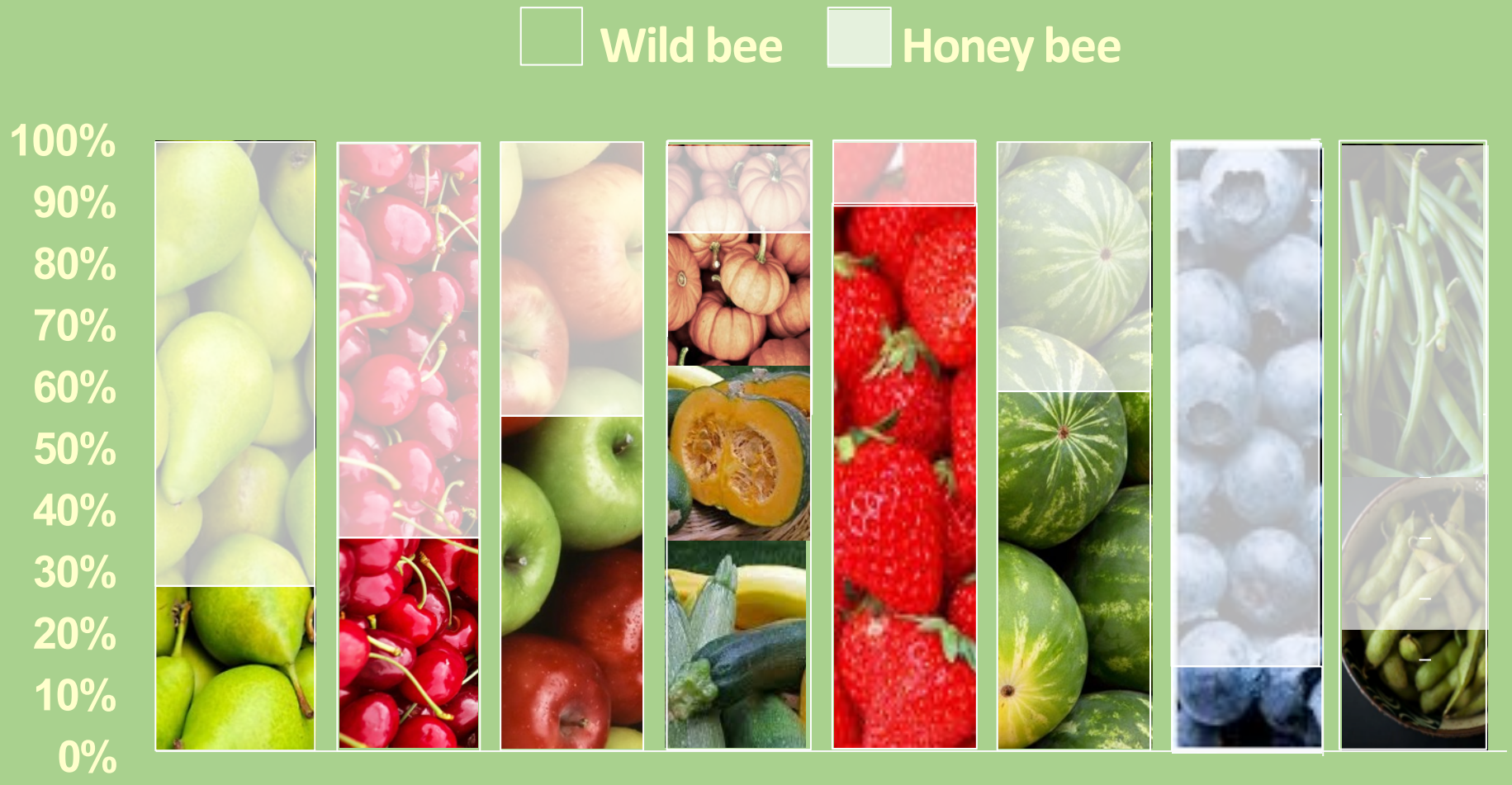
New York State
Pollinator Protection Plan

Pollinator Health:
What we know

Cornell University
College of Agriculture and Life Sciences

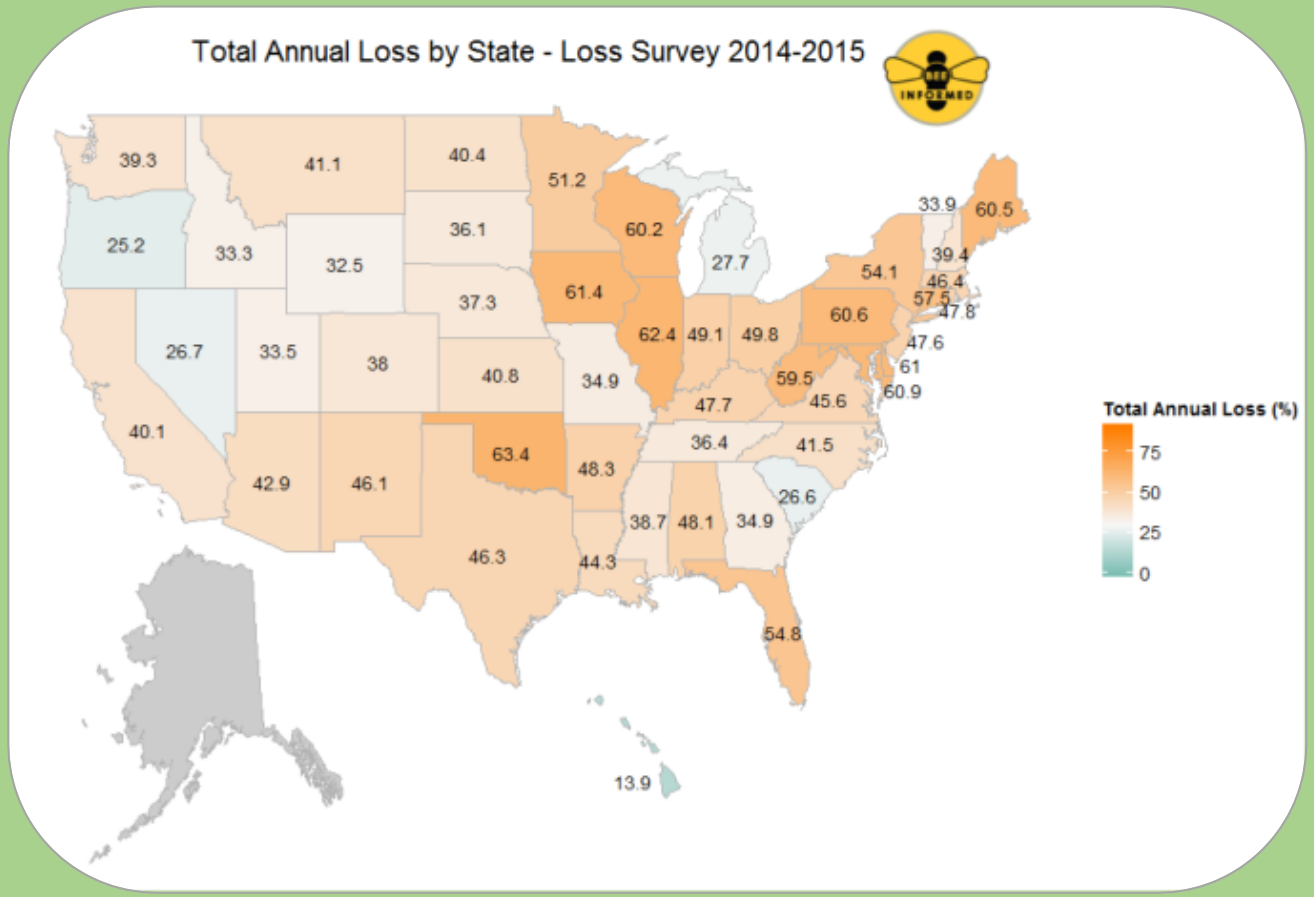
Pollination is a critical ecosystem service

