Biology and Economics of Invasive Species: Spatial and Temporal Interactions

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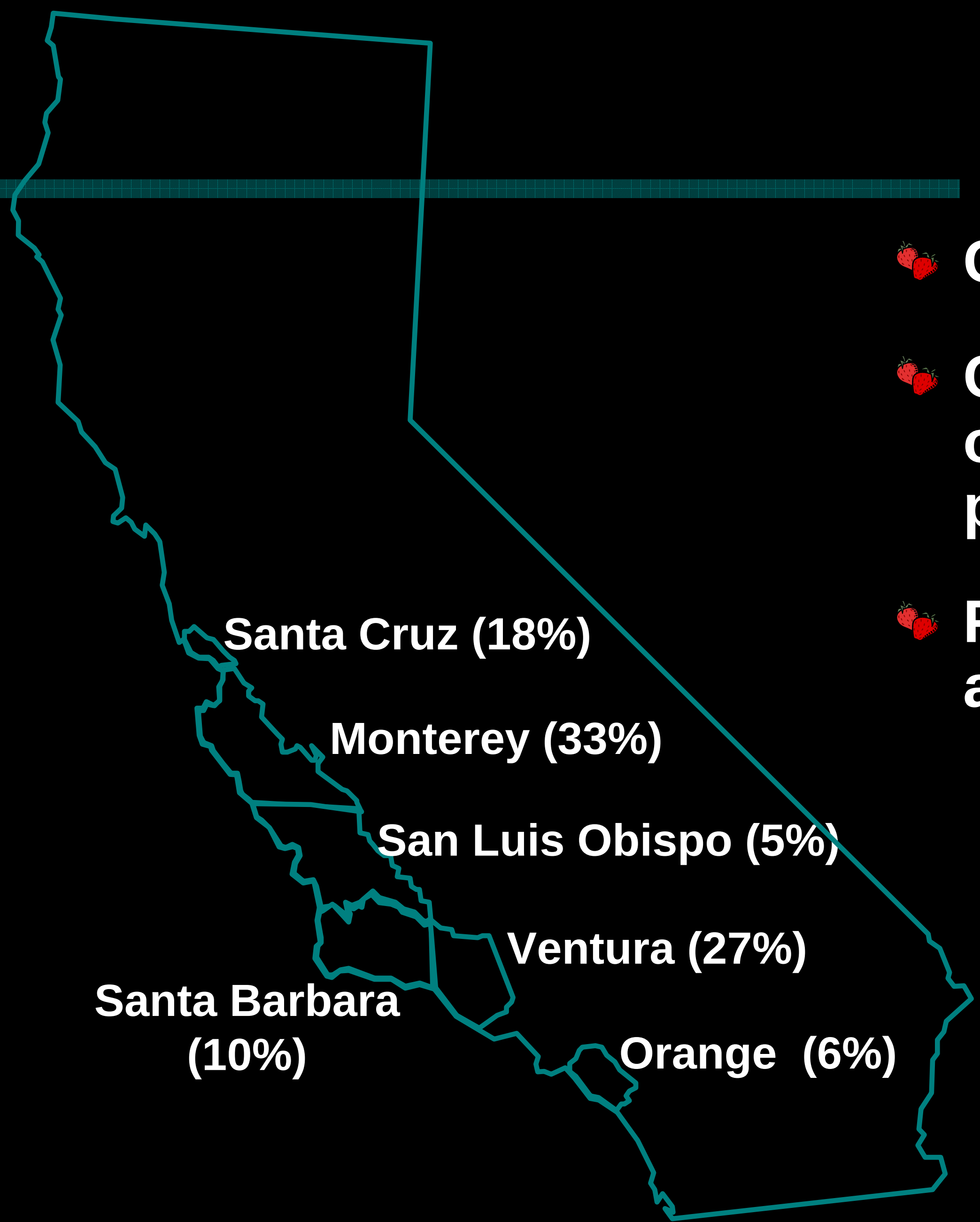
PREISM Workshop, October 2006

Project Goals

- Incorporate spatial and temporal considerations into an invasive species management model
  - Population dynamics, physical and economic damage
- Apply model to a specific invasion
  - Estimate cost and benefits of regulation
- Evaluate value of different modeling approaches
  - Experimental data, econometric estimation only
  - Add information from literature, simulation



- Coastal production
- California accounts for over 80% of U.S. production
- Florida accounts for around 12%

Greenhouse Whitefly in California Strawberries: A "Resident Invader"

- Common pest along CA coast
- Observed in strawberries in 1999-2000
  - Invaded primarily Oxnard and Watsonville areas
  - Heavy infestation in 2002 (Watsonville area)
- Possible explanations
  - Increased summer acreage
  - Expansion of total acreage
  - Increased use of two-year planting cycle (Watsonville)
- Reduces yields
  - Feeds on sap, reducing plant vigor, total yield
  - "Honeydew" reduces marketable yield

Slide 5

GM2 I don't recall this being so much of an issue, but maybe I'm wrong.

One that does belong here is the second-year plantings - they were the particular problem in the Watsonville area.
Gregory Mckee, 10/11/2006

RG1 In the Watsonville area
Rachael Goodhue, 10/11/2006

Why This Invasion?

- Pronounced, multiple temporal and spatial considerations
  - Short plant life cycle
  - Multiple harvests
  - Short invader life cycle
  - Seasonal pattern of output price
  - Spatial and temporal host crop pattern
- Specific policy question
  - Costs and benevits of resistance management policies
  - Applicable to many cases GM3
- Spontaneous cooperation among stakeholders in the Oxnard region

Slide 6

GM3 I think the long-run stuff in chapter 6 also gets at the benefits of these policies as well. You allude to this in the next slide.
Gregory Mckee, 10/11/2006

Project Objectives

1. Measure impact of greenhouse whitefly (GWF) on strawberry yields
2. Model GWF population dynamics, effects of treatments
3. Incorporate population model, damage model, commodity price cycle into bioeconomic model to identify optimal chemical treatment dates. GM4
4. Estimate one-year economic impact of pesticide use regulations by incorporating them into bioeconomic model
5. Incorporate long-term benefit of slowed development of resistance into economic impact estimate
6. Estimate benefits of regional management
7. Derive implications for invasive species management

Slide 7

GM4 and pesticide use restrictions

Gregory Mckee, 10/11/2006

Objective 1

Measure impact of GWF on strawberry yields

Damage Function

- Data from field trial (Frank Zalom)
- Ln(incremental yield) as function of
  - Ln(incremental GWF days)
  - Weeks since planting
  - (Weeks since planting)^2
  - Ln(incremental GWF days)*weeks since planting
  - Treatment dummies

