A BIO-ECONOMIC MODEL OF SPOTTED WING DROSOPHILA FOR CALIFORNIA RASPBERRIES

DEREK FARNSWORTH
WHY STUDY SWD?

• Real-world problem with tangible benefits
  • New invasive that growers are still learning how to manage
    • Lack of management information means I need to investigate
      the science of SWD in addition to the economics

• Multi-disciplinary research excellent for expanding my professional range
  • Awesome dataset and support
    • Thank you Kelly Hamby and Frank Zalom!

• Funding
  • Small Crops Research Initiative
SPOTTED WING DROSOPHILA (SWD)

- SWD (*Drosophila suzukii*) is an invasive species
  - Commonly known as a type of fruit or vinegar fly
  - Originates from Japan
  - Infests ripening fruit **unlike** other fruit flies
- First detected in California in 2008
  - Now all over the continent
    - Oregon, Washington, Florida, Michigan, Canada, Mexico, etc.
- Hundreds of millions in damages to US berry and stone fruit supply chain (Goodhue et al.)
  - California and the Pacific Northwest produce 100% of commercial raspberries and blackberries, 84% cherries, 83% strawberries, 26% blueberries
ECONOMIC COSTS OF SWD

• Fruit losses
  • SWD infests a fruit and it is not worth picking
  • SWD infestations lower a field’s quality to the point it’s not worth harvesting

• Shipment rejection
  • Too many SWD in sample
  • Pesticide usage exceeds maximum residue limit (MRL)

• Management costs
  • Additional pesticide purchases
  • Additional pesticide applications
    • Labor and equipment
SPECIFIC SWD TRAITS

• Wide range of host crops
  • Infests just about any fruit with soft-flesh in the lab
  • Particularly likes raspberries, blackberries, blueberries, cherries, and strawberries in the field

• Females possess a serrated ovipositor
  • Enables SWD to infest undamaged, ripening fruit
  • Only 2 of 3000 species of Drosophila can infest healthy crops (Bolda et al.)
    • Ovipositor scars a source of other infestations

• Males identified by distinctive spot on wings
  • Easier to detect than females
DAMAGE PHOTOS

Ovipositor Scars

Maggot

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TRAPPING PHOTOS

Example of a Trap

Raspberry
KELLY HAMBY DATA

- Weekly observations from Oct 2010 – Dec 2012
  - Watsonville raspberries
  - Organic and conventional sites
- SWD trappings (males, females, and other flies)
  - Apple cider vinegar, yeast, and water traps
  - Monthly vacuums
  - Counts for other flies only available 2011+
- SWD infestations (maggots and eggs)
  - 40 fruit sample when fruit available
- Pesticide applications
  - Amount of chemical and timing of application
STUDY DETAILS

• Commercial raspberry lifecycle is 18 month
  • 2 harvests: 1st fall of planting, 2nd spring next year
• 3 raspberry sampling blocks
  • Each block includes 3 organic and 3 conventional sites
  • Each site has 12 traps (4 apple cider, 4 yeast, 4 water)
• 2 weeks of overlap between blocks

<table>
<thead>
<tr>
<th>Dates</th>
<th>Planted (winter)</th>
<th>Harvest #1 (fall)</th>
<th>Harvest #2 (spring)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block #1</td>
<td>2009</td>
<td>2010</td>
<td>2011</td>
</tr>
<tr>
<td>Block #2</td>
<td>2010</td>
<td>2011</td>
<td>2012</td>
</tr>
<tr>
<td>Block #3</td>
<td>2011</td>
<td>2012</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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SUPPLEMENTAL DATA

• Weather data
  • Watsonville’s National Weather Service Station
  • Precipitation and temperatures

• OSU’s SWD degree day phenology model
  • Estimates generational egg-laying and emergence dates
PURPOSE

• Build a field-level, bio-economic model
  • Evaluate the scientific and economic viability of different management options
• Test the efficacy of different traps
  • Is one trap more predictive than another?
  • Do the traps capture different populations characteristics?
  • Are the traps biased?
  • Does ripening fruit bid SWD away from traps?
• Construct a biological model of infestations for SWD in California raspberries
  • Estimate past and predict future fruit damage
  • Identify major damage factors
HYPOTHESES

- Female SWD trappings predict fruit damage better than male trappings
  - Female egg-laying the cause of damage
- Pesticides are effective population control options
  - Not all pesticides effectively manage infestations
- Traps are accurate estimators of fruit damage
- Warm weather increases fruit infestations
- Major emergence and egg-laying periods implied by a degree-day phenology model of SWD correspond to increased raspberry infestations
• Test damage prediction ability of traps in different real-world scenarios
  • Not every observer has the same ability to identify SWD

• 2 observational regimes
  • Observe flies with perfect knowledge
    • Identify all flies as well as an entomologist
  • Observe flies with imperfect knowledge
    • Only observe flies, not type or gender
TRAPPINGS

Apple-cider-vinegar traps

Yeast-sugar-water traps
PERFECT KNOWLEDGE

### Apple-cider-vinegar traps

<table>
<thead>
<tr>
<th></th>
<th>Infestations</th>
<th>coef.</th>
<th>std. err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. = 676</td>
<td>R-sq. = 0.116</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male SWD</td>
<td>0.320</td>
<td></td>
<td>(0.279)</td>
</tr>
<tr>
<td>Female SWD</td>
<td>2.023***</td>
<td></td>
<td>(0.350)</td>
</tr>
<tr>
<td>Other Flies</td>
<td>-0.00713</td>
<td></td>
<td>(0.184)</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1