Both wild native bees and honey bees are crucial to agricultural production



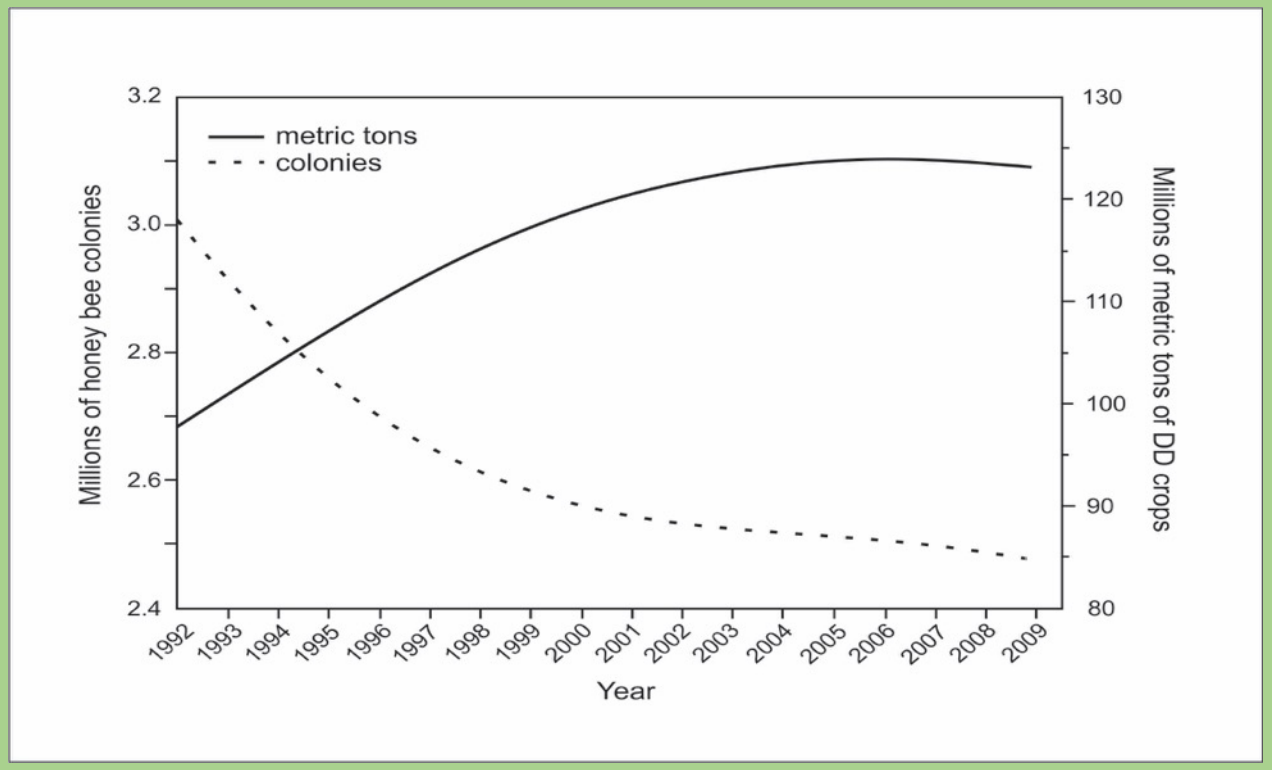
1. Lewis & Smith 1969, Russo et al 2017, Petersen et al 2013, O'Neill et al, 20??, Winfree et al 2008.

Honey bee colony deaths were 54% in New York last year



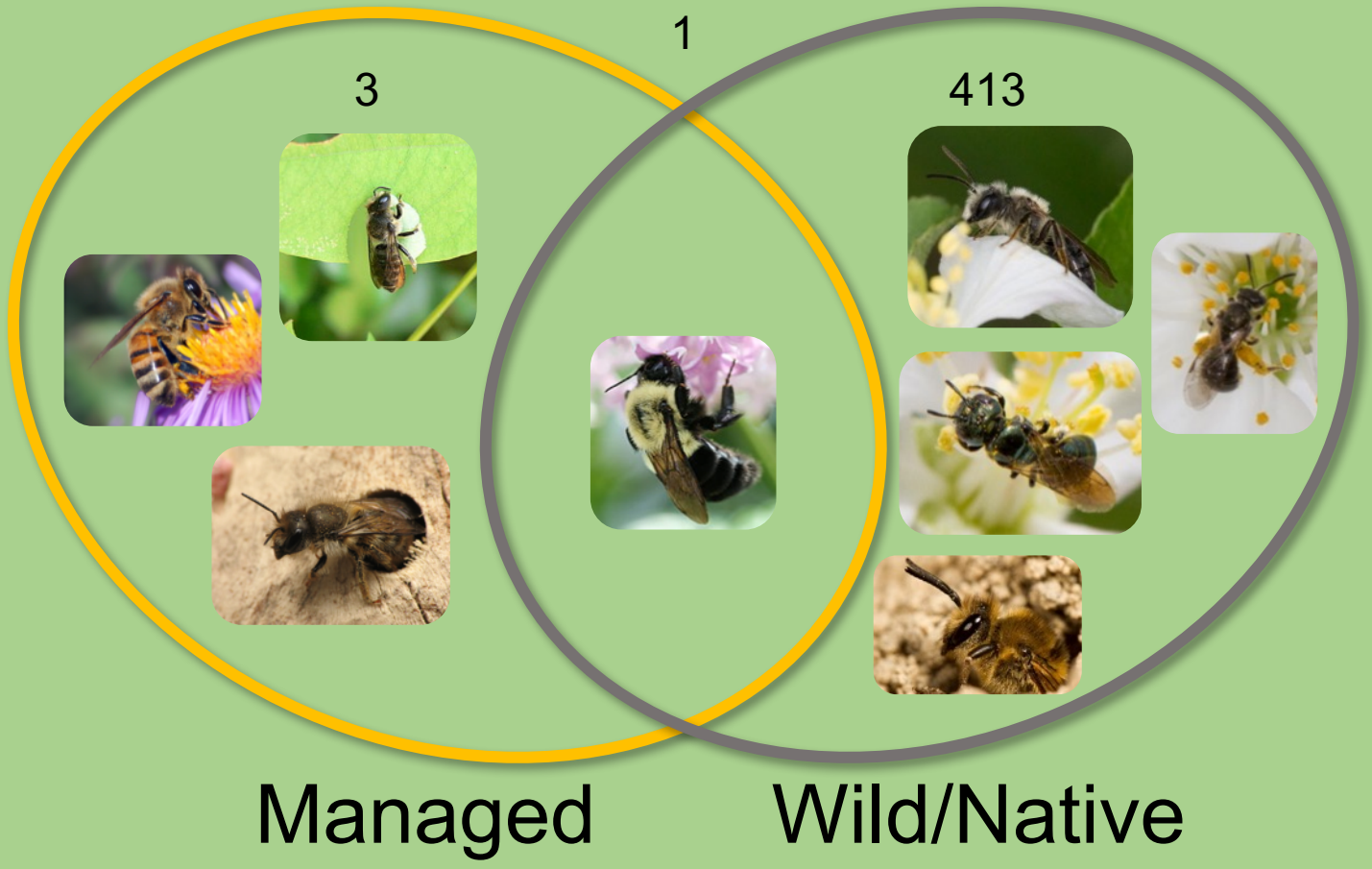
http://beeinformed.org/results/colony-loss-2014-2015-preliminary-results/

The “pollination gap” is filled by wild bees…



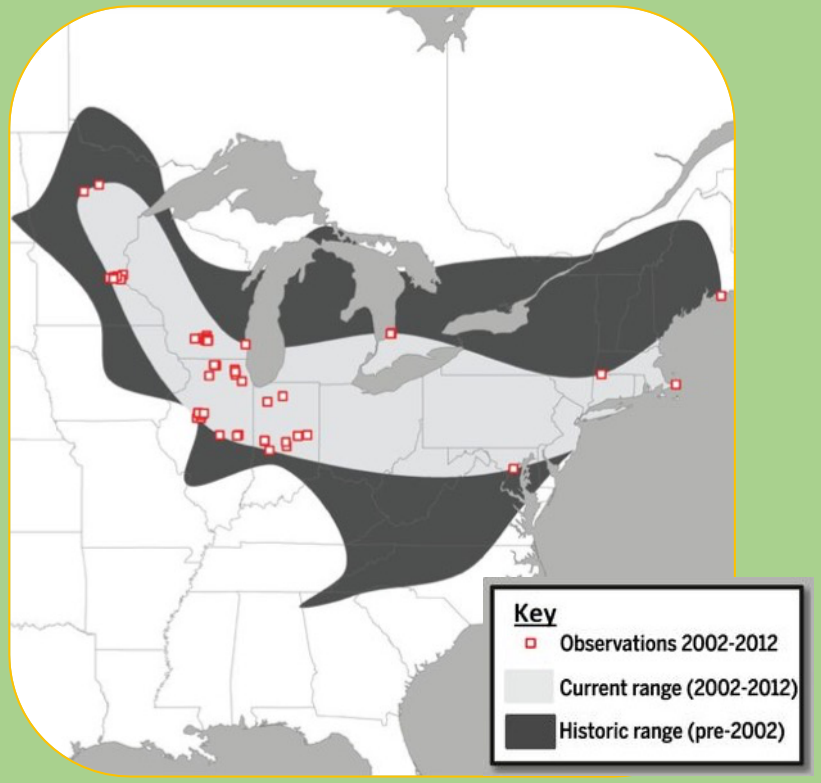
Relationship between number of managed honey bee colonies in the United States and the total production (in metric tons) of directly dependent (DD) crops over the period 1992 to 2009. Calderone 2012]

