New York State
Pollinator Protection Plan

Pollinator Health:
What we know

Cornell University
College of Agriculture and Life Sciences
Pollination is a critical ecosystem service
Both wild native bees and honey bees are crucial to agricultural production.

Honey bee colony deaths were 54% in New York last year.
The “pollination gap” is filled by wild bees...

Relationship between number of managed honey bee colonies in the United States and the total production (in metric tons) of directly dependent (DD) crops over the period 1992 to 2009. [Calderone 2012]
Bees of New York

Managed: 3
Wild/Native: 413

53 species (~13%) are in decline
Native Bee Decline: Range contractions and extinctions of native bees

Goulson et al. 2015. Science

Key
- Observations 2002-2012
- Current range (2002-2012)
- Historic range (pre-2002)

Bombus affinis
The rusty patched bumble bee
Contributions to poor pollinator health

Pests & Pathogens

Agrochemicals

Climate Change

Management Practices

Habitat
Interacting factors contribute to poor pollinator health

- Pests & Pathogens
- Climate Change
- Agrochemicals
- Management Practices
- Habitat
Factors we can control and how they affect bee health

- Pests & Pathogens
- Climate Change
- Agrochemicals
- Management Practices
- Habitat
1) Pesticide negatively affect honey bee health
2) Pesticides negatively affect wild native bee abundance and diversity
3) These negative effects on bee communities can be buffered by landscape context - bee abundance and diversity increase with diverse natural habitat.
4) Fungicides can impact bees more than pesticides
How do diet and pesticide exposure interact to impact wild bee fitness?

Landscape

Diet

Reproduction

Pesticides

Öckinger et al., 2011
Power et al., 2012

Larsen, 2013
Meehan et al. 2011

Di Pasquale et al, 2013
Haider et al, 2014

Rundloff et al, 2015
Stanley et al, 2015
Artz & Pitts-Singer, 2015
Abbot et al, 2008
Alston et al, 2007
2015 Comparative studies: NY apple orchards

**Honey Bees**

- 30 sites
- Natural area: 35-95%
- Chemicals sprayed: 0-36
- Floral diversity: 40-200 spp.

**Assessed during pollination**

1) Pesticides in pollen
2) Landscape
3) Pollen diet

**Wild Solitary Bees**

- 17 sites:
- Natural area: 10-68%
- Chemicals sprayed: 0-36

**Assessed during pollination**

1) Pesticides in pollen
2) Landscape
3) Pollen diet
## Top 13 Pesticide residues in pollen: during apple bloom

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Brand name(s)</th>
<th>Compound Type</th>
<th>Mean residue (ppb)</th>
<th>Positive detection (ppb)</th>
<th>Limit of detection (ppb)</th>
<th>Contact LD50(ug/bee)</th>
<th>Oral LD50(ug/bee)</th>
<th>Mean Contact PHO4</th>
<th>Mean Oral PHO4</th>
</tr>
</thead>
</table>
Pesticide risk: During apple bloom

- Pollen from hives in 22/30 orchards above regulatory agency level of concern for acute or chronic exposure

- **63% pesticide risk from pesticides *not* sprayed during bloom**
## Top 10 most toxic pesticides in *Osmia* (Mason bee) pollen: during apple bloom

