A brief history of *Cactoblastis cactorum* and its effects on Florida native *Opuntia*
Cactoblastis cactorum - Intro

- Family – Pyralidae
- Native to South America
- Feeds exclusively on opuntioid species of cacti
  - *Opuntia*, *Consolea*, *Nopalea*
Cactoblastis cactorum - Intro

- Adult: 5-10 days
- Eggstick: 25-30 days
- Pupal: 15-20 days
- Larval: 30-35 days
Cactoblastis cactorum - History

• 1926-1931
  – Successful biological control agent in Australia
  – 25 million ha of prickly pear cleared

Photos by A.P. Dodd
Cactoblastis cactorum - History
Cactoblastis cactorum - History

- 1957 - Introduced on the Caribbean Island of Nevis
- Used to control native, weedy cacti
  - O. dillenii
  - O. triacantha
- 1960s-80s - Spread through Caribbean, to Puerto Rico, Cuba, Dominican Republic
Cactoblastis cactorum - History

• 1989 - First US record on Big Pine Key, FL
• Has spread northward and westward
  – At least two introductions (Simonsen et al 2008)
  – Northern limit is Bull Island, SC
  – Western leading edge is thought to be coastal LA
Cactoblastis cactorum detections in the Southeastern United States

Farthest Western Outbreak: Delta area south of New Orleans

Oct. 1989 First Continental US Detection – Bahia Honda Key, FL
Cactoblastis cactorum - Control

• Without intervention, the moth was estimated to reach TX coast by 2007

• The USDA intervened
  – Cactus Moth Program begun in 2003
Cactoblastis cactorum - Control

• Sterile Insect Technique
  – AL and MS islands
• Pheromone trapping
• Sanitation/host plant removal
• Sentinel sites for monitoring
• National detection network
• Visual surveys
**Cactoblastis cactorum - Control**

- Ultimate goal is to keep out of desert SW and Mexico
- **Mexico**
  - 56 species of *Opuntia*, 38 endemic
  - 3 million ha wild
  - >200,000 ha cultivated
  - Production value ~200 million USD/yr (Cibrian 2007)
Cactoblastis cactorum - Florida

- Three generations per year
- Host species:
  - Opuntia stricta
  - Opuntia humifusa
  - Opuntia pusilla
  - Opuntia triacanthan *
  - Consolea corallicola *
  - Opuntia cubensis

* State endangered species
Opuntia - Florida

Chelinidea vittiger aequoris  
(cactus coreid)

Gophermus polyphemus  
(Gopher tortoise)

Gerstaeckeria hubbardi  
(cactus weevil)
Melitara prodenialis - native moth

- Damage and adults very similar to *Cactoblastis*
- Larvae are grey to blue-black,
- Tends to be inland
Previous work – Baker and Stiling 2009

% Coastal - non-native Cactoblastis  Inland - native Melitara

- Plants w/ moth damage
- Cladodes w/ moth damage
- Plant mortality
- Survival of moth-damage plants
- Plants w/ Chelinid damage
- Plants w/ Dactylopius damage

n = 600 inland and 500 coastal
Plants followed for 2 years, July 2003 – July 2005 and monitored monthly
Questions?

1. Are plants attacked by *Cactoblastis* more likely to die than unattacked plants?
2. Does a higher attack frequency increase likelihood of death?
3. Are there species differences?
4. How does *Cactoblastis* attack affect growth?
Methods – Sites

• Three coastal sites
  – Honeymoon Island SP
  – Fort deSoto SP
  – Lido Key
Methods - censusing

- 580 plants (327 *humifusa*, 253 *stricta*)
- 2003-2005: Censused monthly
- 2005-2009: Censused at each *Cactoblastis* generation (3x/yr)
- Variables recorded
  - Height (cm)
  - Total # of cladodes
  - # of cladodes with larvae
  - # of cladodes with eggsticks
Survival and attack rates after six years

![Bar chart showing survival and attack rates for different plant species. The chart displays the proportion of plants across survival and attack categories.]

- **Survival:**
  - All plants
  - O. humifusa
  - O. stricta

- **Attack:**
  - All plants
  - O. humifusa
  - O. stricta
Q1: Are attacked plants more likely to die than unattacked plants?

*Opuntia stricta* (n=216) and *O. humifusa* (n=316) monitored for 6 years, 2003-2009.
Q1: Are attacked plants more likely to die than unattacked plants?

- Log linear model
- $H_0 = \text{Cactoblastis attack and survival are independent}$

<table>
<thead>
<tr>
<th>Parameter estimate</th>
<th>SE</th>
<th>Z</th>
<th>p</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G^2$</td>
<td>$p$</td>
<td>1.19</td>
<td>0.376</td>
<td>3.16</td>
<td>0.002</td>
</tr>
<tr>
<td>13.52</td>
<td>0.0002</td>
<td></td>
<td></td>
<td>0.451</td>
<td>1.93</td>
</tr>
</tbody>
</table>
Q1: Are attacked plants more likely to die than unattacked plants?