Bees of New York



53 species (~13%) are in decline

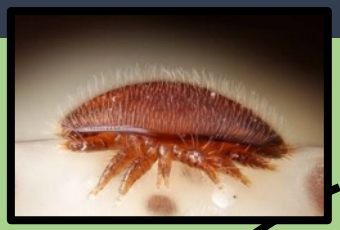
Native Bee Decline: Range contractions and extinctions of native bees



Goulson et al. 2015. Science

Bombus affinis
The rusty patched bumble bee

Contributions to poor pollinator health



Pests & Pathogens

Agrochemicals

Climate Change

Poor management

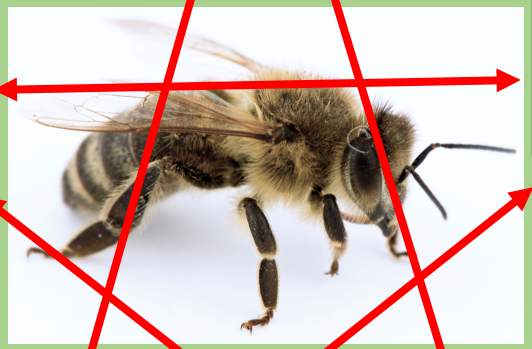
Management Practices

Habitat

Interacting factors contribute to poor pollinator health

Pests & Pathogens

Agrochemicals



Climate Change

Management Practices

Habitat

Factors we can control and how they affect bee health

Pests & Pathogens

Agrochemicals

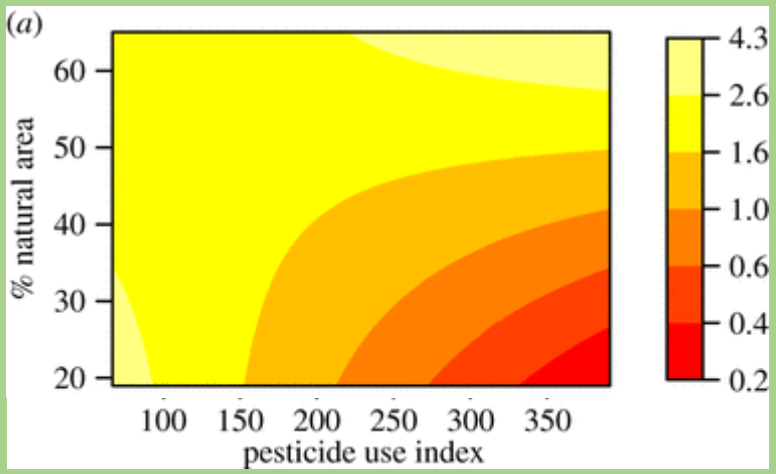
Climate Change

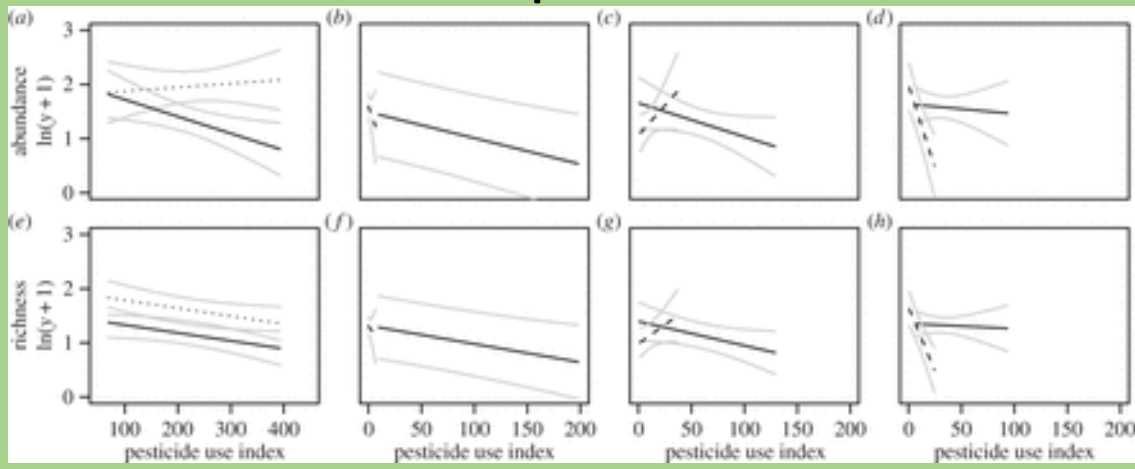
Management Practices

Habitat

Landscape and Pesticides affect pollinator health

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





Park et al 2015, McArt et al, 2017, Connelly *et al*, 2015
also see: Martins *et al*, 2015, Ricketts *et al*, 2008

How do diet and pesticide exposure interact to impact wild bee fitness?

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

Di Pasquale et al, 2013
Haider et al, 2014

Landscape

Diet

Reproduction

Pesticides

Larsen, 2013
Meehan *et al*. 2011

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:

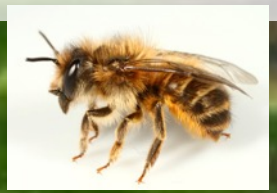
natural area: 10-68%

chemicals sprayed: 0-36

floral diversity: 62-361 spp.

Assessed during pollination

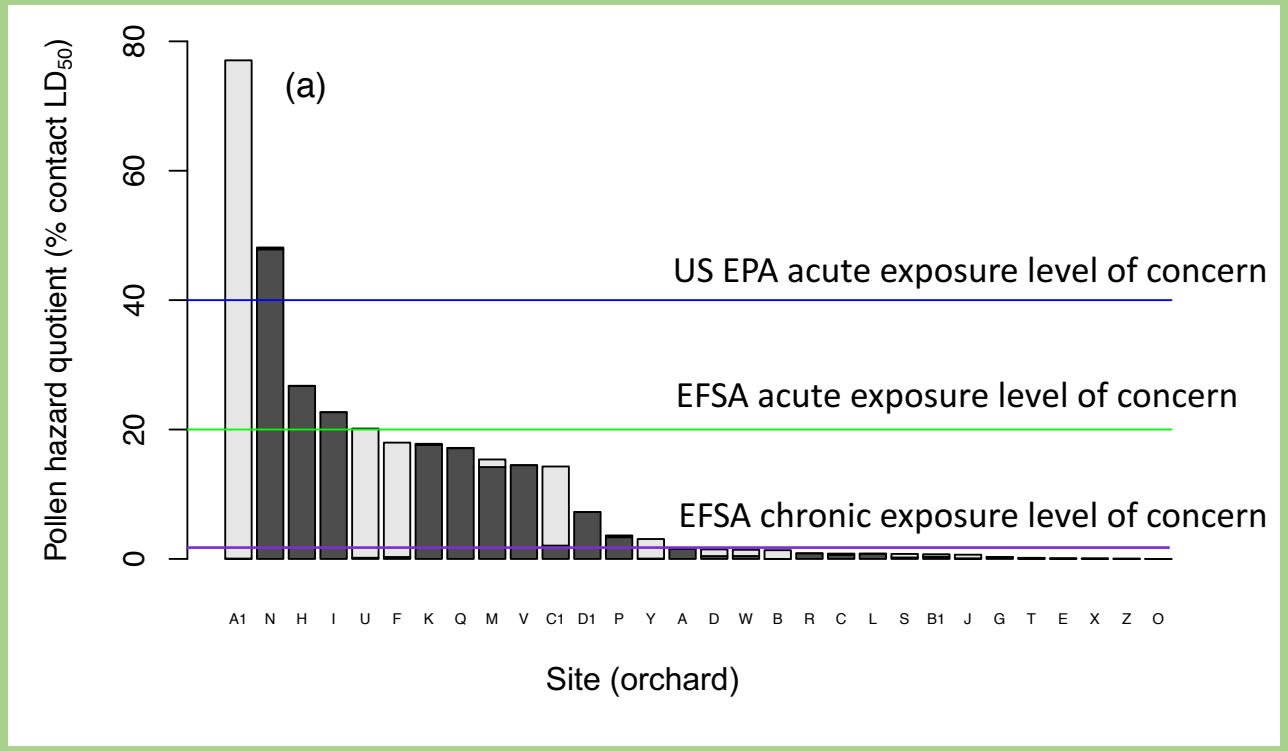
1) Pesticides in pollen
2) Landscape
3) Pollen diet