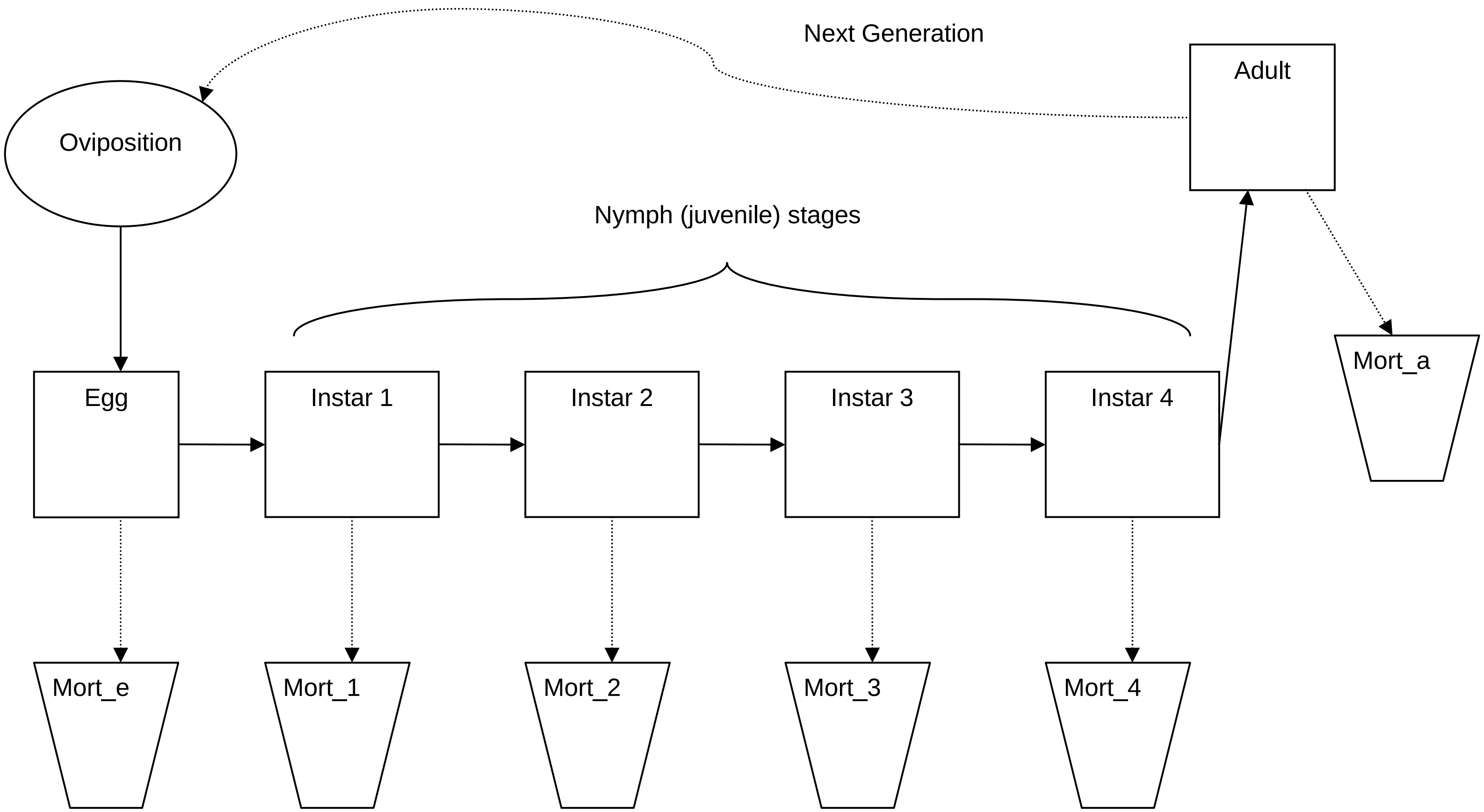
Damage Function
Selected Coefficients

Weeks since planting	4.9*
(Weeks since planting)^2	-0.51
Ln(incremental GWF-days)	52.0*
Ln(incremental GWF-days) X weeks since planting	-52.1*
June dummy	1.2*
Untreated control	84.2