<table>
<thead>
<tr>
<th>Brand name(s)</th>
<th>Pesticide</th>
<th>Pesticide class</th>
<th>% Samples</th>
<th>Max ppb</th>
<th>% HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt, Hatchet, Lorsban</td>
<td><em>Chlorpyrifos</em></td>
<td>ORGANOPHOSPHATE</td>
<td>13.5%</td>
<td>143.0</td>
<td>243.10%</td>
</tr>
<tr>
<td>Avaunt</td>
<td><em>Indoxacarb</em></td>
<td>OXADIAZINE</td>
<td>9.6%</td>
<td>690.0</td>
<td>167.57%</td>
</tr>
<tr>
<td>Somonic, Somonil, Supracide, Suprathion and Entrust, Seduce, Tracer, Blackhawk</td>
<td><em>Methidathion</em></td>
<td>ORGANOPHOSPHATE</td>
<td>3.8%</td>
<td>400.0</td>
<td>52.31%</td>
</tr>
<tr>
<td>Sevin</td>
<td><em>Spinosad</em></td>
<td>SPINOSYN</td>
<td>1.9%</td>
<td>11.0</td>
<td>51.94%</td>
</tr>
<tr>
<td>Entrust, Seduce, Tracer, Blackhawk</td>
<td><em>Carbaryl</em></td>
<td>THINNER</td>
<td>50.0%</td>
<td>2289.0</td>
<td>35.38%</td>
</tr>
<tr>
<td>Actara, Cruiser, Durivo, Voliam, Phosmet</td>
<td><em>Thiamethoxam</em></td>
<td>NEONICOTINOID</td>
<td>21.2%</td>
<td>34.0</td>
<td>24.08%</td>
</tr>
<tr>
<td>Sevin</td>
<td><em>Phosmet</em></td>
<td>ORGANOPHOSPHATE</td>
<td>3.8%</td>
<td>261.0</td>
<td>4.11%</td>
</tr>
<tr>
<td>Diazinon</td>
<td><em>Diazinon</em></td>
<td>ORGANOPHOSPHATE</td>
<td>65.4%</td>
<td>20.0</td>
<td>2.62%</td>
</tr>
<tr>
<td>Couraze, Macho, Admire, Brigadier</td>
<td><em>Imidacloprid</em></td>
<td>NEONICOTINOID</td>
<td>3.8%</td>
<td>6.6</td>
<td>2.56%</td>
</tr>
<tr>
<td>Belay</td>
<td><em>Clothianidin</em></td>
<td>NEONICOTINOID</td>
<td>5.8%</td>
<td>4.8</td>
<td>1.86%</td>
</tr>
</tbody>
</table>

### Organophosphates
- Other Insecticides
- Neonicotinoids
Bee genera are differentially affected by the same chemical

LC 50 of chemicals on three bee groups

Clothianidin

- ■ = A. mellifera
- ● = B. terrestris
- ▲ = O. bicornis

Dimethoate

480 h (twice test length);
720 h (= lifetime of a summer worker A. mellifera or bumblebee)
2160 h (= life-time over wintering of a worker A. mellifera).

Heard et al, 2013
Landscape influence pollen collection & Fungicides are more prevalent in honey bee collected pollen

![Image](https://via.placeholder.com/150)

**Percent apple area** vs **Total pesticides in pollen (ppb)**

- $P < 0.001$
- $R^2 = 0.37$

**Percent apple pollen** vs **Total pesticides in pollen (ppb)**

- $P < 0.001$
- $R^2 = 0.47$

**Percent apple pollen** vs **Total fungicides in pollen (ppb)**

- $R^2 = 0.46$

Landscape influence on pollen collection & Fungicides are more prevalent in honey bee collected pollen

- **Insecticides**
- **Fungicides**

$R^2 = 0.46$

$P < 0.001$

$R^2 = 0.37$

$P < 0.001$
Fungicides, not insecticides, impact bees

Wild richness vs. wild abundance for different pesticide use intensities. The graph shows a negative correlation between pesticide use intensity (2011 pesticide use index) and wild richness, with fungicides having a more significant impact than insecticides.
Increasing floral diversity within 250 m of crop will help wild bees the most BUT reducing pesticide risk is still important

**Landscape**

AG 250

Larsen, 2013
Meehan *et al.*, 2011

AG 2000

**Diet Diversity**

\[
\text{poln1} = -0.450 (0.153)
\]

\[
\text{poln2} = +0.389 (0.130)
\]

\[
\text{poln1*poln2} = -0.1755
\]

**Pesticides**

\[
\text{pest1} = +0.320 (0.180)
\]

\[
\text{pest2} = -0.306 (0.130)
\]

\[
\text{pest1*pest2} = -0.0416
\]

**Total HQ**

Rundloff *et al.*, 2015
Stanley *et al.*, 2015
Arzt & Pitts-Singer, 2015
Abbot *et al.*, 2008
Alston *et al.*, 2007

**# Females Reproduction**

Di Pasquale *et al.*, 2013
Haider *et al.*, 2014

Öckinger *et al.*, 2011
Power *et al.*, 2012
Interesting Evidence as to why some bumble bees aren’t doing well

10,725 samples
36 *Bombus* species
284 sites
40 states
>75,000 historical records

Cameron et al. PNAS 2011
Greater parasite prevalence in species experiencing range contractions

Cameron et al. PNAS 2011

Nosema bombi
Microsporidian gut parasite

Bombus pensylvanicus
Cameron et al. PNAS 2011
Why?