Top 13 Pesticide residues in pollen: during apple bloom

Chemical	Brand name(s)	Compound Type	Mean residue (ppb)1	Positive detection	Limit of detection (ppb)2	Contact LD50(ug /bee)3	Oral LD50(ug/ bee)3	Mean Contact PHQ4	Mean Oral PHQ4
Indoxacarb	Avaunt	Insecticide	557.1	2	35.5	0.118	0.26	4721.2	2142.7
Cyfluthrin	Leverage, Defcon, Tombston, Aztec, Baythroid	Insecticide	93.3	6	35.5	0.037	0.051	2522.8	1830.3
Thiamethoxam	Actara, Cruiser, Durivo, Platinum, Voliam	Insecticide	21.5	5	3.6	0.024	0.005	895.3	4297.2
Carbaryl	Sevin	Insecticide	69.9	11	3.6	0.84	0.15	83.2	466
Acetamiprid	Assail	Insecticide	160.5	11	1.4	7.9	14	20.3	11.5
Cyprodinil	InspireSuper, Vanguard	Fungicide	1216.4	24	0.4	100	100	12.2	12.2
Iprodione	Rovral 4	Fungicide	929.3	4	355.3	400	25	9.3	148.7
Thiophanate-methyl	Evolve, Topsin-M70 WSP	Fungicide	570	1	1.4	100	100	5.7	5.7
Fluxapyroxad	Priaxor	Fungicide	353.6	12	3.6	100	110.9	3.5	3.2
Difenoconazole	Aprovia Top, Inspire Super, QuadrisTop, RevusTop	Fungicide	327.1	22	1.4	101	177	3.2	1.9
Penthiopyrad	Fontelis	Fungicide	119.2	8	1.4	312	385	3.1	2.5
Trifloxystrobin	Flint, Gem, Luna, Sensation	Fungicide	14.1	18	0.4	200	200	1.3	1.3
Myclobutanil	Rally 40 SWP	Fungicide	49.5	1	35.5	39.6	34	1.2	1.5

Pesticide risk: During apple bloom



Pesticides sprayed during bloom (**37% of risk**)

Pesticides ***not*** sprayed during bloom (**63% of risk**)

- 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**

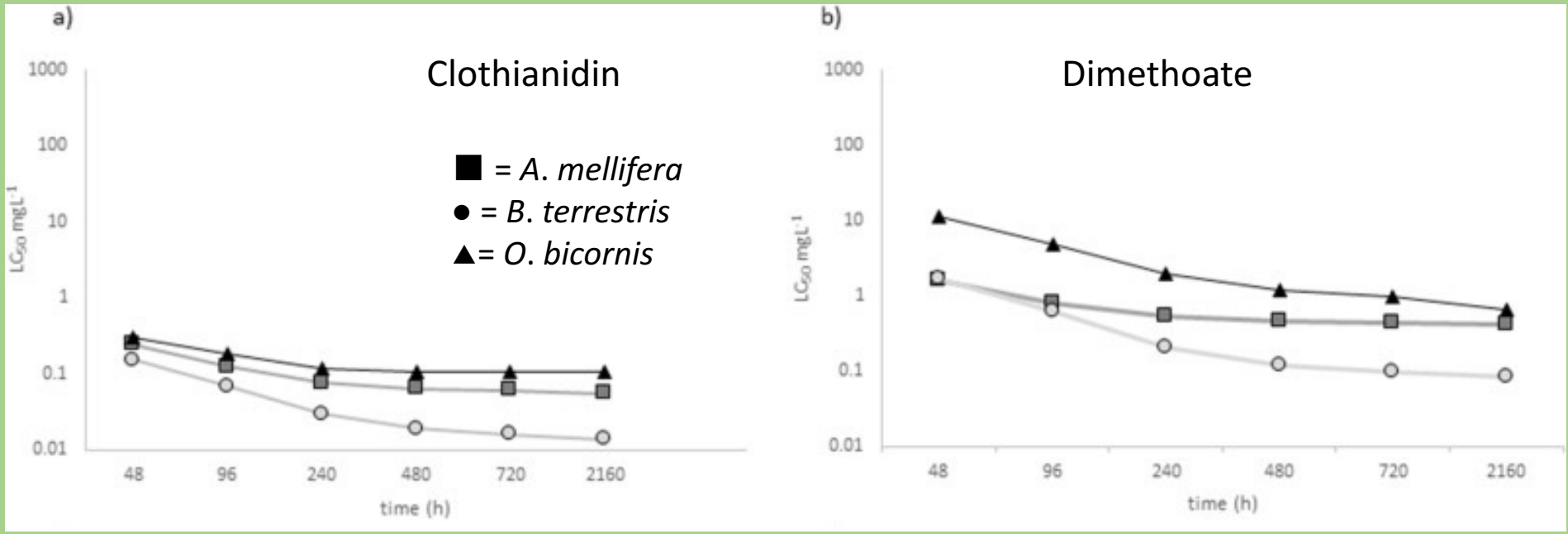
Top 10 most toxic pesticides in *Osmia* (Mason bee) pollen: during apple bloom

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

Organophosphates
Other Insecticides
Neonicotinoids

Bee genera are differentially affected by the same chemical

LC 50 of chemicals on three bee groups



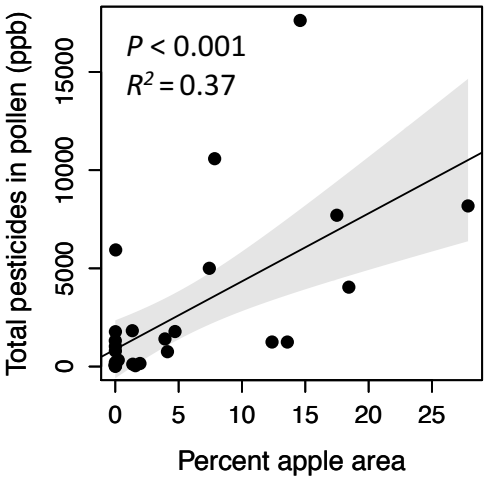
480 h (twice test length);

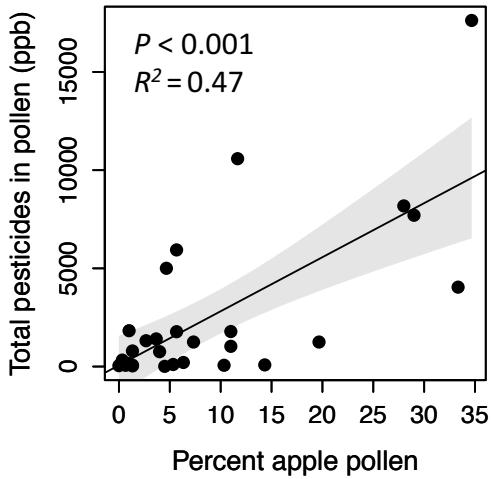
720 h (= lifetime of a summer worker *A. mellifera* or bumblebee)

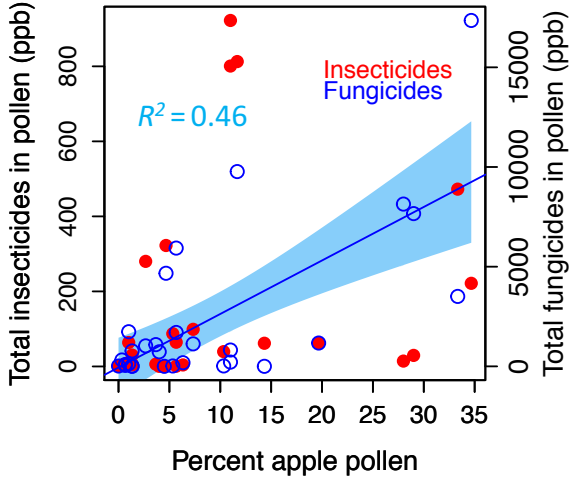
2160 h (= life-time over wintering of a worker *A. mellifera*).