Objective 2

Model GWF population dynamics, effects of treatments

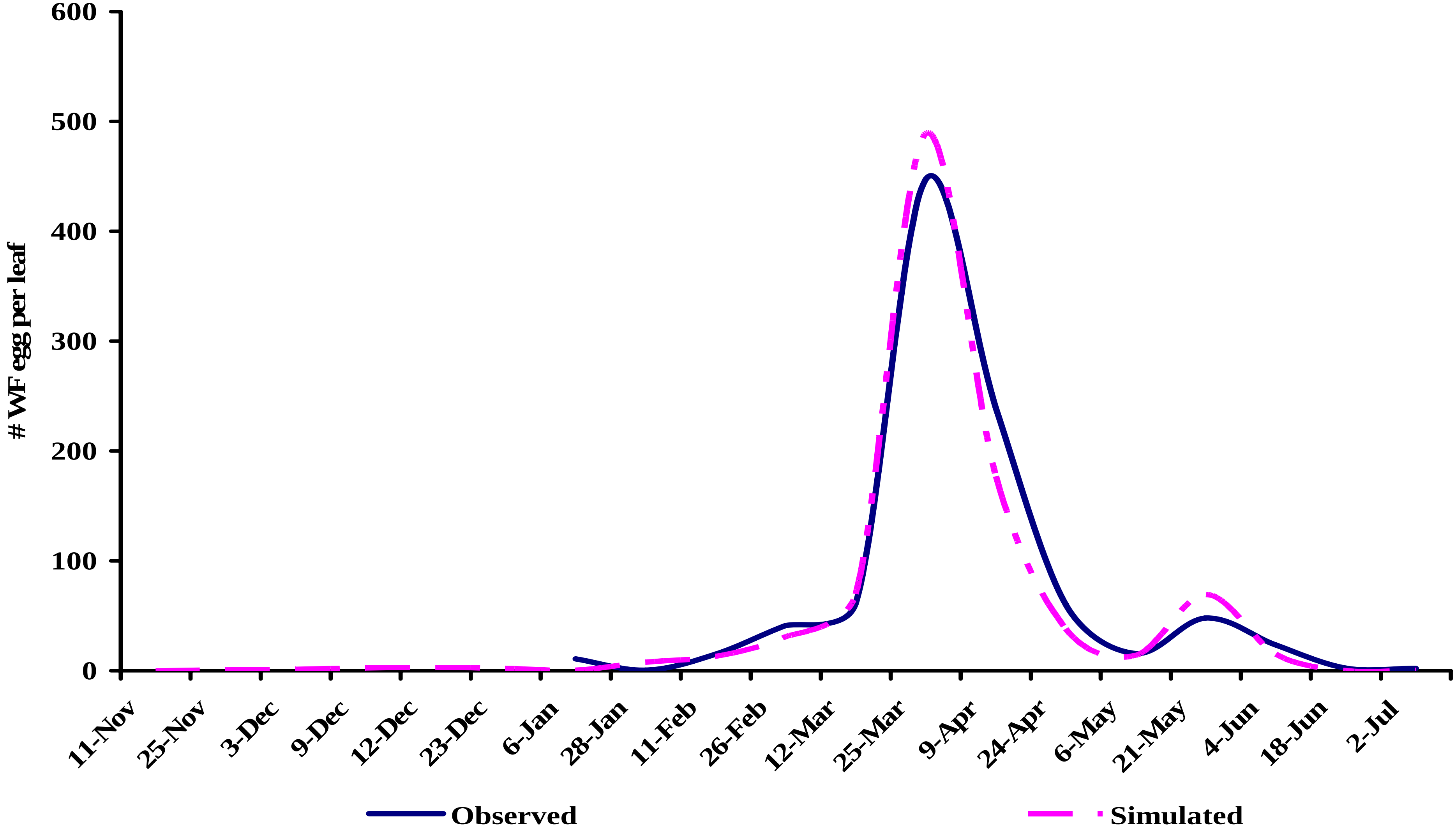
GWF Population Model



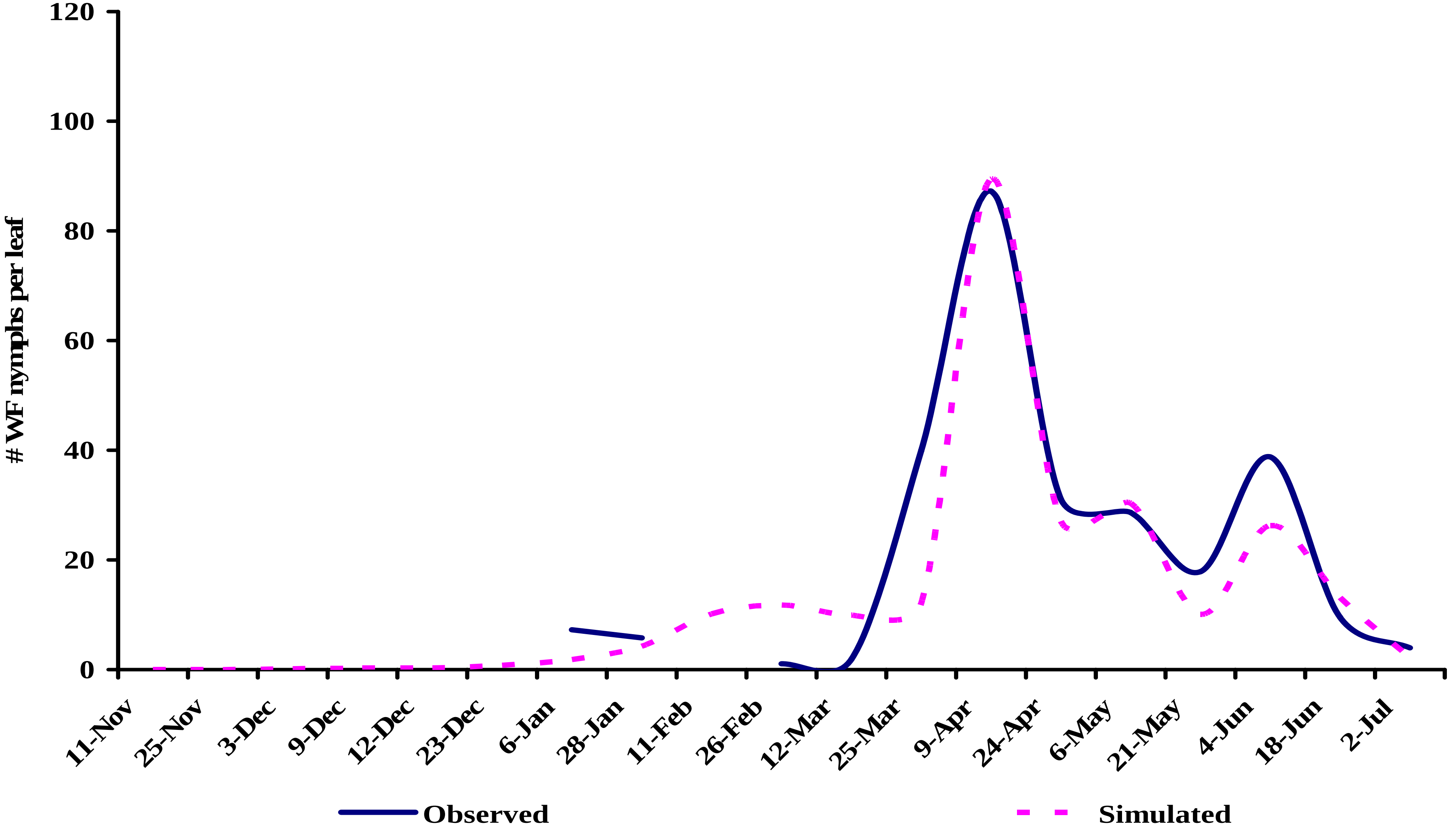
Mort_* = mortality of given life stage

Adapted from Hulspas-Jordaan and van Lenteren (1989)

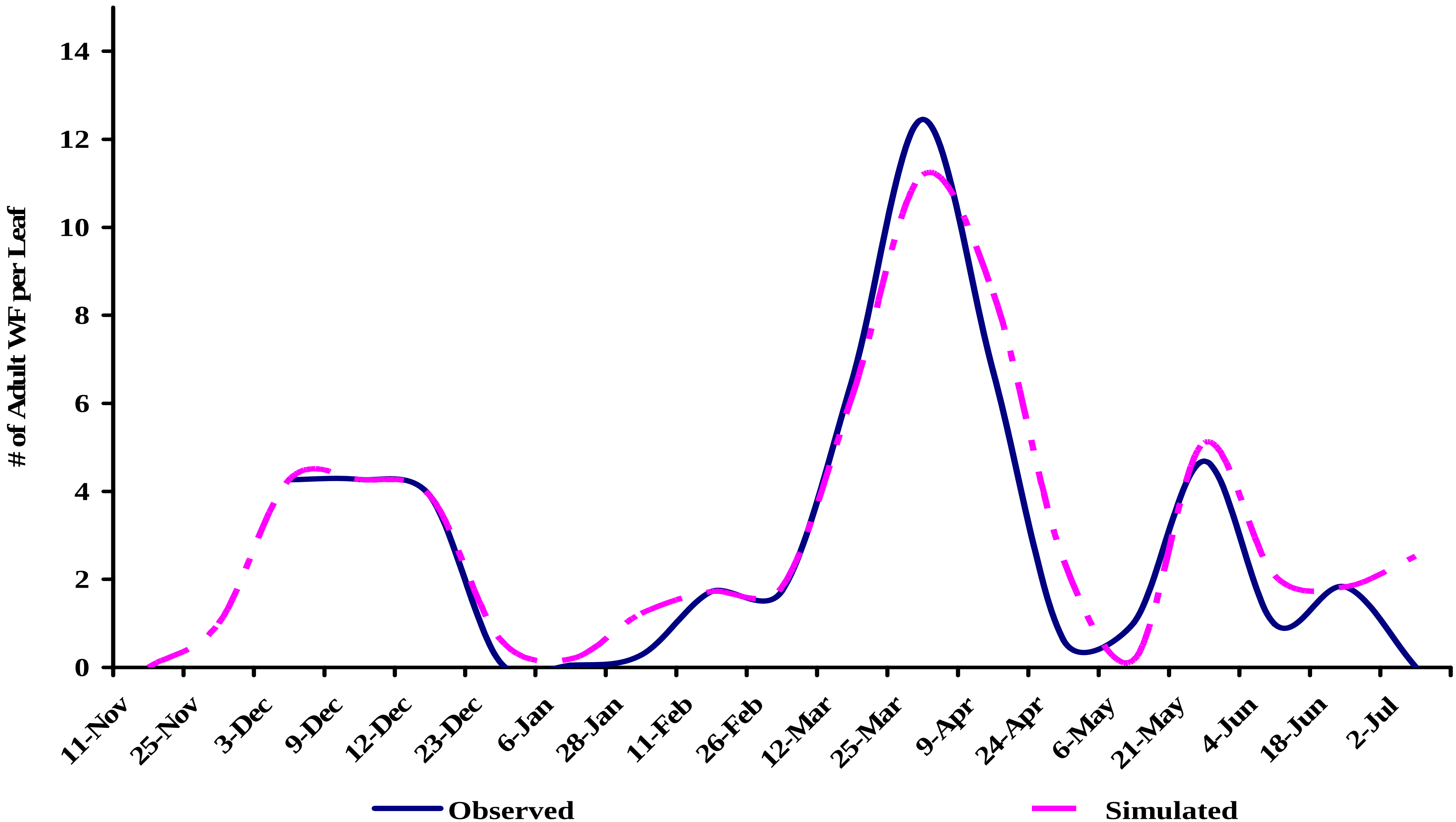
Observed and Simulated Egg Populations on Untreated Plants: Watsonville



