Pollinators: Importance, Decline, and Conservation

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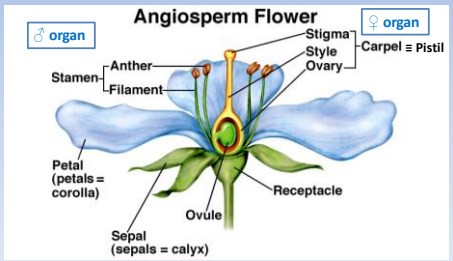
Pollination definition

In flowering plants, transfer of pollen grains from anther (male part) to stigma (female part); must be pollen of same species



Why is pollination important?

1. **Ecological**
~80% of flowering plants rely on animals for gene transfer (seed and pollen). Fruits and seeds comprise ~25% of diets of birds and mammals; so lack pollination means scarce resources

2. **Agricultural**
Insects pollinate ~2/3 of world's crops
account for 1/3 of food we eat

3. **Economics of insect pollination**
~$15 billion per year to the US economy
$217 billion worldwide (Science Daily 2008)

Major insect pollinators

> 70% flowering plants (~250,000 spp.) require an insect to move pollen

Most important insect pollinators: Bees

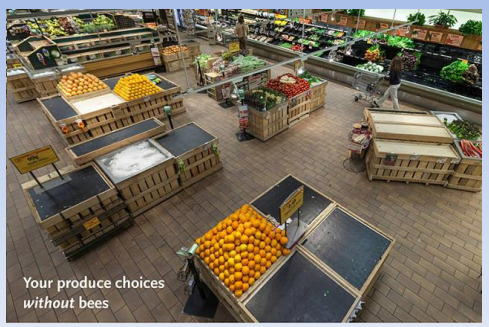
1. Feed on nectar and pollen
2. Pollen collecting structures (scopa, corbicula)
3. Display floral constancy

Why are bees important?

Whole foods and Xerces Society "Share the Buzz" campaign (2013)

Why are bees important?

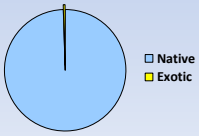
Whole foods and Xerces Society "Share the Buzz" campaign (2013)



Bees

- At least 25,000 known species of bees (more than birds and mammals combined!)
- Social vs. solitary, 90% being solitary
- ~4,500 solitary spp. in North America
- Wisconsin: ~390 spp.

Smallest North American bee (*Perdita minima*) on largest female carpenter bee



Bees: distinguishing characteristics

Bees	vs.	Wasps
Robust		Slender
Hairy		Smooth
Flat rear legs		Slender legs
Feed on nectar and pollen		Predators

The honeybee

General characteristics:
- Medium size, medium build
- Abdomen black and orange-brown stripes

Specific characteristics:
- Pollen baskets on hind legs
- Only species with hairs on eyes

The honeybee

Apis mellifera: the "honey-bearing bee"

Honeybees account for 84% of all insect pollination

- 7 species of honeybees
- Western honeybee, *Apis mellifera* only species in North America
- Non-native, introduced in 1600s
- Social colonies founded by single queen
- Colonies are perennial
- Hive with typically 30 to 50,000 workers

Bumblebees

General characteristics:
- Large size (3/4" long), robust build
- Hairs black and yellow, orange or brown

Specific characteristics:
- Very hairy bodies, fuzzy appearance
- Pollen basket (corbicula)

Bumblebees

All bumble species in genus *Bombus,* meaning "booming"

- 250 known species (probably most discovered)
- 49 species in U.S. (18 species in WI)
- Social colonies
- Most abundant native pollinators of both crops and wild flowers



Bumblebees

- Social colonies founded by a single queen
- Nest in abandoned rodent burrows or under lodged grasses
- Colonies last only one season
- Only queen overwinters
- Nest may contain 100-300 workers
- Nests up to 12" diam and may have several entrances


Goulson, 2010 *Bumblebees. Behavior, ecology, and conservation*

Bumblebee and crop pollination

- Active in cool and wet weather
- Buzz pollination makes them better pollinator of tomatoes, blueberry, cranberry, melons, cucumber, etc…
- Until 1980s, tomato pollination in glasshouses done by hand