Heard et al, 2013

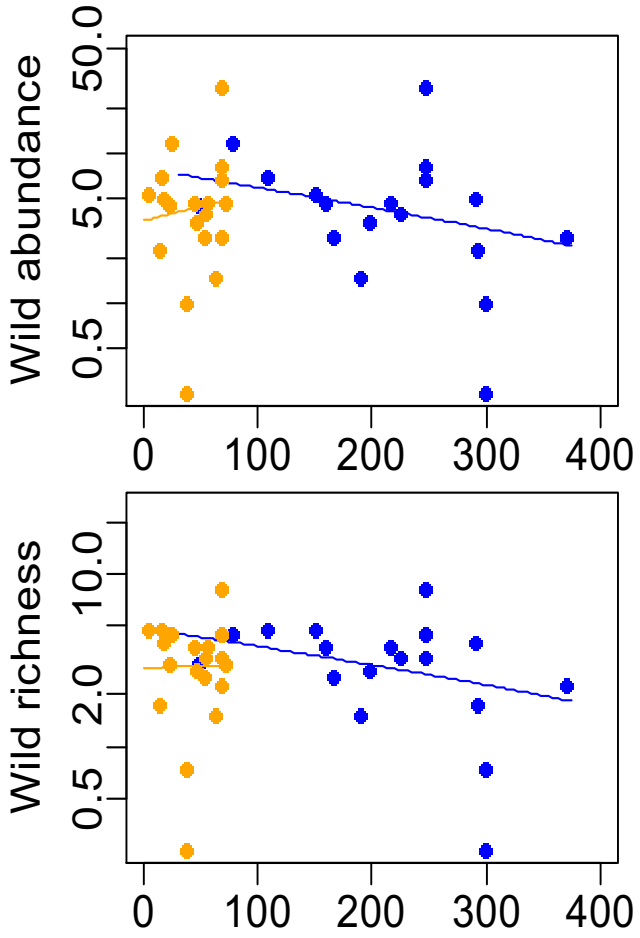
Landscape influence pollen collection &Fungicides are more prevalent in honey bee collected pollen







Fungicides, not insecticides, **impact bees**



Insecticides

Fungicides

Low intensity — 2011 pesticide use index → High intensity

Increasing floral diversity within 250 m of crop will help wild bees the most BUT reducing pesticide risk is still important

Diet Diversity

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

poln1
-0.450
(0.153)

Di Pasquale et al, 2013
Haider et al, 2014

poln2
+0.389
(0.130)

poln1*poln2= -0.1755

AG 250

Landscape

AG
2000

Females
Reproduction

pest1*pest2=-0.0416

Pesticides

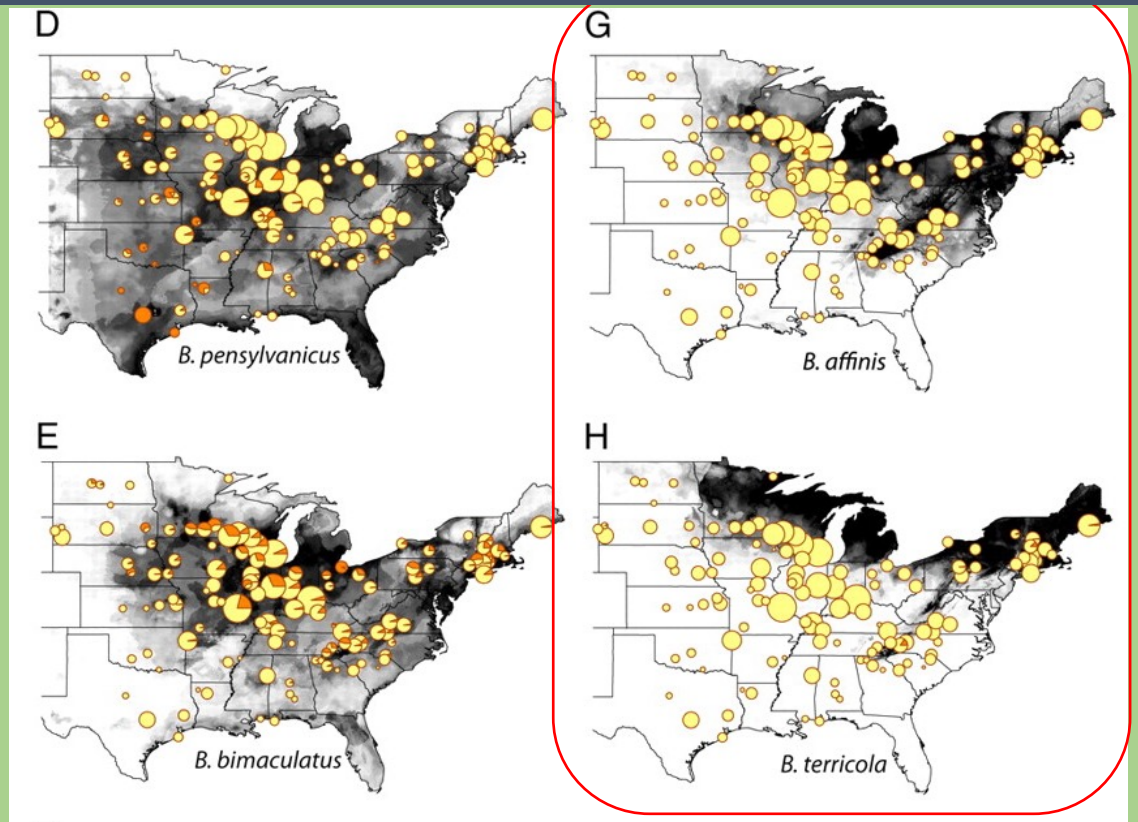
pest1
+0.320
(0.180)

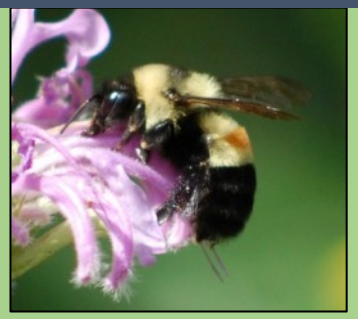
pest2
-0.306
(0.130)