Observed and Simulated Nymph Populations on Untreated Plants: Watsonville



Observed and Simulated Adult Populations on Untreated Plants: Watsonville



Esteem (pyriproxyfen)

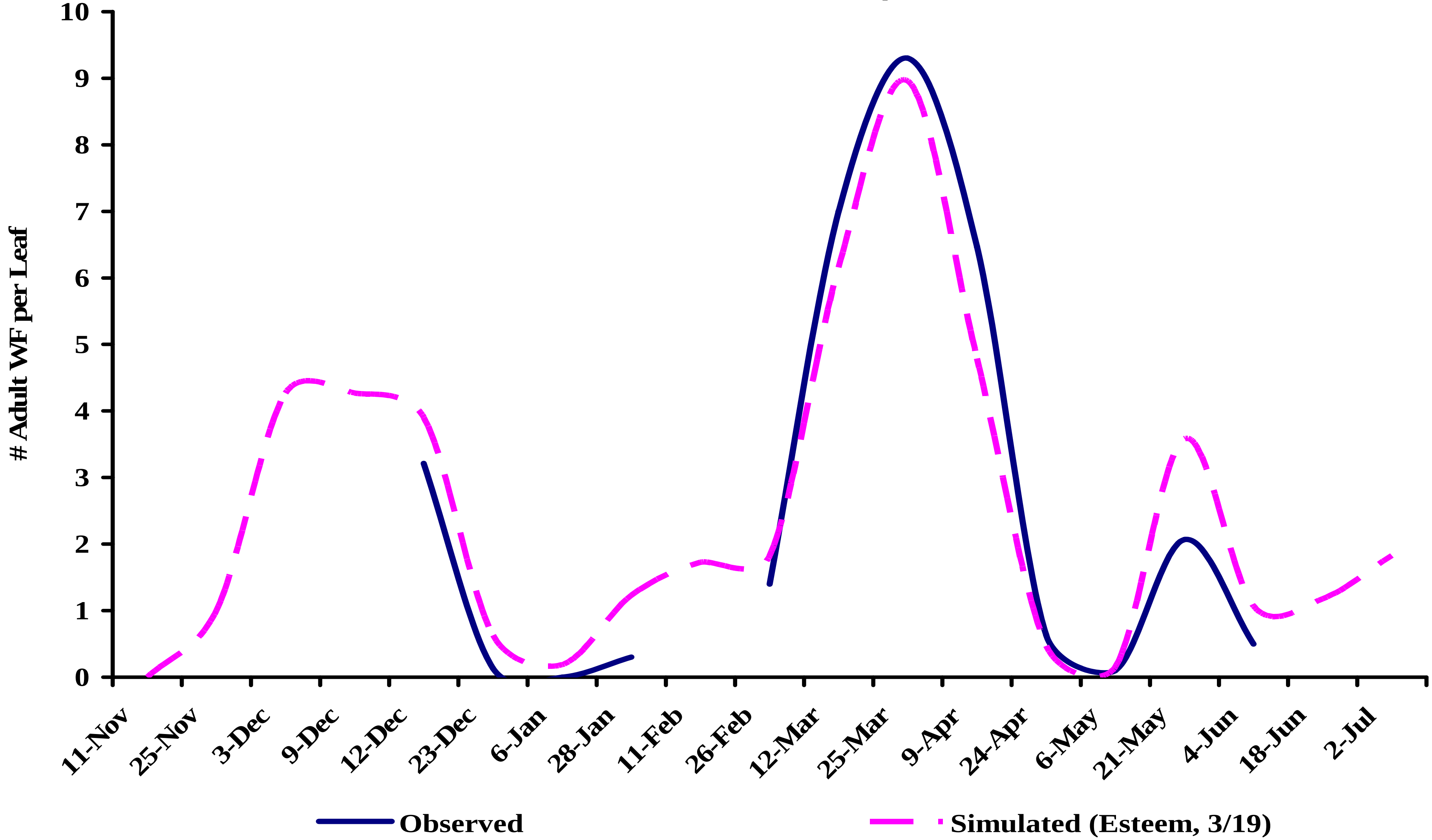
- Esteem provides effective post-plant whitefly control
  - Application costs approx. $40/acre
  - Effective for up to nine weeks
  - Emergency registration during study period
  - **Restricted** to no more than two applications per acre per year GM5
  - **Restricted** to use only if Admire (imidacloprid) applied at transplanting, given a previous infestation GM6

Slide 16

GM5 Be sure to indicate that this was a maximum; it reads as though growers were required to make two applications, which was not the case.
Gregory Mckee, 10/11/2006

GM6 I don't expect this will come up, but recall that the restriction actually says that this only has to happen if whiteflies were in the field the previous season. Otherwise it's optional. In my analysis I've taken the approach that growers who've experienced the problem may be more likely (no data to support this) to use the best treatment option available, Admire + Esteem.
Gregory Mckee, 10/11/2006

Observed and Simulated Adult GWF Populations: Esteem Treatment March 19, Watsonville



