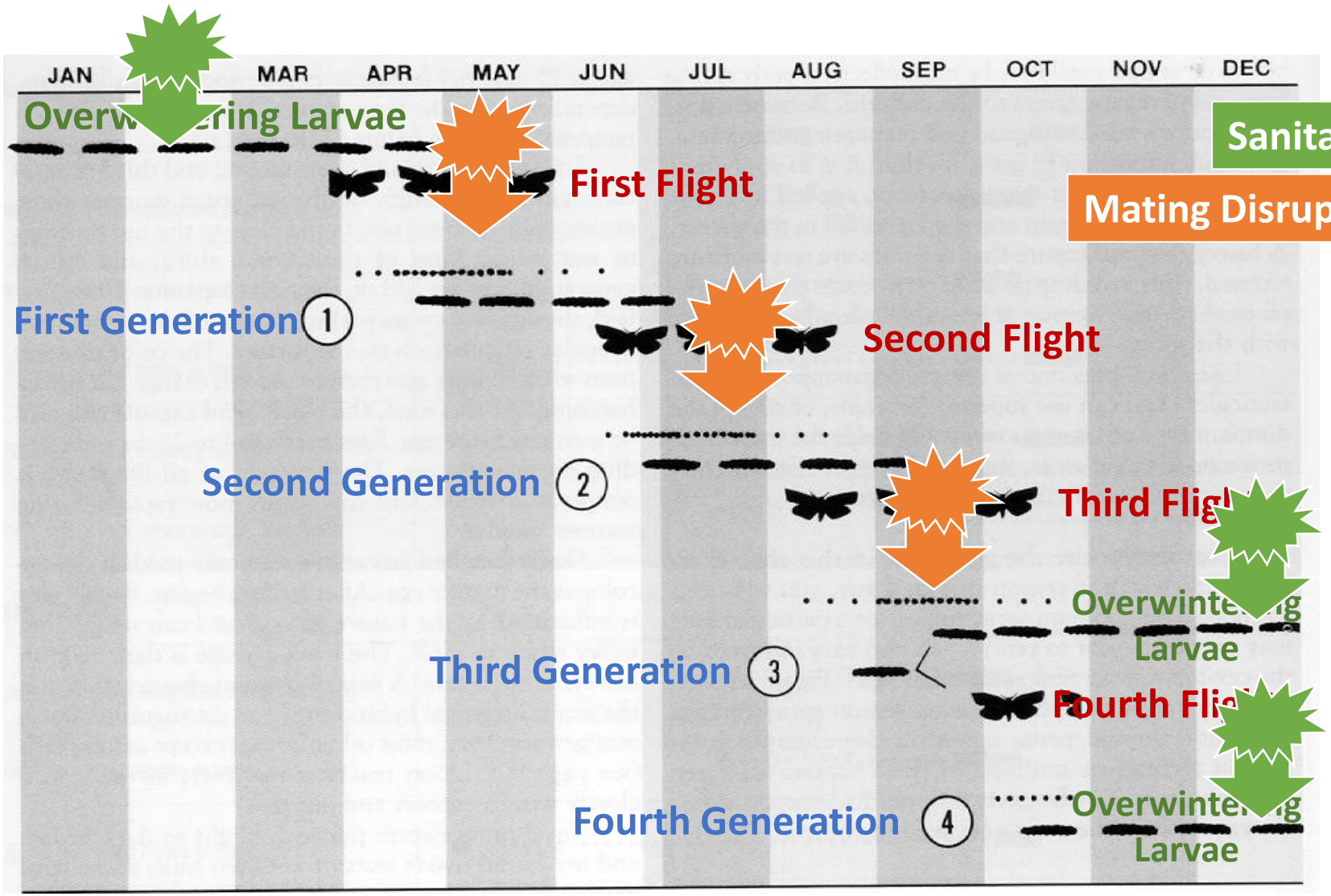