• Odds ratio = \frac{\text{odds of dying if attacked}}{\text{odds of dying if unattacked}}

<table>
<thead>
<tr>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.45</td>
<td>1.65</td>
</tr>
</tbody>
</table>
Q3: Are there species differences?

- Log linear model
- $H_0 = \text{Cactoblastis} \text{ attack and Opuntia species are independent}$

<table>
<thead>
<tr>
<th>$G^2$</th>
<th>$p$</th>
<th>Parameter estimate</th>
<th>SE</th>
<th>Z</th>
<th>$p$</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 0.000</td>
<td>1.59</td>
<td>0.250</td>
<td>6.33</td>
<td>&lt; 0.000</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.08</td>
</tr>
</tbody>
</table>
Q3: Are there species differences?

- Odds ratio = odds of *O. stricta* being attacked
  odds of *O. humifusa* being attacked

<table>
<thead>
<tr>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.98</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>3.03</td>
</tr>
</tbody>
</table>
Q3: Are there species differences?

- Log linear model
- $H_0 =$ mortality after *Cactoblastis* attack and *Opuntia* species are independent

<table>
<thead>
<tr>
<th>$G^2$</th>
<th>$p$</th>
<th>Parameter estimate</th>
<th>SE</th>
<th>$Z$</th>
<th>$p$</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>14.57</td>
<td>&lt; 0.000</td>
<td>0.945</td>
<td>0.255</td>
<td>3.71</td>
<td>&lt; 0.000</td>
<td>0.445</td>
</tr>
</tbody>
</table>
Q3: Are there species differences?

- Odds ratio = \( \frac{\text{odds of } O. \text{ stricta dying after attack}}{\text{odds of } O. \text{ humifusa dying after attack}} \)

<table>
<thead>
<tr>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.60</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>1.57</td>
</tr>
</tbody>
</table>
Q2: Does a higher attack frequency increase likelihood of death?

\[
\text{Attack frequency} = \frac{\text{Number of generations attacked}}{\text{Number of generations observed}}
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SE</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td># gens attacked</td>
<td>2.57</td>
<td>0.100</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td># gens observed</td>
<td>16.42</td>
<td>0.183</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Attack frequency</td>
<td>0.17</td>
<td>0.006</td>
<td>0</td>
<td>0.74</td>
</tr>
</tbody>
</table>
Q2: Does a higher attack frequency increase likelihood of death?

• Logistic regression
• Dependent - survival
• Predictors - attack frequency and cladode number
• Used only plants which were attacked
Q2: Does a higher attack frequency increase likelihood of death?

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\beta$</th>
<th>$p$</th>
<th>Change in $G^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.12</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attack frequency</td>
<td>-4.294</td>
<td>0.000</td>
<td>29.75</td>
<td>0.000</td>
</tr>
<tr>
<td>Cladode number</td>
<td>0.006</td>
<td>0.039</td>
<td>5.65</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Negative $\beta$ indicates that odds of survival go down as attack frequency increases.
Q4: How does *Cactoblastis* attack affect growth?

<table>
<thead>
<tr>
<th>Growth*</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All plants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unattacked</td>
<td>127</td>
<td>-.0183</td>
<td>.06683</td>
<td>0.157</td>
<td>0.692</td>
</tr>
<tr>
<td>Attacked</td>
<td>453</td>
<td>-.0142</td>
<td>.10187</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Surviving plants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unattacked</td>
<td>109</td>
<td>.0046</td>
<td>.06683</td>
<td>2.142</td>
<td>0.144</td>
</tr>
<tr>
<td>Attacked</td>
<td>331</td>
<td>.0199</td>
<td>.10187</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Growth was quantified as the proportional change in cladodes per generation*
Q4: How does *Cactoblastis* attack affect growth?

For surviving plants, there is no relationship between attack frequency and growth $R^2=0$, $p=0.773$.
Conclusions

• *Cactoblastis* attack rates are high, but so is overall survival
• Plants are more likely to die when attacked
• Odds of survival decrease with increasing attack frequency
• *O. stricta* is more likely to get attacked AND more likely to die after an attack than *O. humifusa*
Conclusions

• Surviving plants showed positive growth over the six years

• For surviving plants, growth does not seem to be affected by *Cactoblastis* attack frequency
Future directions

• Fitness measures
  – Fruit/seed sets
  – Vegetative versus sexual reproduction

• Effects on native *Opuntia*-feeding arthropods, including status of *Melitara*

• Interactions with ants
Acknowledgements

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References


• Cibrian Tovar J. 2007. Potential Economic Impacts of *C. cactorum* in Mexico. Presented at The International *Cactoblastis cactorum* Conference, Phoenix, AZ.