Solitary bees

Photos: James Cane; Steve Javorek (Ag Canada); Edward S. Ross

Solitary bees

Photos: Bob Greenhouse; Edward S. Ross; Mace Vaughan; USDA-ARS/Jack Dykinga

Solitary bees

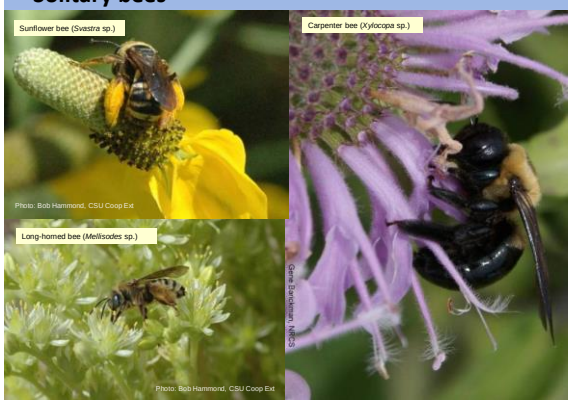
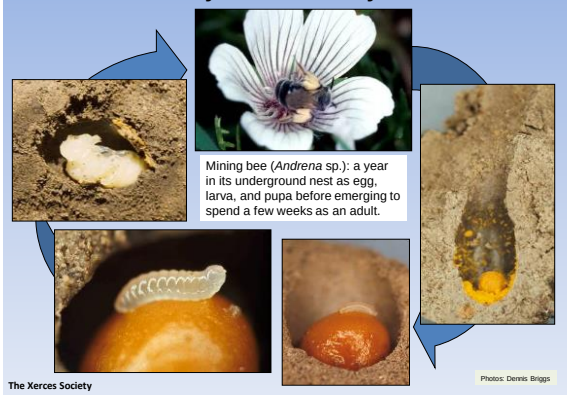


Photo: Bob Hammond, CSU Coop Ext

Photo: Bob Hammond, CSU Coop Ext

Gene Dechetney, Video

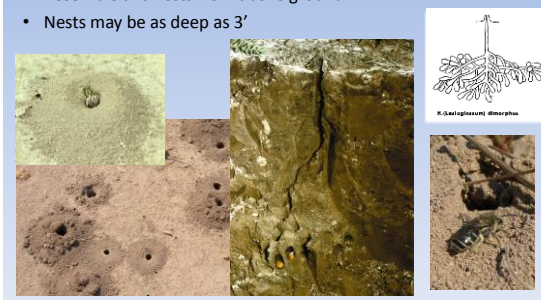
Life Cycle of a Solitary Bee



Ground-nesting solitary bees

~70% of native bee species nest underground

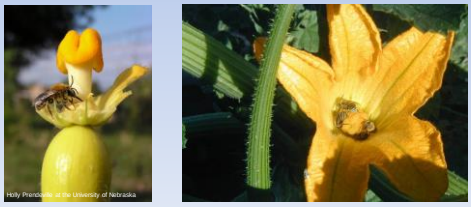
- Resemble ant-nests from above ground
- Nests may be as deep as 3'



Ground-nesting solitary bees

Squash bees

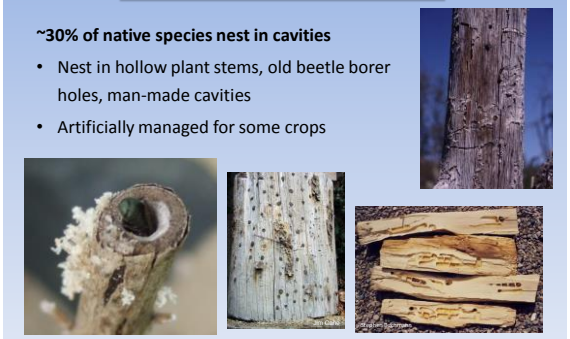
- Native solitary bees (*Peponapis* and *Xenoglossa*)
- Most important floral specialists in agriculture
- Active during first few hours after sunrise, by noon, asleep in withered flowers
- Females forage at flowers of squashes, pumpkins and gourds



Cavity-nesting solitary bees

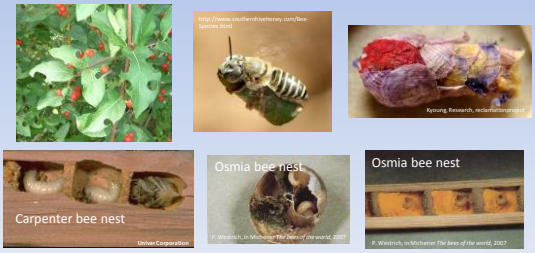
~30% of native species nest in cavities

- Nest in hollow plant stems, old beetle borer holes, man-made cavities
- Artificially managed for some crops