Nosema bombi
Microsporidian gut parasite

Cameron et al. PNAS 2011
### Predictors of *Nosema* prevalence

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coef</th>
<th>Pithr</th>
<th>P value</th>
<th>ΔAIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log developed area</td>
<td>-0.315</td>
<td>1.00</td>
<td>0.002</td>
<td>8.5</td>
</tr>
<tr>
<td>Latitude</td>
<td>0.033</td>
<td>1.00</td>
<td>0.091</td>
<td>0.9</td>
</tr>
<tr>
<td>Log chlorothalonil</td>
<td>1.825</td>
<td>0.94</td>
<td>&lt;0.001</td>
<td>107.0</td>
</tr>
<tr>
<td>Longitude</td>
<td>-0.013</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural area fragmentation</td>
<td>-0.472</td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log human population</td>
<td>0.000</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log elevation</td>
<td>0.040</td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log 2,4-D</td>
<td>-0.409</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log captan</td>
<td>-0.240</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log aldicarb</td>
<td>2.430</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log agricultural area</td>
<td>-0.019</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*B. affinis*  
*B. occidentalis*  
*B. pensylvanicus*  
*B. terricola*
## Predictors of range contractions

<table>
<thead>
<tr>
<th>Variable</th>
<th>coef</th>
<th>Pithr</th>
<th>P value</th>
<th>ΔAIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>0.161</td>
<td>1.00</td>
<td>0.001</td>
<td>8.4</td>
</tr>
<tr>
<td>Log fungicides</td>
<td>0.342</td>
<td>0.84</td>
<td>&lt;0.001</td>
<td>32.5</td>
</tr>
<tr>
<td>Longitude</td>
<td>0.023</td>
<td>0.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log chlorothalonil</td>
<td>2.131</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log developed area</td>
<td>0.240</td>
<td>0.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log 2,4-D</td>
<td>-0.128</td>
<td>0.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log aldicarb</td>
<td>-2.636</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log captan</td>
<td>-0.125</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log human population</td>
<td>0.013</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log atrazine</td>
<td>-0.117</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log agricultural area</td>
<td>-0.009</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figures show: B. affinis, B. occidentalis, B. pensylvanicus, B. terricola*
Bumble bees: Fungicide increases the chance of infection by *Nosema* spores

*Bombus impatiens* produce fewer workers, less bee biomass, and have smaller mother queen following fungicide exposure (Bernauer et al 2015).

What is the mechanism, dear physiologists and toxicologists?

Pettis et al, 2017
Bumble bees perform poorly in suburban areas

Colony weight

<table>
<thead>
<tr>
<th>Landscape</th>
<th>Avg. weight (g)</th>
<th>Avg. number of bees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suburb</td>
<td></td>
<td>a</td>
</tr>
<tr>
<td>Organic Ag</td>
<td></td>
<td>b</td>
</tr>
<tr>
<td>Natural</td>
<td></td>
<td>b</td>
</tr>
<tr>
<td>Convent Ag</td>
<td></td>
<td>b</td>
</tr>
</tbody>
</table>

Colonies 40% lighter in suburban areas

Bumble bees perform poorly in suburban areas.
Top pesticides found in Bumble bee wax