### Yeast-sugar-water traps

<table>
<thead>
<tr>
<th></th>
<th>Infestations</th>
<th>coef.</th>
<th>std. err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. = 676</td>
<td>R-sq. = 0.164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male SWD</td>
<td>-0.0171</td>
<td></td>
<td>(0.410)</td>
</tr>
<tr>
<td>Female SWD</td>
<td>2.223***</td>
<td></td>
<td>(0.306)</td>
</tr>
<tr>
<td>Other Flies</td>
<td>0.297</td>
<td></td>
<td>(0.211)</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
## Imperfect Knowledge

**Apple-cider-vinegar traps**

<table>
<thead>
<tr>
<th>Obs. = 676</th>
<th>Infestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-sq. = 0.086</td>
<td>coef.</td>
</tr>
<tr>
<td>All Flies</td>
<td>0.677***</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1

**Yeast-sugar-water traps**

<table>
<thead>
<tr>
<th>Obs. = 676</th>
<th>Infestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-sq. = 0.134</td>
<td>coef.</td>
</tr>
<tr>
<td>All Flies</td>
<td>0.880***</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.1
INTERPRETATIONS

• Yeast-sugar-water is the better trap
  • Explains more of the variation
  • Performs better in both regimes
  • Explains damages with females

• Apple-cider-vinegar traps have much less explanatory power and are misleading
  • Seems to trap *Drosophila melanogaster* (typical fruit fly) better than *Drosophila suzukii* SWD
EXPLAIN SWD RASPBERRY INFESTATIONS WITH
- Past infestations
- Current population
- Weather
- Predicted egg-laying/emergence dates
- Field type (organic?)
- Field location
- Insecticide applications

USE POOLED OLS
BIOLOGICAL MODEL RESULTS

<table>
<thead>
<tr>
<th>Obs. = 900</th>
<th>% Infestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-sq. = 0.811</td>
<td>coef.</td>
</tr>
<tr>
<td>Lagged Infestations</td>
<td>0.529</td>
</tr>
<tr>
<td>Female SWD</td>
<td>0.0159</td>
</tr>
<tr>
<td>Degree Days (last week)</td>
<td>0.0168</td>
</tr>
<tr>
<td>Peak 2nd Gen. Emergence</td>
<td>1.45</td>
</tr>
<tr>
<td>Peak 2nd Gen. Egg-laying</td>
<td>1.53</td>
</tr>
<tr>
<td>Organic Dummy</td>
<td>0.909</td>
</tr>
<tr>
<td>Block Dummy #1</td>
<td>-0.301</td>
</tr>
<tr>
<td>Block Dummy #2</td>
<td>-0.827</td>
</tr>
<tr>
<td>Entrust and Pyganic week 1</td>
<td>-0.419</td>
</tr>
<tr>
<td>Entrust and Pyganic week 2</td>
<td>-0.529</td>
</tr>
<tr>
<td>Delegate week 1</td>
<td>-0.313</td>
</tr>
<tr>
<td>Delegate week 2</td>
<td>-0.354</td>
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<tr>
<td>Delegate week 3</td>
<td>-0.698</td>
</tr>
<tr>
<td>Mustang and Malathion week 2</td>
<td>-0.300</td>
</tr>
<tr>
<td>Mustang and Malathion week 3</td>
<td>-0.313</td>
</tr>
</tbody>
</table>
• Female population and lagged infestations explain most of the variation
• Warm weather increases infestations
• Peak egg-laying and emergence periods for 2nd generation are major infestation events
• Infestations tend to be more severe in organic fields and can vary substantially between sites
• Insecticides are effective control options
  • Organic insecticide Pyganic ineffective
  • Conventional insecticides Mustang and Malathion underperform expectations
SUMMARY

- Yeast-sugar-water traps and fruit-sampling are effective estimators of infestations
- Most insecticides effective at controlling SWD
  - 50%-70% reduction in infestations 2-3 weeks later with Entrust (organic) and Delegate (conventional)
    - Don’t use Pyganic to manage SWD
  - Insecticide applications timing endogenous
    - Grower detects large SWD population and applies insecticide
- Established basics of controlling SWD
  - Use trappings and/or fruit sampling to track population
  - Apply insecticides 2-3 weeks prior to predicted 2nd generation egg-laying and emergence dates
FUTURE WORK

- Value costs, risks, and losses
  - Fruit losses
    - Infestations
    - Stopping harvest early
  - Shipment rejection
    - Too many infestations
    - Exceeding pesticide residue limits
  - Management costs
    - Skilled labor and equipment to apply insecticides
    - Unskilled labor to perform field sanitation
    - Insecticide costs and label restrictions
IDEAS

• A continuous scale for raspberry losses
  • % Loss = Infestations/40 if Infestations<40, otherwise 100%
    • Use 40 because 40-fruit sample
    • Worst infestations are 200+ maggots in 1 sample

• Incorporate other fruits and counties

• Test if harvest ends earlier in high infestation years
  • Account for weather and first harvest

• Model risk of rejection
  • Increases with % Loss and additional pesticide applications
  • Should Driscoll’s test fruit more during warm weeks?
MORE IDEAS

- IPM costs = Additional insecticides, capital usage, and labor hours
- Calculate the opportunity cost of unskilled labor
  - Attempt to explain lack of field sanitation
  - Possibly incorporate results from California labor paper
- Simulate potential benefits to research
  - Using yeast-sugar-water vs. other traps
  - Timing insecticide applications to population events
- Test for significant increase in CA pesticide use
  - Pesticide Use Reporting (PUR) database
QUESTIONS?

Thank you!