Larsen, 2013
Meehan *et al*. 2011

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

Interesting Evidence as to why some bumble bees aren't doing well





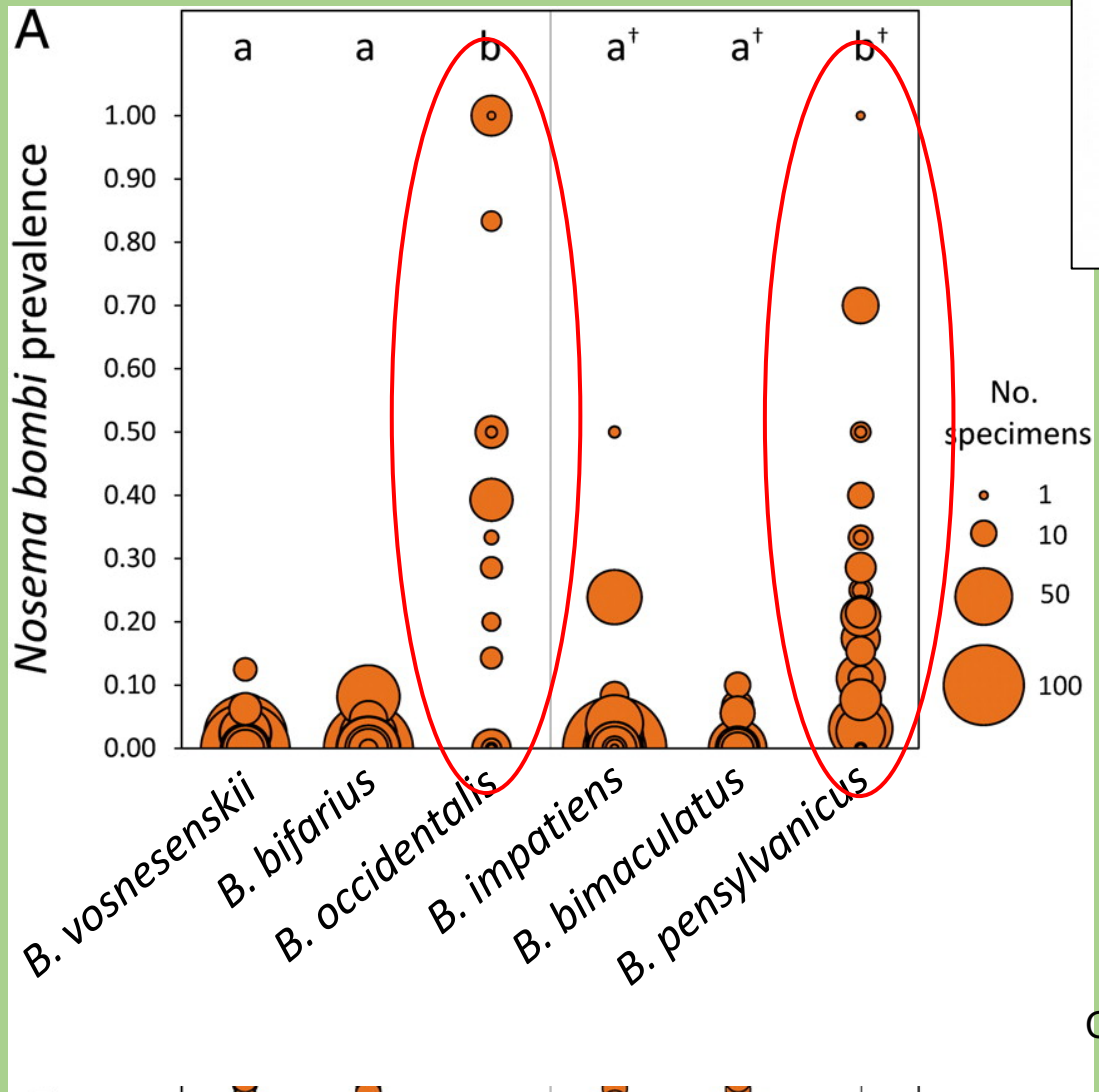
Bombus affinis

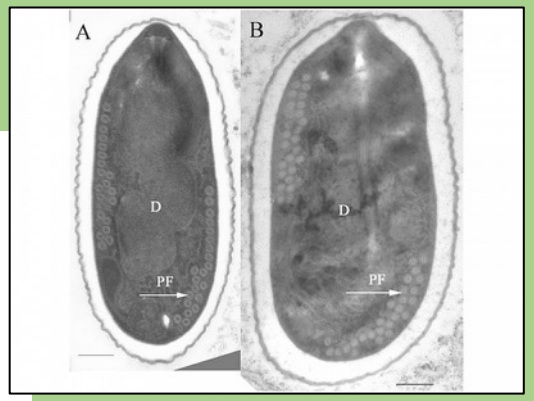
Bombus terricola

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





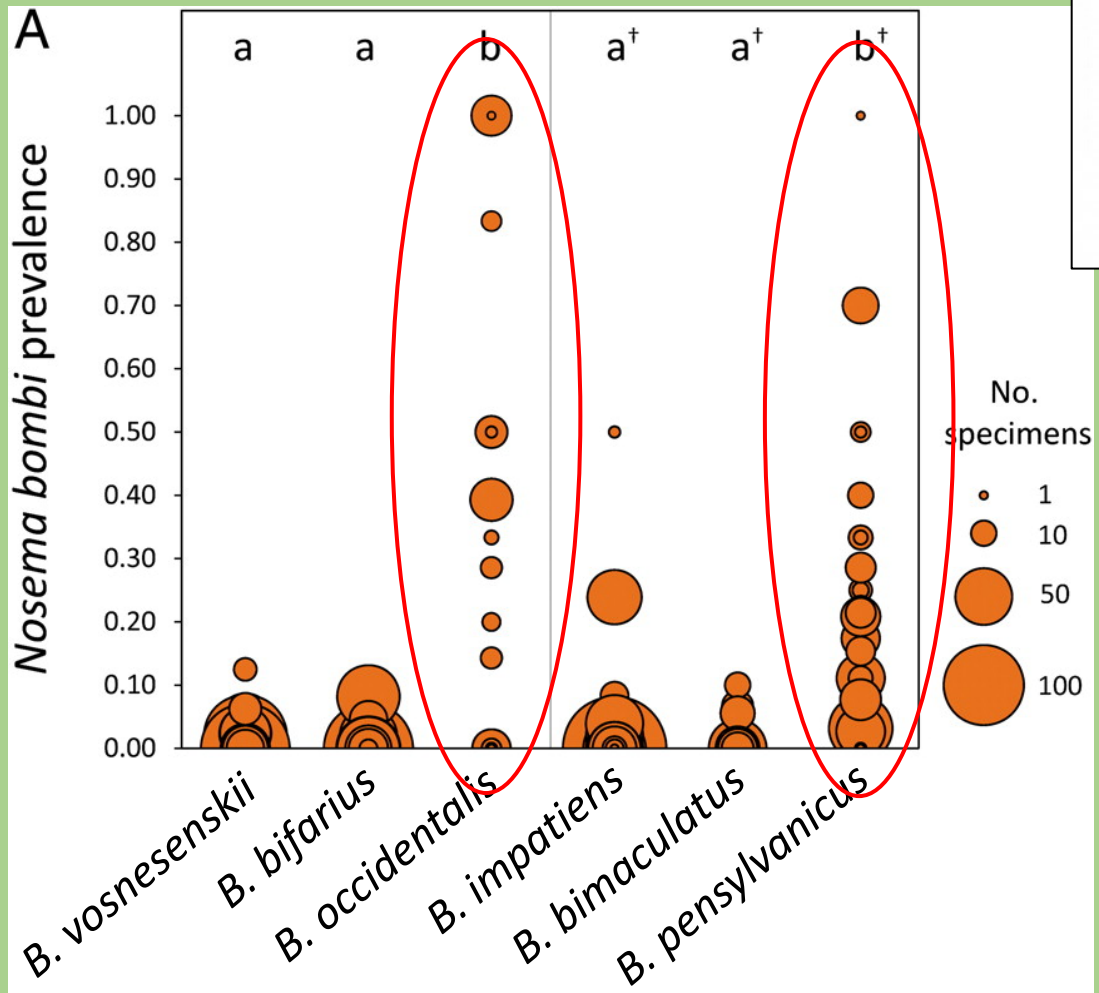
Nosema bombi

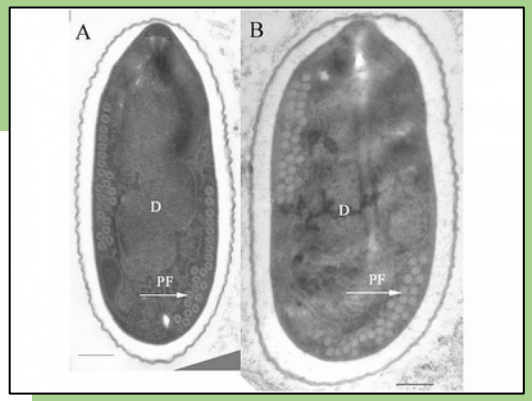
Microsporidian gut parasite

Bombus pensylvanicus

Cameron et al. PNAS 2011

Why?