<table>
<thead>
<tr>
<th>Compound</th>
<th>Type</th>
<th>Product</th>
<th># positive detections</th>
<th>Mean residue (ppb)</th>
<th>Mean contact WHQ</th>
<th>Mean oral WHQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imidacloprid</td>
<td>Insecticide</td>
<td>Couraze, Macho, Admire*, Brigadier*</td>
<td>1</td>
<td>2.76</td>
<td>0.009202118</td>
<td>0.0138031770</td>
</tr>
<tr>
<td>Indoxacarb</td>
<td>Insecticide</td>
<td>Avaunt</td>
<td>6</td>
<td>31.65</td>
<td>0.033669958</td>
<td>0.0121722985</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Insecticide</td>
<td>Sevin</td>
<td>20</td>
<td>12.46</td>
<td>0.001482784</td>
<td>0.0069196600</td>
</tr>
<tr>
<td>Spinetoram J</td>
<td>Insecticide</td>
<td>Radiant</td>
<td>17</td>
<td>1.59</td>
<td>0.006640809</td>
<td>0.0011384240</td>
</tr>
<tr>
<td>Spinetoram L</td>
<td>Insecticide</td>
<td>Radiant?</td>
<td>9</td>
<td>0.25</td>
<td>0.001039851</td>
<td>0.0001782600</td>
</tr>
<tr>
<td>Acetamiprid</td>
<td>Insecticide</td>
<td>Assail</td>
<td>5</td>
<td>10.36</td>
<td>0.000127890</td>
<td>0.0000714420</td>
</tr>
<tr>
<td>Piperonyl butoxi</td>
<td>Synergist</td>
<td>Pyrethrum TR, Pyronyl Crop Spray</td>
<td>93</td>
<td>0.16</td>
<td>0.000000632</td>
<td>0.000000632</td>
</tr>
<tr>
<td>Propiconazole</td>
<td>Fungicide</td>
<td>Bumper, Propimax EG, Quilt(2)</td>
<td>10</td>
<td>1.54</td>
<td>0.000162624</td>
<td>0.0007356790</td>
</tr>
<tr>
<td>Azoxystrobin</td>
<td>Fungicide</td>
<td>Custodia, Quadris, Quilt</td>
<td>93</td>
<td>43.02</td>
<td>0.000021511</td>
<td>0.0001720850</td>
</tr>
<tr>
<td>Trifloxystrobin</td>
<td>Fungicide</td>
<td>Flint, Gem, Luna Sensation</td>
<td>86</td>
<td>25.41</td>
<td>0.000012706</td>
<td>0.0000127059</td>
</tr>
<tr>
<td>Cyprodinil</td>
<td>Fungicide</td>
<td>Inspire Super, Switch 62.5 WG, Vanguard</td>
<td>19</td>
<td>9.21</td>
<td>0.000009210</td>
<td>0.0000092096</td>
</tr>
<tr>
<td>Propamocarb</td>
<td>Fungicide</td>
<td>Previcur Flex</td>
<td>4</td>
<td>7.51</td>
<td>0.000007513</td>
<td>0.0000089439</td>
</tr>
<tr>
<td>Thiophanate-Me</td>
<td>Fungicide</td>
<td>Evolve, Topsin-M 70 WSP</td>
<td>13</td>
<td>7.86</td>
<td>0.000003932</td>
<td>0.0000039323</td>
</tr>
<tr>
<td>Difenoconazole</td>
<td>Fungicide</td>
<td>Aprovia Top, Inspire Super, Quadris Top, Revus Top</td>
<td>30</td>
<td>6.9</td>
<td>0.000006902</td>
<td>0.0000036909</td>
</tr>
<tr>
<td>Pyraclostrobin</td>
<td>Fungicide</td>
<td>Pristine, Merivon, Headline, Priaxor, Cabrio EG &amp; Plus</td>
<td>77</td>
<td>1.63</td>
<td>0.000001629</td>
<td>0.0000022289</td>
</tr>
<tr>
<td>Cyflufenamid</td>
<td>Fungicide</td>
<td>Miltrex, Cyflufenamid</td>
<td>3</td>
<td>1.12</td>
<td>0.000001121</td>
<td>0.0000011211</td>
</tr>
</tbody>
</table>
Management Recommendations

- Growers should follow integrated pest & disease management practices
  - scouting early and often
  - Use disease risk models
  - Spray between late afternoon and very early morning
  - Select fungicides with lower risk rankings
  - Make effort to learn about honey bee hives within 2000m
- Grower should consider increasing natural habitat floral diversity within 250 meters of crop
- Growers and beekeepers need to communicate more
Indirect effects of fungicides

1. Fungicide exposure causes sub-lethal stress to bee increasing susceptibility to *Ascospahaera*
2. Fungicide exposure inhibits beneficial microbes and allows *Ascospahaera* to proliferate
Indirect effects of fungicides

1. Fungicide exposure causes sub-lethal stress to bee increasing susceptibility to *Ascosphaera*
2. Fungicide exposure inhibits beneficial microbes and allows *Ascosphaera* to proliferate
3. Fungicides inhibit *Ascosphaera* growth, reducing prevalence
Management Recommendations

Fungicides are generally considered of limited risk to bees, thus their use during bloom has been assumed to be relatively safe to pollinators. However research shows certain fungicides, used alone or in combination with other pesticides, can have direct or indirect harmful effects on bees. They may disrupt adult bee foraging behavior or, when residues are brought back to hives and fed to larvae, they can affect bee development.
During apple bloom

Focal crop pollen foraging

Ashley Fersch

Apple pollen

Buckthorn pollen

avg = 8.7%

avg = 38.6%
11 most common pollen species

- **Rosaceae** – apple, cherry, pear, cinquefoil, etc.
- **Vitaceae** – grape
- **Caprifoliaceae** – honeysuckle
- **Rhamnaceae** – Buckthorn
- **Cornaceae** – Dogwood
- **Juglandaceae** – Walnut
- **Onagraceae** – Willowherb
- **Oleaceae** – Privet
- **Fabaceae** – Sweet clover
- **Adoxaceae** – Viburnum
- **Brassicaceae** – mustard