Cavity-nesting solitary bees

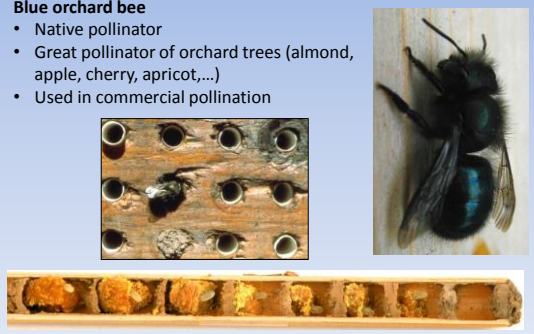
- Build nest with linear series of cells
- Tunnel partitions constructed of mud, leaf pieces, or sawdust



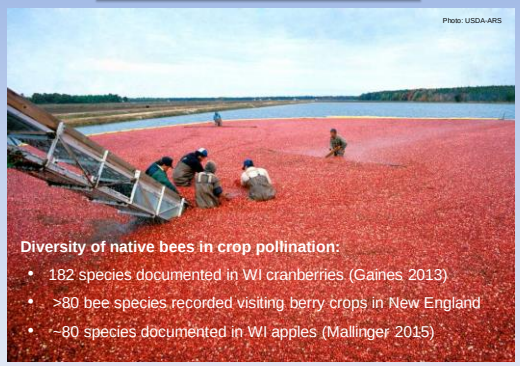
Cavity-nesting solitary bees

Blue orchard bee

- Native pollinator
- Great pollinator of orchard trees (almond, apple, cherry, apricot,…)
- Used in commercial pollination



Native bee diversity in agriculture



Diversity of native bees in crop pollination:

- 182 species documented in WI cranberries (Gaines 2013)
- >80 bee species recorded visiting berry crops in New England
- ~80 species documented in WI apples (Mallinger 2015)

Bee economic impact to agriculture

- Annual value of honey bee pollination to U.S. agriculture estimated at $14.6 billion
- Commercial value of non-honeybee pollinators to crop yields estimated at $6.7 billion per year

Pollinator decline

Politico: Bees bring new buzz to Capitol Hill

Pollinator decline

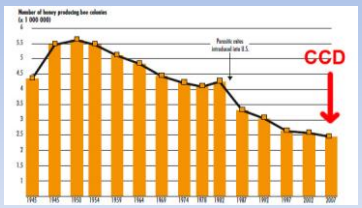
Colony collapse disorder: Honeybees

In 2006, U.S. beekeepers reported losses of 30-90% of hives

Main symptoms: very low or no worker bees, queen is alive, with larvae present, and no dead bodies inside or in front of hive (thus hard to study potential causes…)

Honeybees

Currently, estimated 2.62 million colonies of honeybees in USA

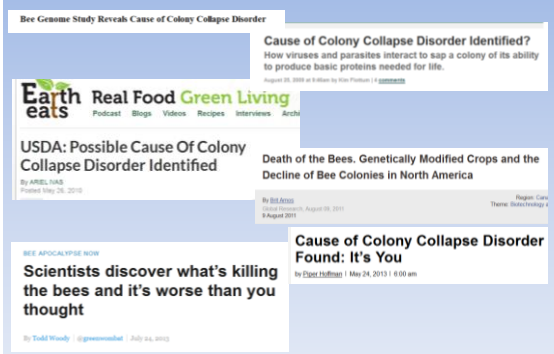


Pollinator decline

- Since CCD identified in 2006, average losses ~30% annually
- Of these percentages, ~1/3 attributed to CCD
- Prior to Varroa mite introduction, losses averaged 5-10%
- Late 1980s, losses were around 15% per year
- Decrease also reported in Europe and Mexico (FAO, 2009)

USDA CCD 2012 Progress report from CCD Steering Committee

Colony collapse disorder



Pollinator decline

Factors associated with honeybee declines:

- Arthropod pests and pathogens
- Poor nutrition
- Bee management practices
- Agricultural practices and pesticides
- *Habitat fragmentation*
- Bee biology, genetics, and breeding

Not a single factor, but a combination of factors

Pests and pathogens

Parasitic mite: *Varroa destructor*

- Single most detrimental pest of honeybees
- Introduced from Eastern Asia and identified in U.S. hives in 1987
- Blood sucking parasites that also transmit viruses to bees
- Cause significant colony losses each year

Pests and pathogens

Since 1984, multiple introduction of invasive species:

- parasitic tracheal mite *Acarapis woodi* (identified 1984)
- parasitic mite *Varroa destructor* (identified 1987)
- Africanized honey bees (1991)
- small hive beetle *Aethina tumida* (identified 1996)
- Israeli Acute Paralysis Virus - IAPV (identified 2007)
- gut parasite *Nosema ceranae* (identified 2007)

USDA CCD 2012 Annual Progress Report

Poor nutrition

Monoculture, i.e. almond and other commercial crops provide no diversity of food

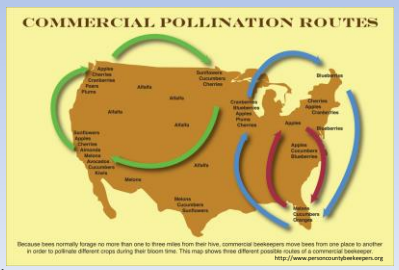
Pollinator decline

Sign of nutritionally desperate bees?

Bees from apiaries in France have acquired taste for processed sugars at local biogas plant that processes waste from Mars chocolate factory (maker of M&Ms)

Bee management practices

Not uncommon for beekeeper to travel 37,000-40,000 miles per year to pollinate 4 or more different crop



Rucker et al 2001

Bee management practices

Agricultural/residential practices

Nature Deficit Disorder
- Monocultures
- Lack of cover crops (natural fertilizers)
- Herbicides to kill off weeds (dandelion, clover, etc…)

In 2001, 11% of pesticides were used on lawns and 5% greenhouse gases produced by mowing our lawns

Pesticide exposure

Pesticides: insecticides, fungicides, and herbicides (and adjuvants)

Pesticide exposure

How do pesticides affect pollinators

- Lethal effects: acutely toxic to bees and result in death
- Sublethal effects: do not kill bees but affect performance that inhibit tasks such as olfactory learning, foraging, reproduction, longevity,…thus affecting colony health
- Synergistic effects: toxic effects when in combination with other pesticides

