**Conservation Biological Control:** Can it Work in the Cotton System?

Dr. Steven E. Naranjo, USDA-ARS

"Manipulation of the environment to favor natural enemies, either by removing or mitigating adverse factors or by providing lacking requisites."
DeBach 1974

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**Biological Control - Approaches**

*Conservation*

Classical  Augmentation

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**Conservation Biological Control Approaches**

Reduce Direct Mortality
- Selective insecticides
- Ecological
- Physiological
- Cultural practices

Provide Resources
- Refugia
- Cover & inter-crops
- Landscape pattern
- Strip harvesting

Integrate

Controlling Secondary Enemies
- Hyperparasitism
- Intraguild predation

Manipulating Host Plant Attributes
- Plant breeding
- Transgenics
- Cultural practices

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**Conservation Biological Control Components**

Survey & Identification of Potentially Important Natural Enemies

Study of Biology & Ecology; Determination of Factors Constraining or Enhancing Biological Control

Implementation & Evaluation

Progress

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**Survey**

Is there potential for natural biological control?
**Natural Enemy Complex - Western U.S.**

- Parasitoids: 30+ species
  - Hypostris, Copidosoma, Microplitis, Lysiphlebus, Chelonus, Encarsia, Anaphes, Lysiphlebus, Chelonus, Eretmocerus
- Predators: 50+ species
  - Geocoris, Orius, Nabis, Zelus, Collops, Hippodamia, Drapetis, Chrysoperla, Misumenops
- Pathogens: Various viruses, bacteria & fungi

**Natural Enemies – Pectinophora gossypiella**

- Arizona/California
- Predators: ≈23 species described
  - 9 species (immunological ID)
- Parasitoids: 4 native species described (rare)
  - 16 exotic species introduced (0 established)
- Pathogens: 3+ Viruses and bacteria

**Natural Enemies – Bemisia tabaci**

- Worldwide
  - 114+ Predators (various methods)
  - 50+ Parasitoids
  - 11+ Fungi
- Arizona Cotton
  - 20 Predators (immunological ID)
  - 3 Native parasitoids
  - Many exotic parasitoids introduced
  - 2 established
  - 2 Fungi?

**Natural Enemies – Lygus hesperus**

- Arizona/California
- Predators: 10+ species described
  - 5 species (immunological ID)
- Parasitoids: 3 native species described
  - 2 exotic species introduced
  - Both established in CA
- Pathogens: 2+ Fungi

**Qualitative Gut Analyses**

- Pink bollworm: Total Mortality: 0.7, 0.8, 0.9, 1.0

**Natural Mortality of Bemisia (Arizona Cotton)**

- Total Mortality
  - Dislodgement (29.2%)
  - Parasitism (7.1%)
  - Inviability (8.8%)
  - Predation (33.4%)
  - Physiological & Unknown (21.5%)

- N = 14

Hagler & Naranjo 1994a,b; Naranjo & Hagler 1997

Naranjo & Ellsworth (in prep)
Biological Control Potential? (Sudan Cotton, Abdelrahman & Munir 1989)

Adult whiteflies per leaf

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Untreated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nidiana 1986/87</td>
<td></td>
</tr>
</tbody>
</table>

| Nidiana 1987/88 |

Reducing Constraints

Controlling Secondary Enemies

- Hyperparasitism
- Intraguild predation

Sorting out the Players

<table>
<thead>
<tr>
<th>Clubionidae</th>
<th>Simea spp.</th>
<th>Zeuzera spp.</th>
<th>Salticidae</th>
<th>Thomisidae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lygus hesperus</td>
<td>Geocoris spp.</td>
<td>Orius ustulatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encarsia spp.</td>
<td>Benisia</td>
<td>Eretmocerus spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasa spp.</td>
<td>Phytoseiulus persimilis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Encarsia parasitizing Eretmocerus in Bemisia

Displaced mycetome stage VS. Early 4th stage

Preference (parasitized)

- Geocoris: P<0.0001
- Orius: P<0.0001
- Hippodamia: P<0.0001

Naranjo (in prep)
**Visual Predators?**
- Late 4th Stage WF ("pupa")
- Displaced mycetomes stage
- Parasitoid pupa
- Early 4th Stage WF

**Reducing Constraints**
Can insecticides be managed to promote biological control?

**Compatibility?**

**Conventional Insecticides (by Threshold)**

Brawley, CA 1995
Maricopa, AZ 1994
- Control
- 1 leaf
- 2 leaves
- 3 leaves

**Conventional Insecticides** (by Threshold)

![Graph showing number of sprays versus total spray (degree-days after planting).]