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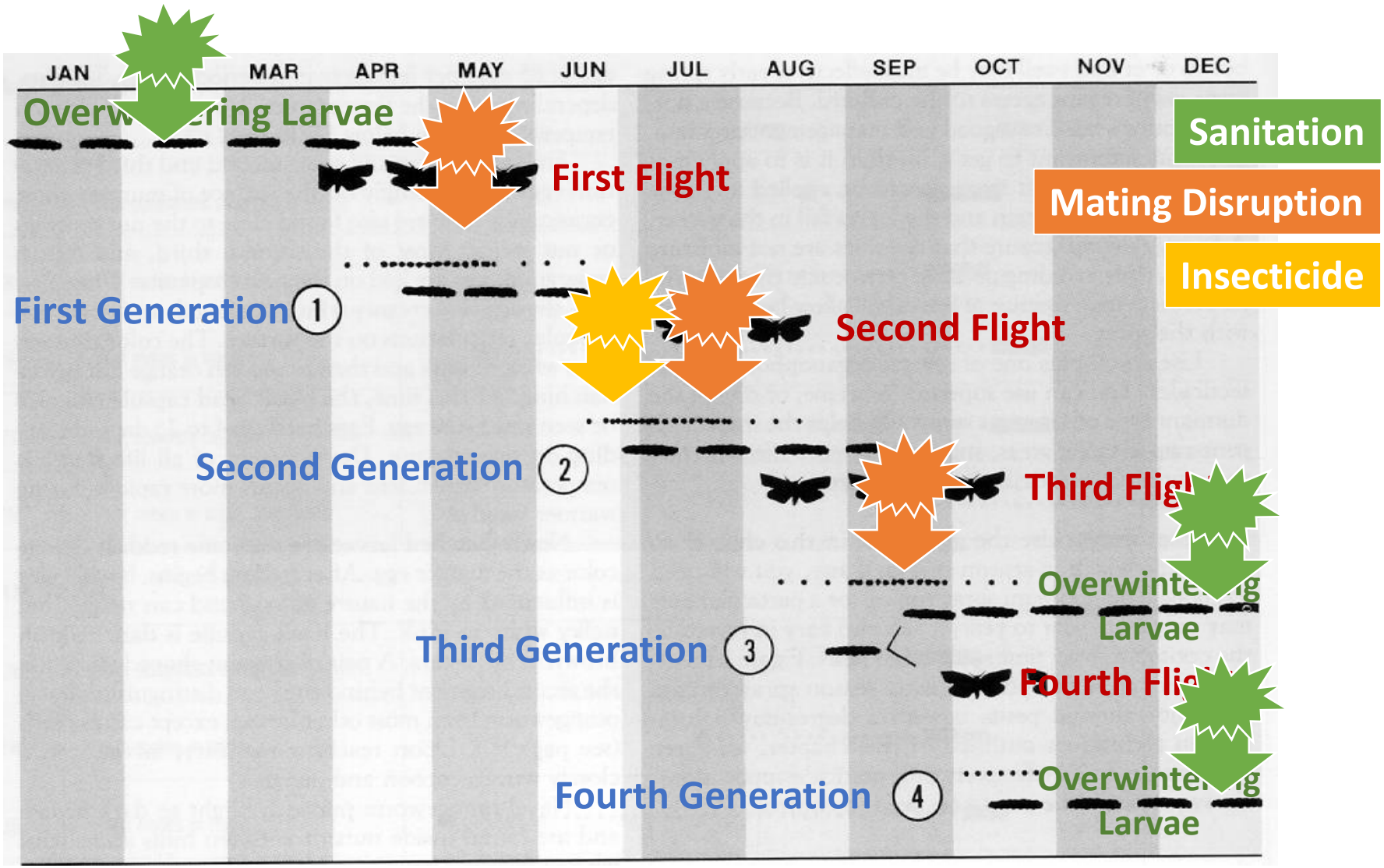