Pesticide exposure

List of pesticides found in pollen on honeybees returning to hive

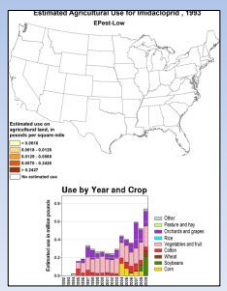
Fungicides
Herbicides
Insecticides

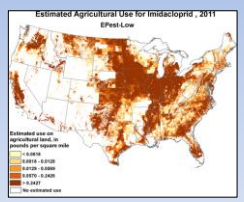
Pesticide	Insecticide family	LD_{50} (µg/bee)[a]	Crops in which detected[b]	Detections	Quantity detected, mean (± se; max) (ppb)	Relative risk (95% CI)
Fungicides						
Azoxystrobin		>1,562.5 (64)	O, Cu, Ma	10	60.2 (±25.6; 221.2)	0.75 (0.56, 1.02)
Captan		>79.11 (61)	Ap, Cl, Cu, Ma	8	976.9 (±704.4; 15,600)	0.89 (0.61, 0.87)[c]
Chlorothalonil		>1,414.96 (56)	Ap, B, Cr, Cu, Pu, Ra	17	6.49 (±2.1; 158.7; 27,600)	0.51 (1.05, 0.94)[c]
Cyprodinil		>6,122 (67)	Ap	3	596.0 (±707.5; 12,700)	0.31 (0.15, 0.65)[c]
Difenoconazole		>791.25 (68)	Ap	3	171.4 (±154.4; 2,110)	0.31 (0.15, 0.65)[c]
Fenbuconazole		>2,860.65 (69)	Ap, Cl, Cu	10	237.0 (±98.3; 2,400)	0.59 (0.43, 0.80)[c]
Pyraclostrobin		973.45 (70)	Cr, Pu	4	2,787.1 (±1,998.1; 27,600)	2.89 (2.16, 3.75)[c]
Quinoxyfen (PQM)		>9.95 (71)	Cr	2	0.25 (±0.14; 7)	0.07 (0.05, 0.01)
THPI	Captan metabolite		Cl, Cu	3	832.1 (±151.2; 3,470)	0.42 (0.21, 0.83)[c]
Herbicides						
Carfentrazone ethyl		>217.87 (72)	Cr	1	0.1 (±0.08; 1.4)	1.43 (0.34, 2.05)
Pendimethalin		>300.28 (73)	Ap, Cr, Pu	3	5.1 (±3.7; 69.3)	1.47 (1.38, 1.93)[c]
Insecticides						
2,4-Dimethylphenyl formamide (DMPF)[d]	Amitraz (formamidine metabolite)		B, Cu, Pu, Ma	10	175.3 (±117.3; 2,060)	2.13 (1.36, 2.62)[c]
Acetamiprid	Neonicotinoid	10.47 (63)	Ap	3	28.1 (±12.2; 401)	0.21 (0.15, 0.65)[c]
Bifenthrin	Pyrethroid	0.11 (74)	Ru, Ma	3	6.61 (±3.10; 51.1)	2.00 (1.93, 3.60)[c]
Carbaryl	Carbamate	0.59 (75)	Ap, Cu, Ma	6	57.8 (±10.0; 400)	0.42 (0.27, 0.66)[c]
Chlorpyrifos	Organophosphate	0.60 (76)	Ap, Cl, Cu, Pu	7	3.1 (±1.1; 19.5)	0.89 (0.64, 1.23)
Coumaphos[e]	Organophosphate	37.94 (10)	B, Cl, Cu	6	2.2 (±1.1; 17.7)	0.62 (0.43, 0.97)[c]
Cyfluthrin	Pyrethroid	>0.01 (78)	Cl, Ma	2	0.6 (±0.1; 2.4)	1.31 (0.85, 3.12)
Cyhalothrin	Pyrethroid	0.30 (77)	Ap, Pu, Ma	7	1.6 (±1.7; 11.1)	0.94 (0.69, 1.29)
Cypermethrin	Pyrethroid	0.15–0.38 (79)	Cr	1	0.4 (±0.4; 0.9)	1.45 (0.34, 2.05)
Deltamethrin	Pyrethroid	0.20 (75)	Cr	1	4.3 (±4.5; 65.2)	1.45 (0.34, 2.04)
Dioxinon	Organophosphate	1.72 (80)	Ap, Cr	8	1.4 (±1.2; 19.8)	0.26 (0.22, 0.37)[c]
Endosulfan I	Cyclodiene	34.49 (16)	Ap, Cl, Cu, Pu, Ma	8	1.9 (±0.7; 12.8)	1.40 (1.20, 2.14)[c]
Endosulfan II	Cyclodiene	34.09 (16)	Ap, Cl, Cu, Pu	8	0.8 (±0.3; 5.3)	1.41 (1.34, 1.97)[c]
Endosulfan sulfate	Endosulfan metabolite		Cl, Cu	4	0.3 (±0.1; 2.1)	0.75 (0.51, 1.13)
Esfenvalerate	Pyrethroid	0.13 (81)	Ap, Cl, Cu	7	14.8 (±12.3; 121.6)	0.51 (0.35, 0.75)[c]
Fluvalinate[e]	Pyrethroid	1.96 (82)	B, Cl, Cu, Pu, Ma	16	42.6 (±29.7; 277.8)	2.45 (1.49, 3.96)[c]
Hexaflumuron suspended	Insecticide[f] (cyclodiene) metabolite		Cl	1	0.6 (±0.2; 1.3)	1.45 (0.34, 2.04)
Imidacloprid	Neonicotinoid	0.23 (83)	Ap	3	2.9 (±2.2; 16.3)	0.51 (0.19, 0.65)[c]
Indoxacarb	Oxadiazine	1.41 (84)	Ap	2	2.5 (±1.2; 3)	1.23 (1.11, 1.75)[c]
Methidathion	Organophosphate	1.65 (85)	Cr	1	1.6 (±1.6; 2)	1.45 (0.34, 2.04)
Methomyl	Carbamate	>3.91 (86)	Ma	1	13.6 (±13.6; 27.8)	1.34 (0.91, 2.61)
Phosmet	Organophosphate	8.85 (85)	Ap, Cl, Cu	5	198.1 (±77.3; 1,170)	0.36 (0.21, 0.61)[c]
Pyrethrins	Pyrethroid	0.10 (16)	Cl	1	5.1 (±3.1; 107.4)	1.45 (0.34, 2.05)
Thiacloprid	Neonicotinoid	114.95 (58)	Ap	2	1.1 (±0.1; 2.4)	0.35 (0.15, 0.62)[c]
Control diets						
BTs	NA	NA	NA	NA	NA	0.00 (0.23, 1.48)
Nogalbee	NA	NA	NA	NA	NA	0.76 (0.33, 1.07)

Pettis et al 2013 PlosOne 8: 1-9

Pesticide exposure

- Imidacloprid (Admire) registered in 1994
- 1st neonic registered





US Geological Survey
http://www.usgs.gov/

Pesticide exposure

Soybean treated with insecticide seed treatment

Pesticide exposure

In 2008, 80% seed treatments were neonicotinoids

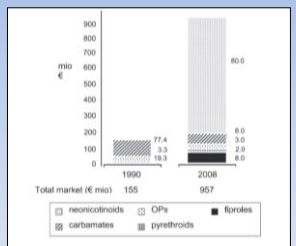


Figure 2. Development of insecticide classes in seed treatment, 1990–2008, expressed as percentage of total.