Nosema bombi

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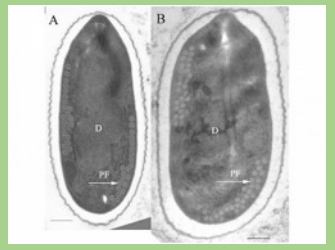
Cameron et al. PNAS 2011

Predictors of *Nosema* prevalence



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

B. affinis

B. occidentalis

B. pensylvanicus

B. terricola

Predictors of range contractions

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

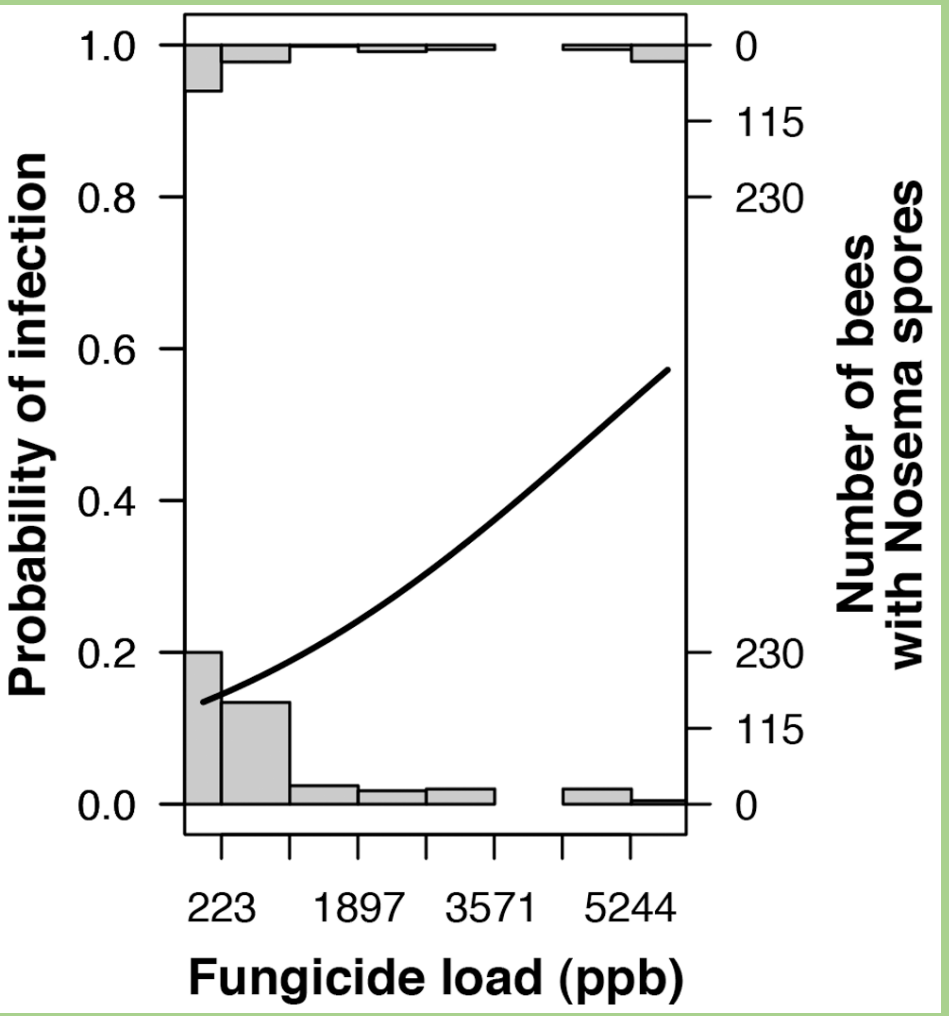
B. affinis

B. occidentalis

B. pensylvanicus

B. terricola

Bumble bees: Fungicide increases the chance of infection by **Nosema** spores



Pettis et al, 2017

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

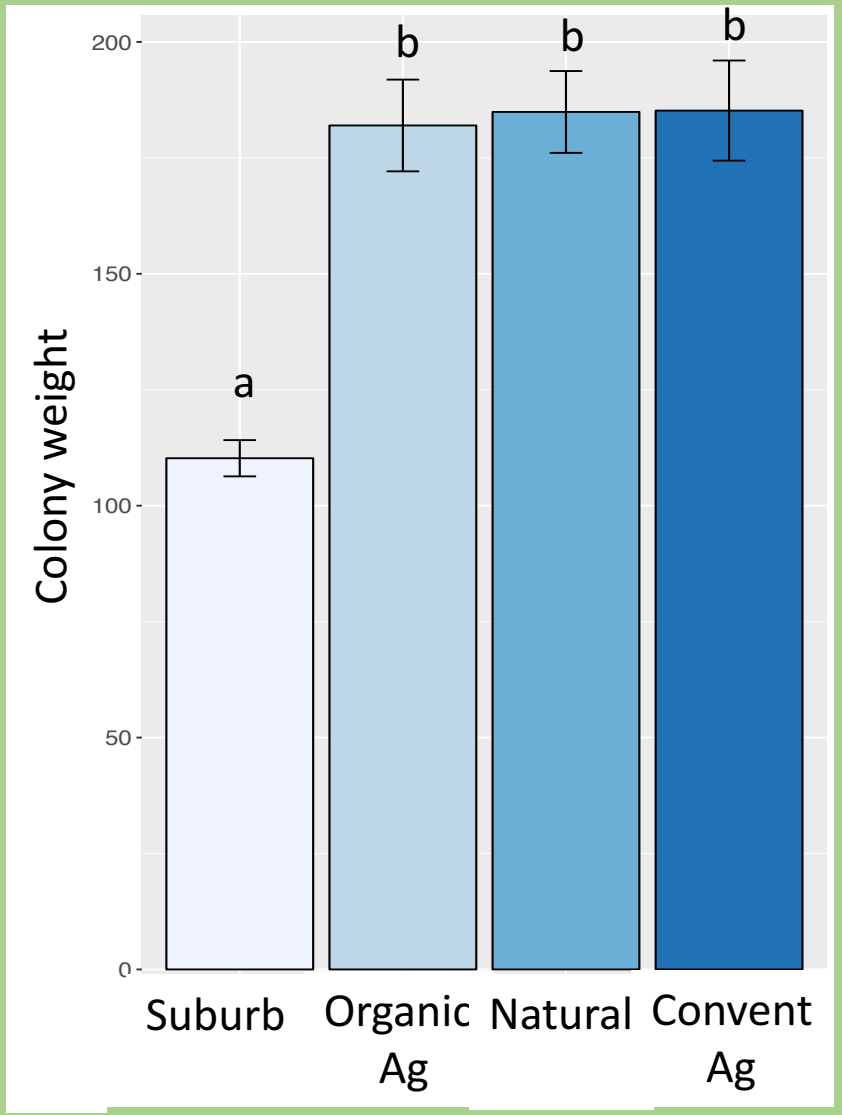
What is the mechanism, dear physiologists and toxicologists?

☺

QUESTIONS?