Objective 3

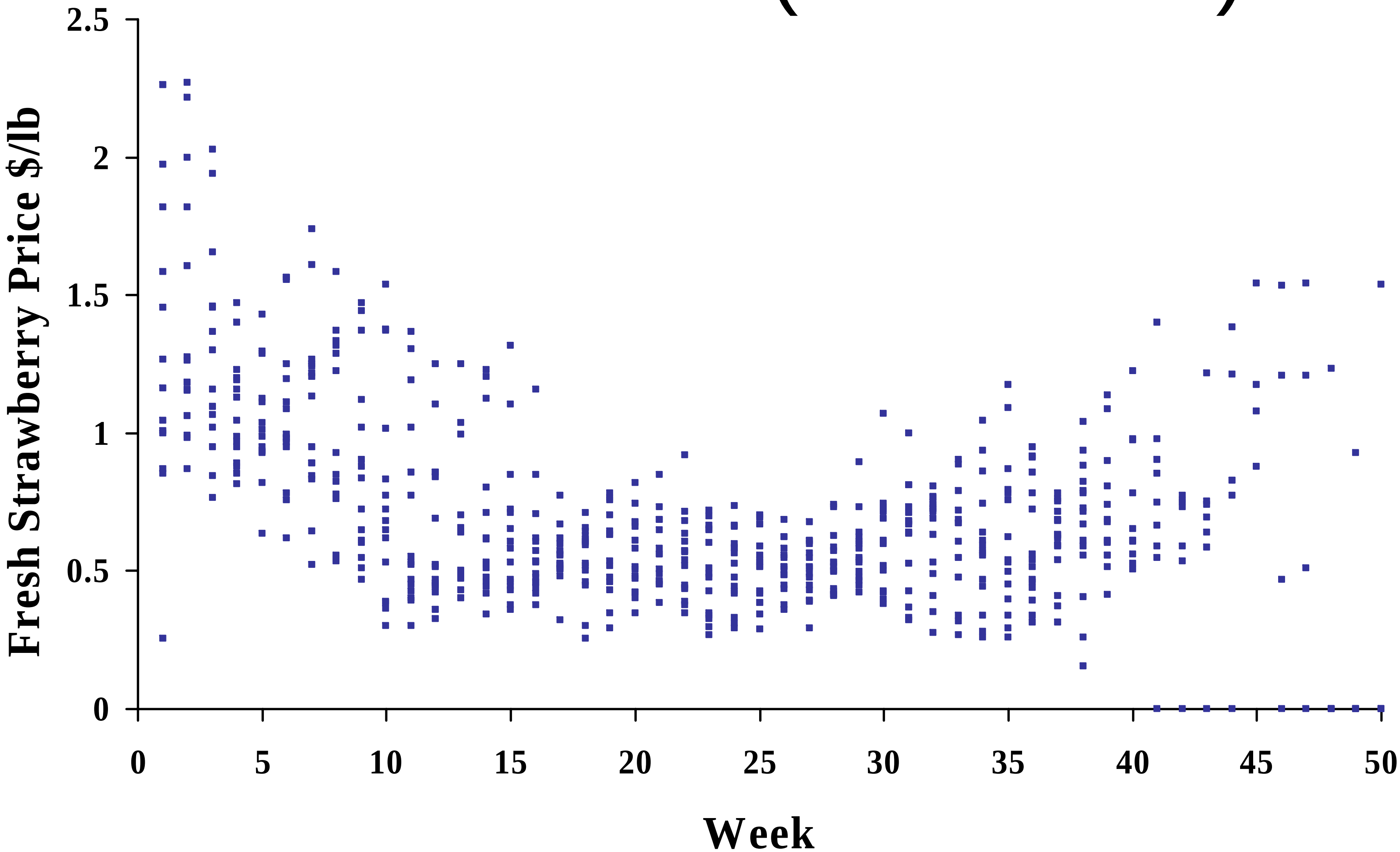
Incorporate population model, damage model, commodity price cycle into bioeconomic model to identify optimal chemical treatment dates.

GM7

Slide 18

GM7 and incorporate pesticide use restrictions
Gregory Mckee, 10/11/2006

Price Cycle: California Fresh Strawberries (1988-2002)



Optimal Treatment Dates (Watsonville)

Number of Treatments	Profit-Maximizing Application Date(s)
1	March 5
2	February 1 March 5
3	February 4 March 12 May 5

Factors Influencing Optimal Treatment Dates

- Timing of population peaks
- Magnitude of population peaks
- Seasonal strawberry price variation does not matter
  - Constant price experiment
  - Reversed cycle experiment

Objective 4

Estimate one-year economic impact of pesticide use regulations by incorporating them into bioeconomic model

Economic Impact of Use Regulations

- Restriction to two or fewer treatments
  - Reduces profits
  - Not offset by Admire requirement
- Requirement to use Admire
  - Increases profits
  - Complements

Change in Profits per Acre Relative to an Untreated Field: Watsonville

- Top table: Two Esteem treatments versus none

	Admire	No Admire
Esteem	**$8,200**	$3,100
No Esteem	$2,900	$0

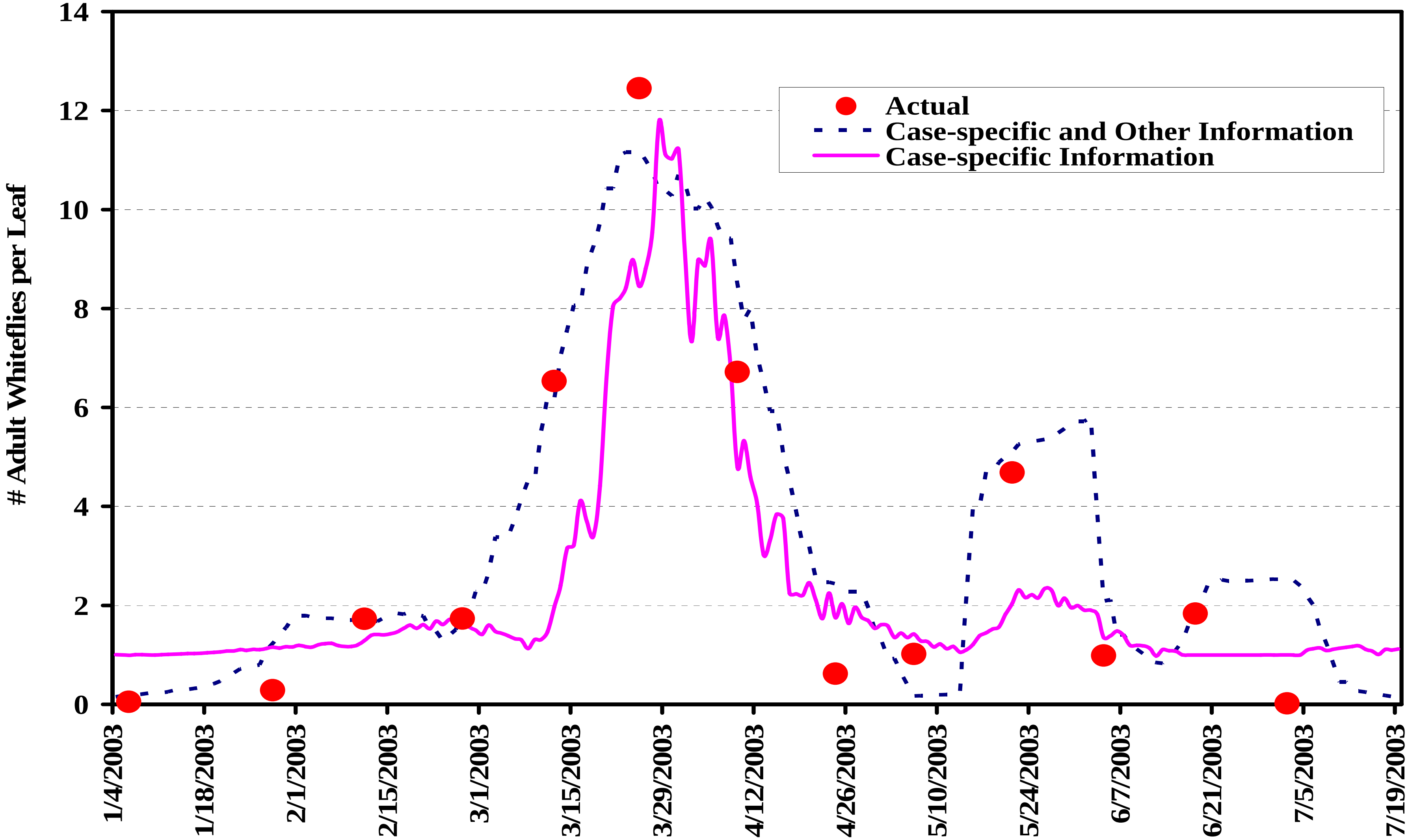
- Bottom table: Three Esteem treatments versus none