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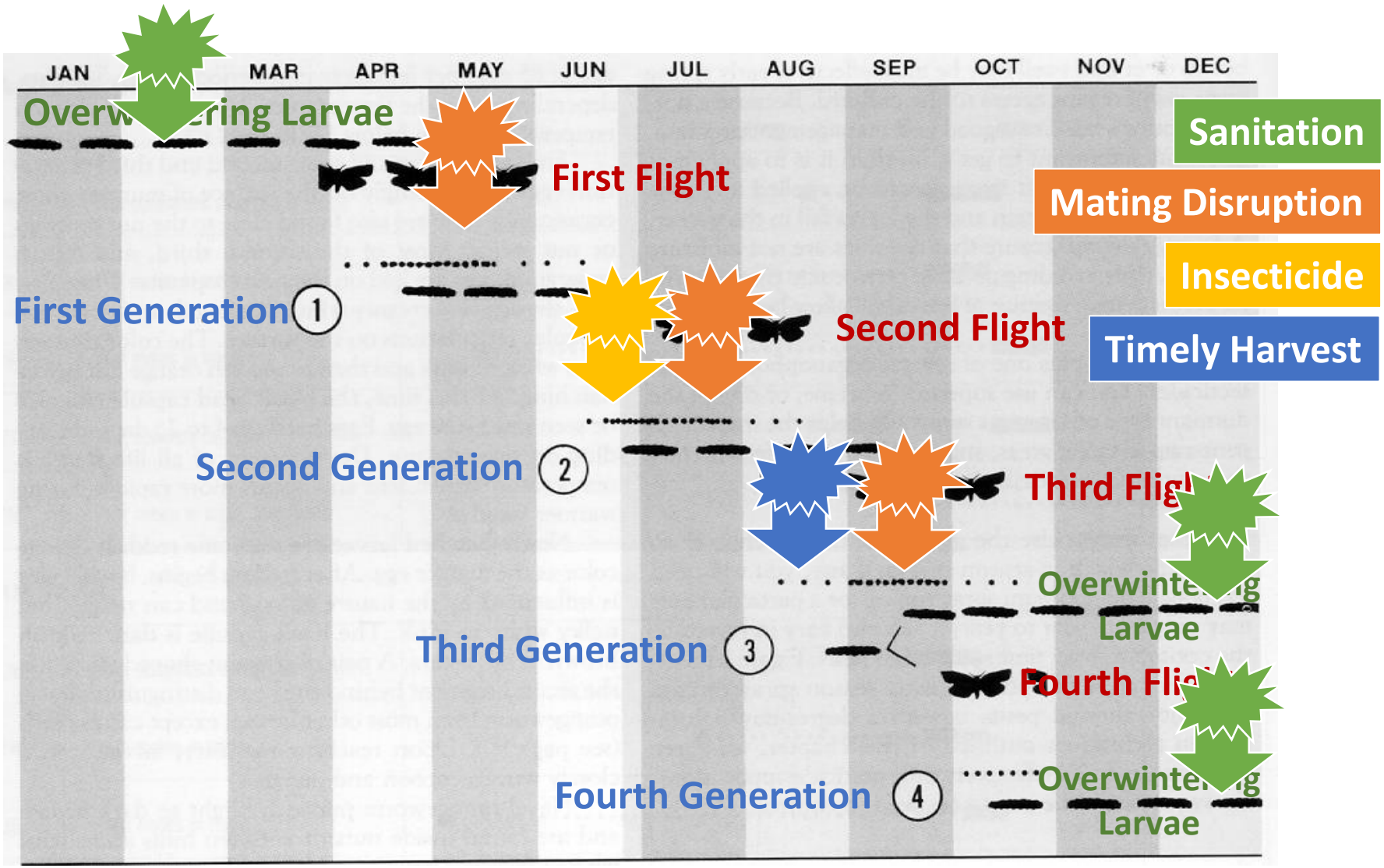
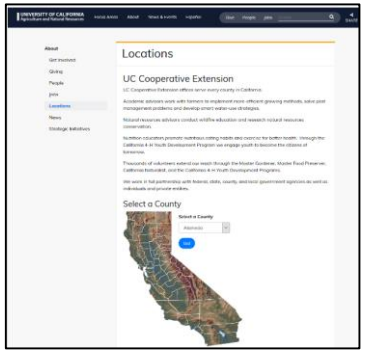


Key Additional Resources



Local Farm/IPM Advisor

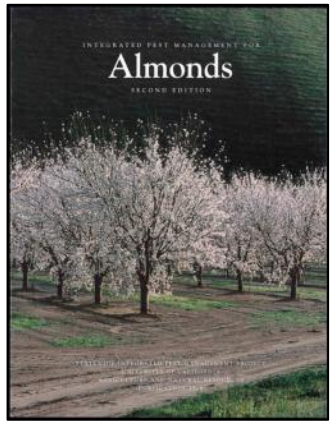
- https://ucanr.edu/About/Locations/

UC Statewide IPM Program Website (most current info)

- ALMOND - https://www2.ipm.ucanr.edu/agriculture/almond/Navel-Orangeworm/
- PISTACHIO - https://www2.ipm.ucanr.edu/agriculture/pistachio/Leaffooted-Bugs/

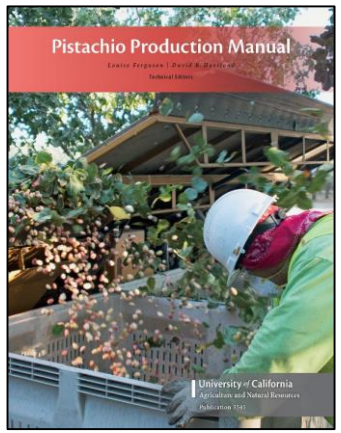
Integrated Pest Management for Almonds (2002)

- UC ANR Publication #3308
- http://ipm.ucanr.edu/IPMPROJECT/ADS/manual_almonds.html



Pistachio Production Manual (2016)

- UC ANR Publication #3545
- https://anrcatalog.ucanr.edu/Details.aspx?itemNo=3545



Thank You!! Questions??

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