Bumble bees perform poorly in suburban areas

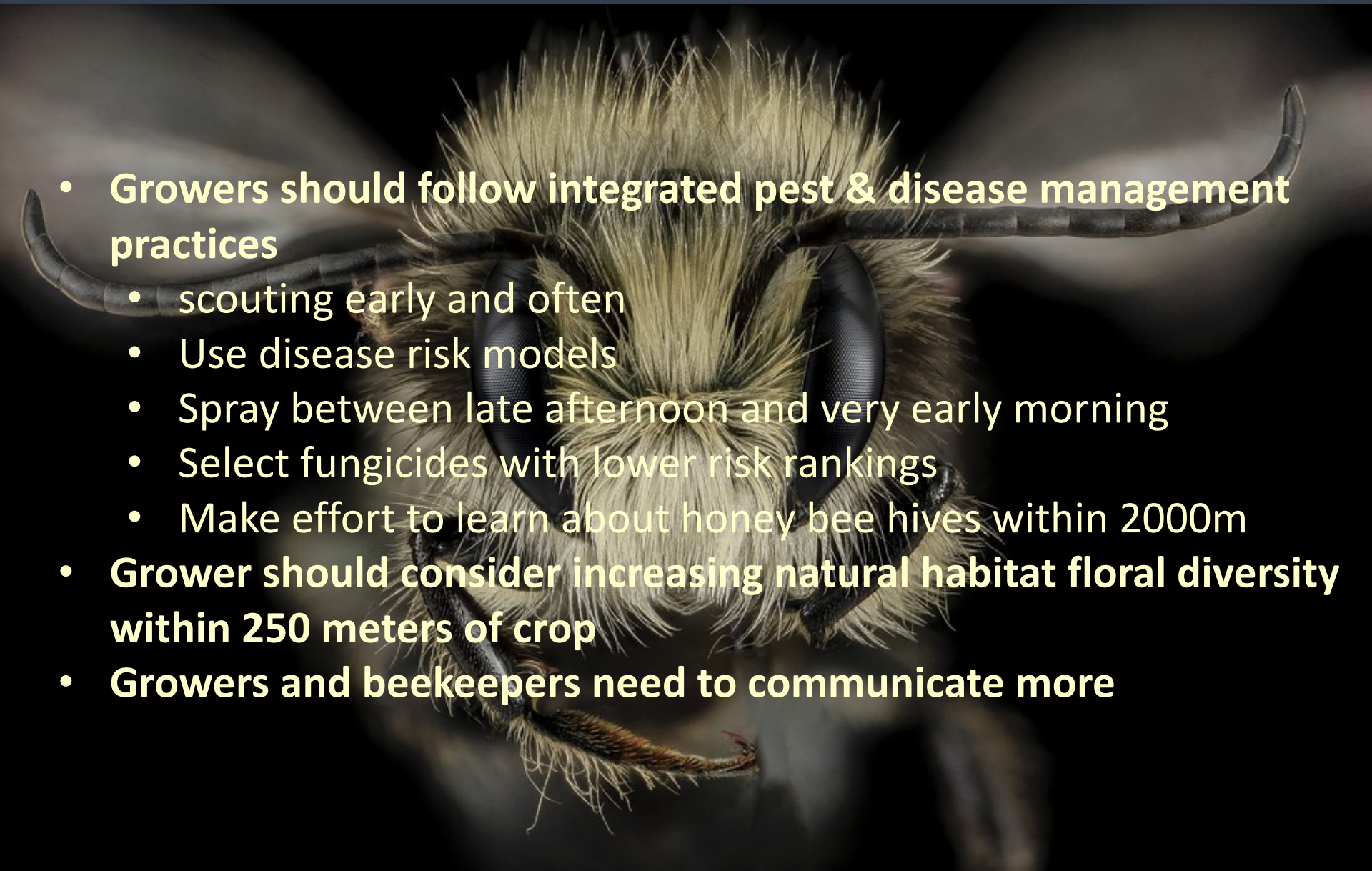
Colonies 40% lighter in suburban areas



Top pesticides found in Bumble bee wax

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

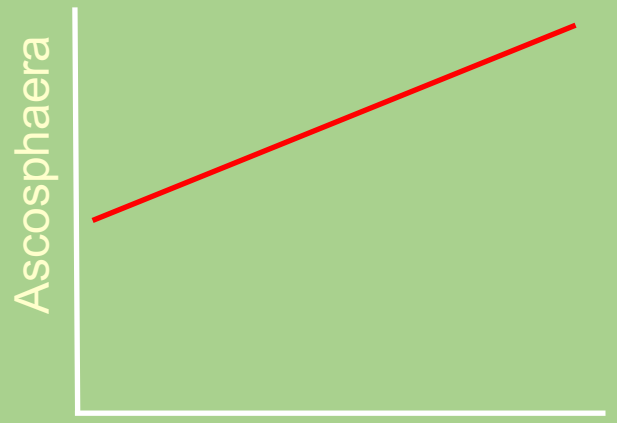
Management Recommendations



- **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

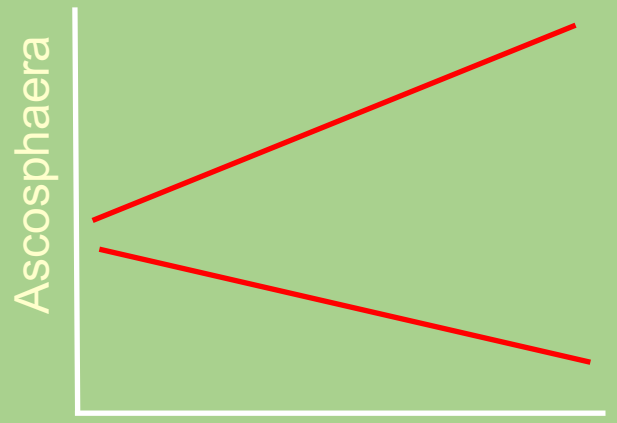
Fungicides



1. Fungicide exposure causes sub-lethal stress to bee increasing susceptibility to *Ascosphaera*
2. Fungicide exposure inhibits beneficial microbes and allows *Ascosphaera* to proliferate

Indirect effects of fungicides

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

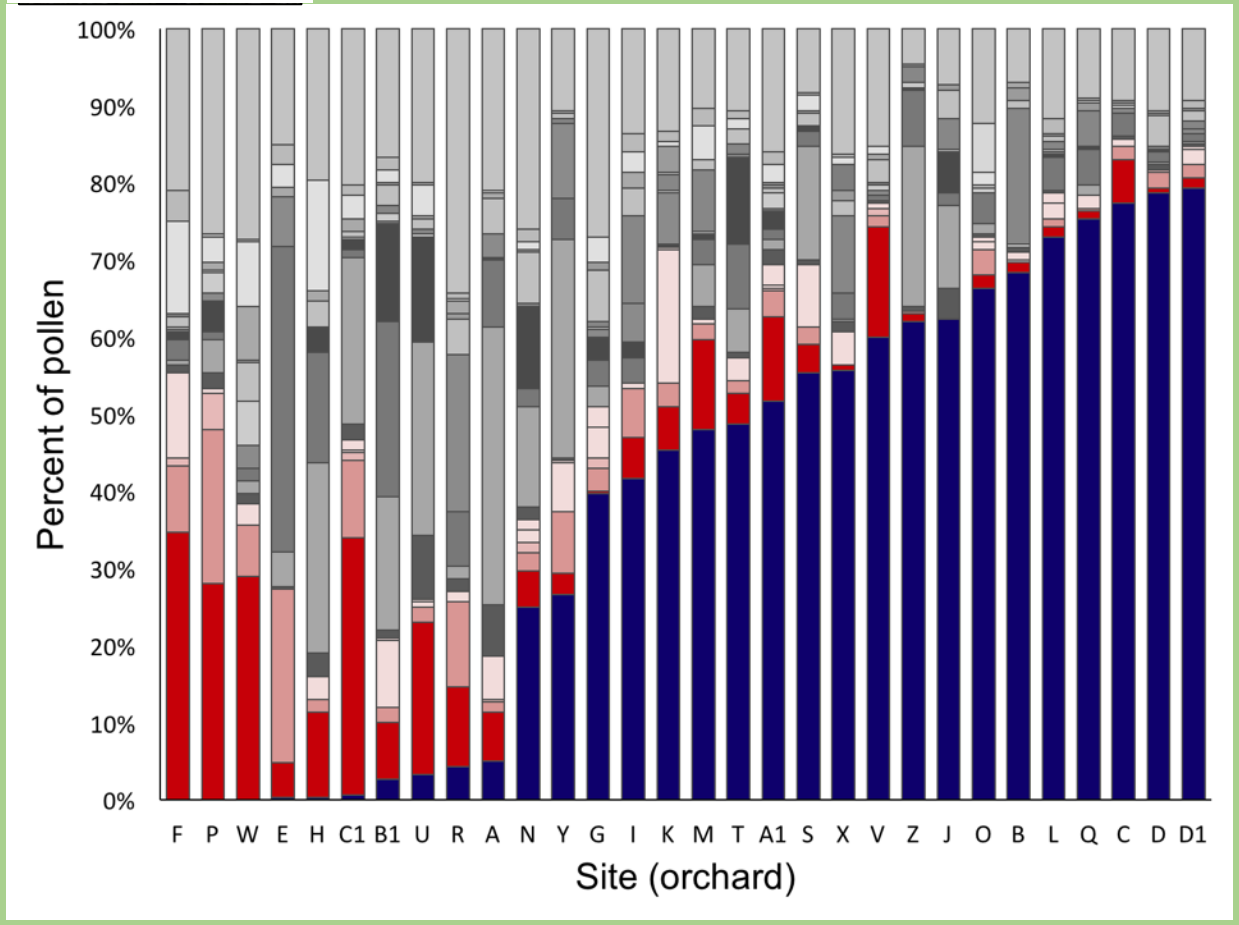
Management Recommendations

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.

Focal crop pollen foraging

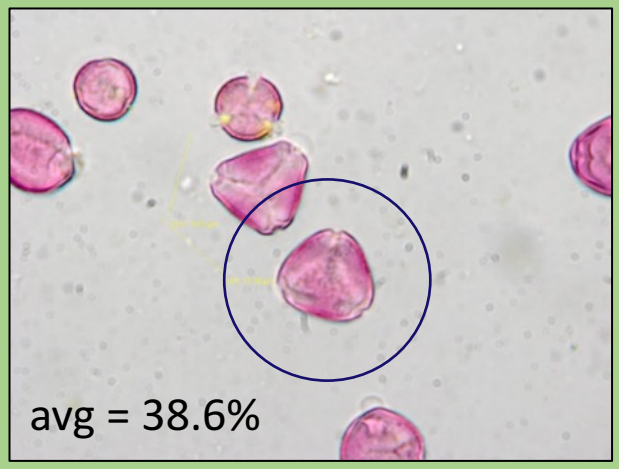
Ashley Fersch

During apple bloom



Apple pollen

Buckthorn pollen



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