	Admire	No Admire
Esteem	**$9,500**	$4,100
No Esteem	$2,900	$0

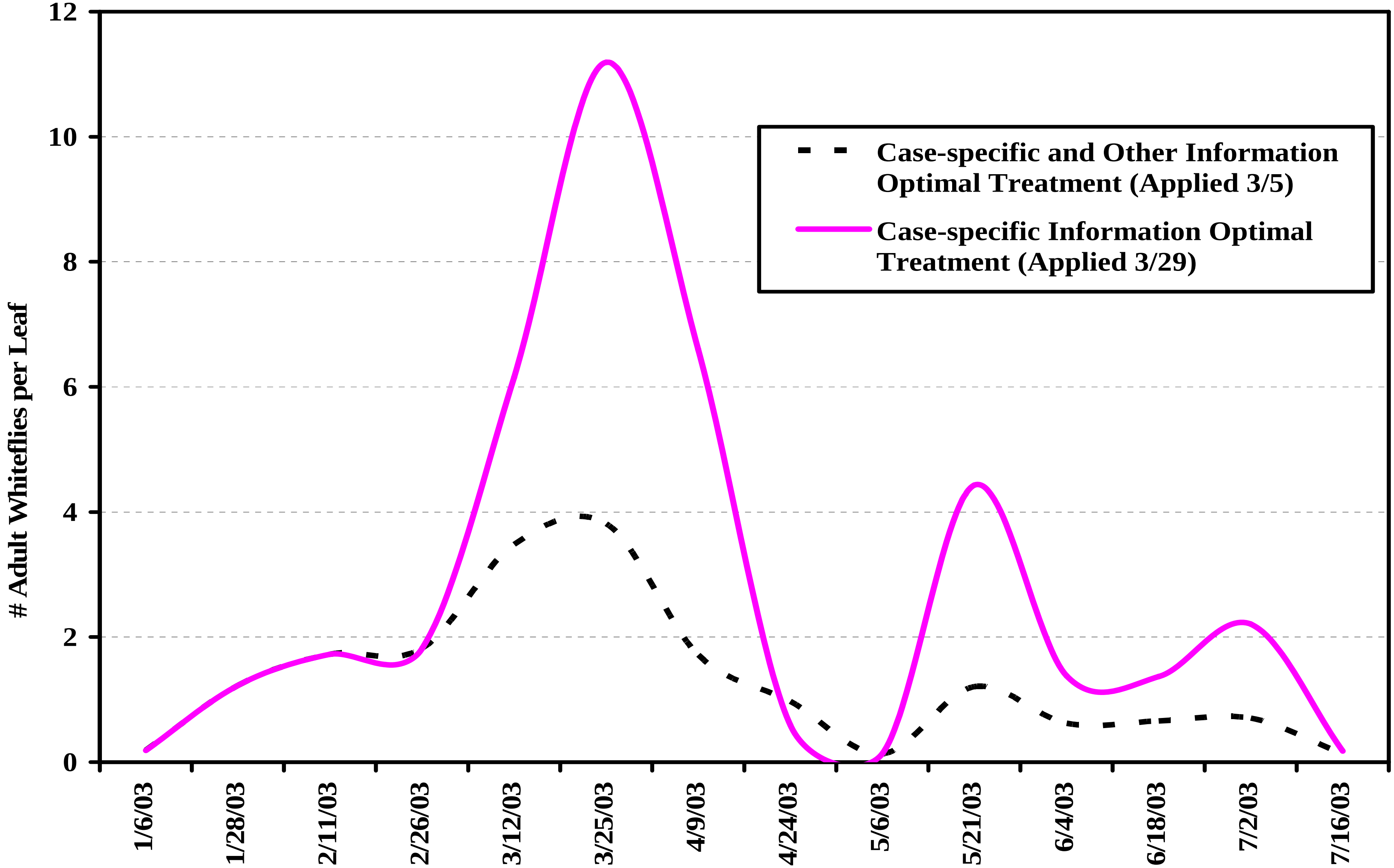
Comparing Modeling Approaches

- Simulation model
  - Field trial data and population dynamics and parameters from literature
- Autoregression model
  - Field trial data only

Comparing Modeling Approaches



Comparing Modeling Approaches



Comparing Modeling Approaches

- 26% difference in the estimated cost of the restriction to two or fewer applications.
  - Autoregression model: $2,300 per acre
  - Simulation model: $1,700 per acre

Objective 5

Incorporate long-term benefit of slowed development of resistance into economic impact estimate