**Insecticide Use Patterns**

*Arizona Cotton*

![Bar graph showing mean applications per acre from 1990 to 2000.]

**Selective Insecticides?**

- *Bt* Transgenic Cotton
- Applaud (Chitin Inhibitor)
- Knack (Juvenoid)

**Science or Emotion?**

- Resistance management
- Food safety
- Non-target effects

**Non-Target Effects**

- Natural enemy abundance
- Natural enemy diversity
- Natural enemy function

**Natural Enemy Abundance**

<table>
<thead>
<tr>
<th>Species</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Rhamangyna</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dipotes virosum</em></td>
<td>0.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chorizagetes carnafalicornis</em></td>
<td>0.13</td>
<td></td>
<td></td>
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<tr>
<td><em>Panolis flammea</em></td>
<td></td>
<td>0.06</td>
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<tr>
<td><em>Lycosa hentz</em></td>
<td>0.20</td>
<td>0.42</td>
<td>0.64</td>
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<tr>
<td><em>Nactis alternata</em></td>
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<tr>
<td><em>Zea mays</em></td>
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<td></td>
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<tr>
<td><em>Crynectes</em></td>
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<tr>
<td><em>Gonoelepidia</em></td>
<td>0.12</td>
<td>0.13</td>
<td>0.23</td>
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<tr>
<td><em>Gonoelepidia pallidula</em></td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lygus hesperus</em></td>
<td>0.14</td>
<td>0.20</td>
<td>0.11</td>
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<tr>
<td><em>Pseudatomoscelis seriatus</em></td>
<td>0.21</td>
<td>0.28</td>
<td>0.25</td>
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<td><em>Chrysoperla carnea</em></td>
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<tr>
<td><em>Drapetis</em></td>
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<td>0.76</td>
<td>0.53</td>
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<tr>
<td><em>Hymenoptera</em></td>
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<td>0.59</td>
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<td><em>Nabidae</em></td>
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<td>0.57</td>
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<td><em>Tetranychids</em></td>
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<td><em>Closterina</em></td>
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<td><em>Mimecyphora</em></td>
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<td>0.71</td>
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<tr>
<td><em>Agromyzidae</em></td>
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<tr>
<td><em>Nasonia</em></td>
<td></td>
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**Principal Response Curves Analysis**

- Time-dependent multivariate analysis
- Derived from redundancy analysis (constrained form of principal component analysis)
- Provides a simple means of visualizing and testing the overall response of a biological community to an environmental disturbance

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**Selectivity of Bt cotton**

<table>
<thead>
<tr>
<th>Year</th>
<th>Selectivity</th>
<th>P-value</th>
</tr>
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<tbody>
<tr>
<td>1999</td>
<td>Bt cotton</td>
<td>0.05</td>
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<td>Non-Bt</td>
<td>0.13</td>
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<tr>
<td>2001</td>
<td>Bt cotton</td>
<td>0.005</td>
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</tr>
<tr>
<td>2002</td>
<td>Bt cotton</td>
<td>0.006</td>
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<tr>
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<td>Non-Bt</td>
<td>0.13</td>
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<tr>
<td>2003</td>
<td>Bt/RR</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>RR</td>
<td>0.13</td>
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**Selectivity of Bt/RR cotton**

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<td>0.13</td>
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</table>
Natural Enemy Function
Predation on Pink Bollworm Eggs

- Proportion eaten
- 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6
- Bt, Non-Bt

2001

Natural Enemy Function
Predation on Pink Bollworm Pupae

- Proportion eaten
- 0.0, 0.2, 0.4, 0.6, 0.8
- Bt, Non-Bt

2002

Natural Enemy Function
Mortality of Whitefly Nymphs

- Predation Parasitism
- Marginal rate of mortality
- 0.0, 0.2, 0.4, 0.6, 0.8
- Bt, Non-Bt

2002

Selective Insecticides?

- Bt Transgenic Cotton
- Applaud (Chitin Inhibitor)
- Knack (Juvenoid)

Selectivity of IGRs

- 1997
- Canonical coefficient
- P = 0.002
- Control

Selectivity of IGRs

- 1999
- Canonical coefficient
- P = 0.002
- Control

Implementation & Evaluation

Can conservation contribute to pest control?

Life Table Analyses

Impact of Conservation

Pest Management

Foundation of IPM
Some mitigating factors

Selective Insecticide Use
Arizona Cotton

Lygus Control - no selective options!

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