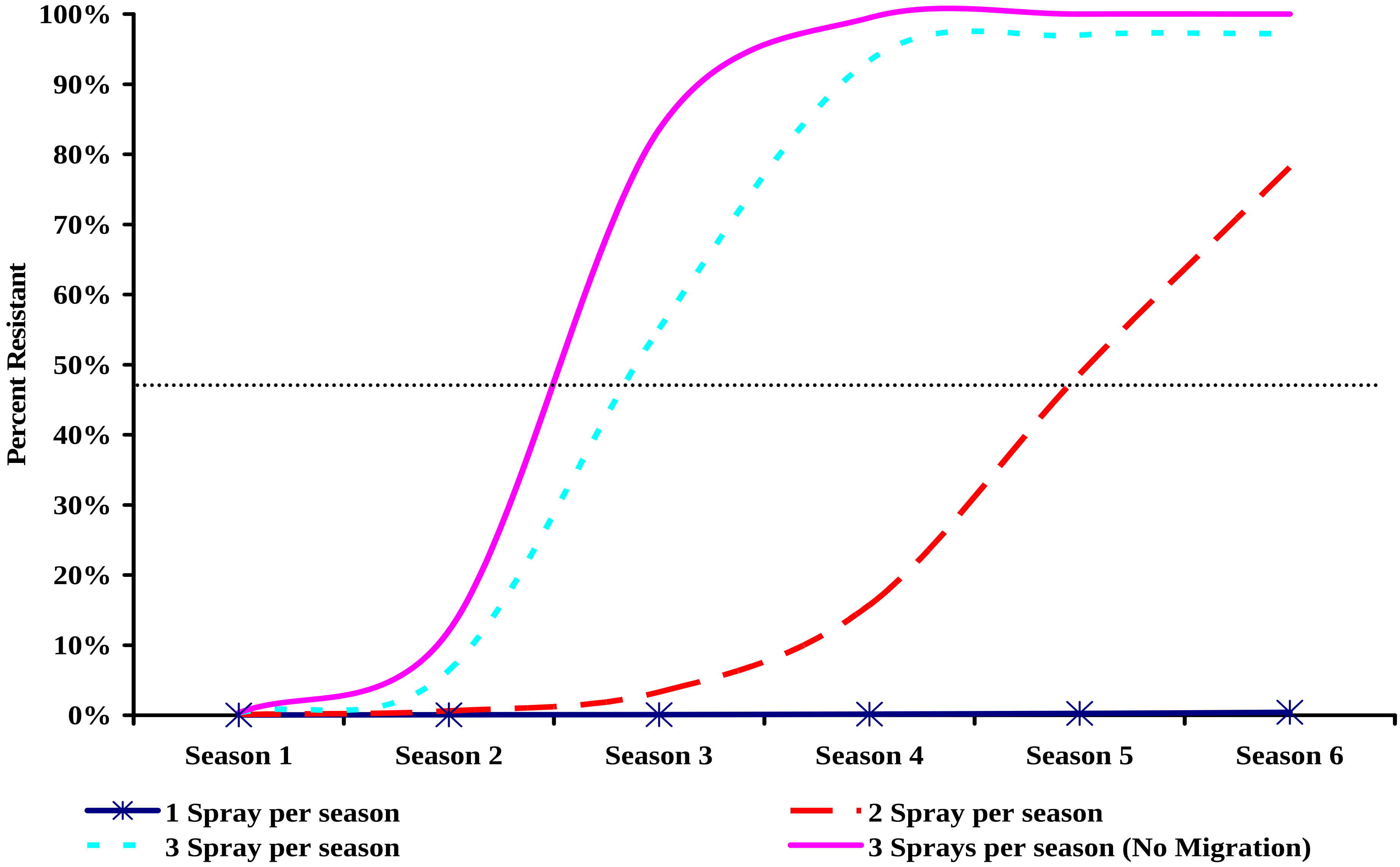
Long-Term Impact of Use Restriction

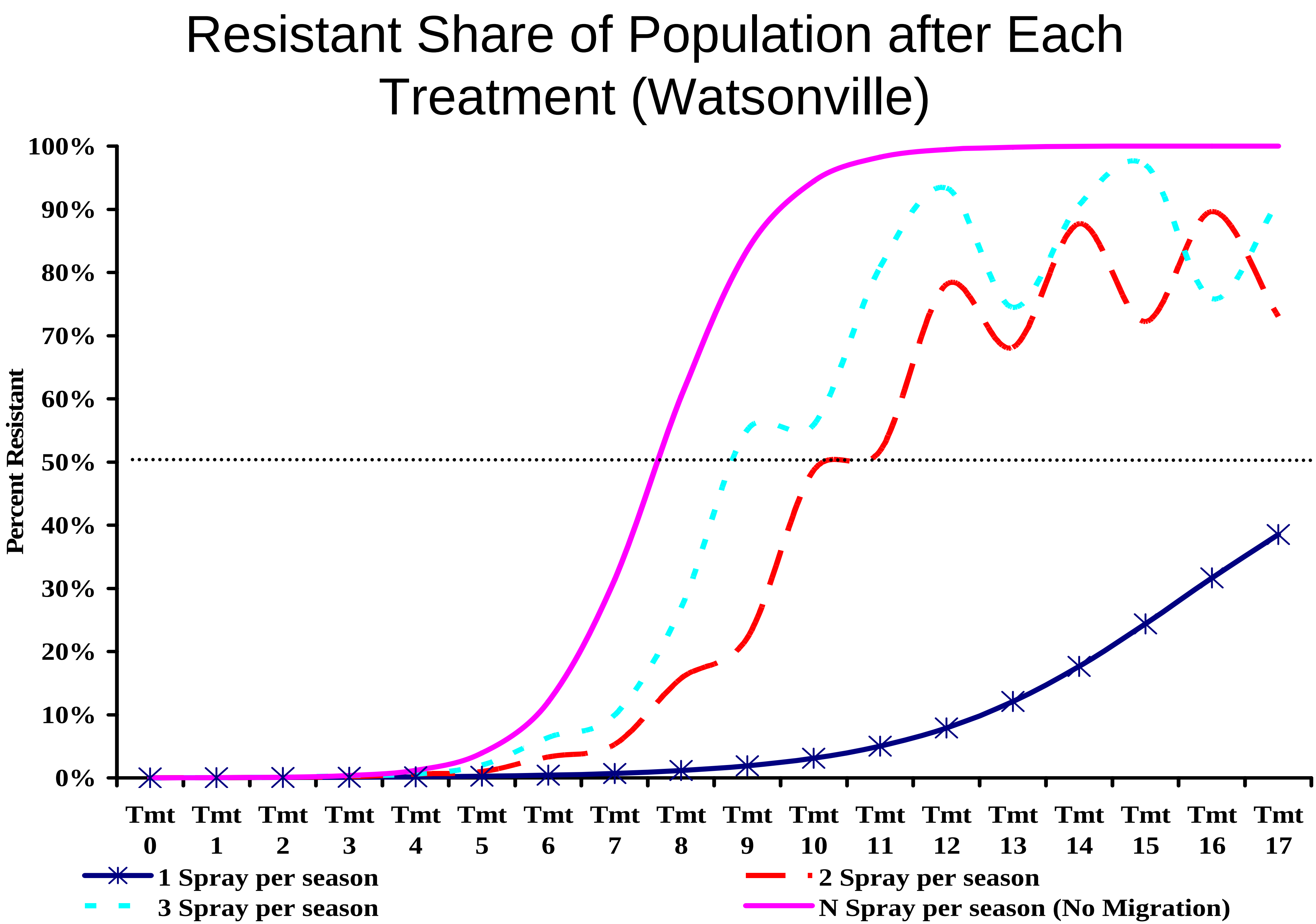
- Objective of use restriction: slow the development of resistance to Esteem, encourage the development of alternative efficacious treatments
- Model the number of applications as a determinant of the rate of resistance development
  - Evaluate net benefits of one-, two- and three-treatment programs

Modeling Pesticide Resistance

- Time horizon: 6 production cycles
  - Based on usual three or fewer years for an emergency registration, possible development of alternatives
- Sensitivity analysis over three factors governing development of resistance
  - Interseasonal migration between treatment programs
    - Dilution of resistance
  - Share susceptible individuals killed per application
  - Share of population that's naturally resistant prior to the first application

Resistant Share of Population at the End of Each Season (Watsonville)





Resistant Share of Population after Each Treatment (Watsonville)
Percent Resistant
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Tmt 0
Tmt 1
Tmt 2
Tmt 3
Tmt 4
Tmt 5
Tmt 6
Tmt 7
Tmt 8
Tmt 9
Tmt 10
Tmt 11
Tmt 12
Tmt 13
Tmt 14
Tmt 15
Tmt 16
Tmt 17
1 Spray per season
2 Spray per season
3 Spray per season
N Spray per season (No Migration)

Is the Limit on the Number of Applications Cost-Effective?

- Depends on resistance parameters
- More likely to be cost effective as GM8
  - Migration is less effective at diluting resistance
  - Applications kill a greater share of the susceptible population
  - Share of natural resistance in pre-treatment population increases

Slide 34

GM8 typo

Gregory Mckee, 10/11/2006

Objective 6

Estimate benefits of regional management

Value of Cooperation

- GWF will migrate to an adjacent field
  - When a host crop is harvested
  - When the nearby crop becomes a more attractive host
- Question: Are there benefits to cooperating with one's neighbors?
  - Evaluate for grower of a fall-planted strawberry field
  - Cooperation as communication regarding cropping, harvest plans

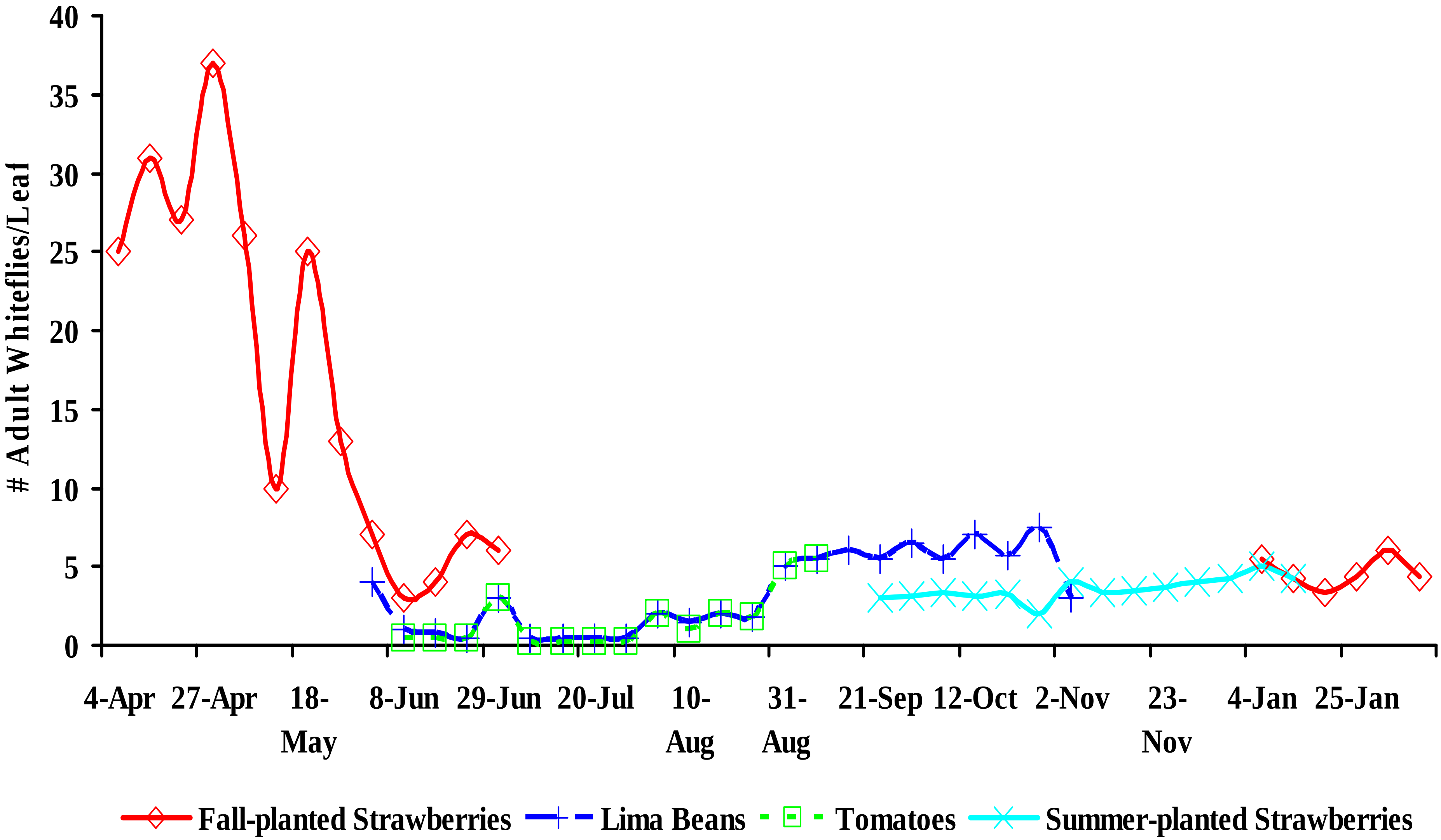
GM9

Slide 36

GM9 The analysis measures benefits from the perspective of a fall-planted strawberry grower. I do use the case of an adjacent summer strawberry planting as the first example.

Gregory Mckee, 10/11/2006

Whitefly Movement Among Crops



Source: Dr. Nick Toscano, UCR - 1999

Value of Cooperation

Three categories for all possible harvest/migration weeks:

- Optimal application dates unchanged
- Optimal application date(s) change, but can observe necessary information prior to relevant application date(s)
- Cooperation pays. Optimal application date(s) change, but can't observe prior to relevant application dates

- Overall, strawberry grower benefits from cooperation

Objective 7

Derive implications for invasive species management

Implications

- Developed and illustrated a general method for analyzing invasive species management
- Temporal and spatial relationships are critical components of an invasive species problem
  - Host and invader life cycles and population dynamics
  - Damage function
  - Market relationships
  - Easy to see roles due to the nature of our application
  - In our case, market relationships didn't matter; dominated by the other two

Implications

- Data tradeoff: controlled experiments in context of invasion scientific gold standard, but slow, expensive
  - Role for simulation analysis
    - Calibration, fit considerations
  - Use simulations to prioritize further data collection, which in turn can improve the simulation model
    - E.g. uncertainty regarding resistance parameters

Implications

- Sharing information can improve returns from invasive species management, even in the absence of coordinating management activities
  - Suggests possibility for intermediate policy choices between simply allowing private management choices and requiring regional management.