Jeschke et al. 2011

Pesticides in your garden

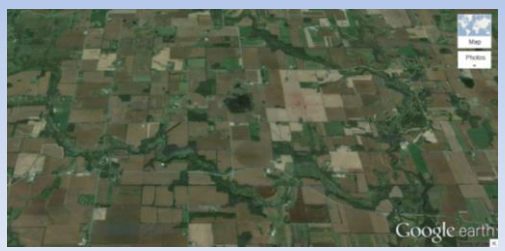
Examples of Neonicotinoid Garden Products Used in the United States

Neonicotinoid	Garden & ornamental uses	Garden product trademark names
Imidacloprid	Seed dressing, soil drench, granules, injection, or spray to a wide range of ornamental plants, trees, and turf.	Bayer Advanced 3-in-1 Insect, Disease, & Mite Control Bayer Advanced 12 Month Tree & Shrub Insect Control Bayer Advanced 12 Month Tree & Shrub Protect & Feed Bayer Advanced Fruit, Citrus & Vegetable Insect Control Bayer Advanced All-in-One Rose & Flower Care concentrate DIY Tree Care Products Multi-Insect Killer Ferti-lome 2-N-1 Systemic Hi-Yield Systemic Insect Spray Hunter Knockout Ready-To-Use Grub Killer Lesco Bandit Marathon Merit Monterey Once a Year Insect Control II Ortho Bug B Gon Year-Long Tree & Shrub Insect Control Ortho MAX Tree & Shrub Insect Control Surrender Brand GrubZ Out
Clothianidin	Seed treatment, foliar spray or soil drench for turf, a variety of ornamental trees, and flowers.	Bayer Advanced All-in-One Rose & Flower Care granules Green Light Grub Control with Arena
Thiamethoxam	Soil drench, injection, granules, or foliar spray to a wide range of ornamental plants and turf.	Flagship Meridian Meridian Dual Action Insect Killer
Acetamiprid	Foliar spray for fruits, vegetables, ornamental plants, and flowers.	Ortho Flower, Fruit and Vegetable Insect Killer Ortho Rose and Flower Insect Killer
Dinotefuran	Soil drench or foliar spray to leafy & fruiting vegetables, turf & ornamental plants.	Green Light Tree & Shrub Insect Control with Safari 2 G Safari Transect Zylam 20SG Systemic Turf Insecticide

The Xerces Society for invertebrate conservation

Pollinator habitat

- Loss of suitable habitat
- Fragmentation into smaller isolated habitat patches



Pollinator decline

Not just honeybees…

Rusty patched bumble bee
Bombus affinis

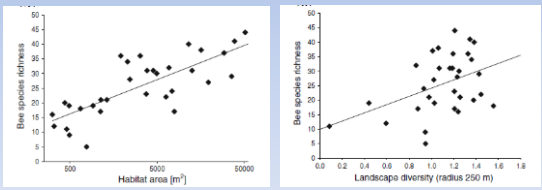
Yellow banded bumble bee
Bombus terricola

- were some of most common bumble bees in the Eastern U.S.
- now gone from most of their historic range
- potential causes: diseases and pathogens introduced in by commercially reared bumble bee colonies, fragmented habitats,…

The Xerces Society

Habitat fragmentation

Species richness influenced by declining habitat area and reduced diversity of surrounding landscape



Jauker et al 2013 Landscape Ecology 28: 107-120

Pollinator decline

Hand pollination of apples and pears in China's Sichuan Province

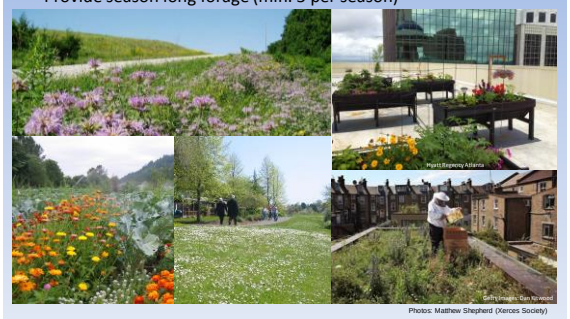
Pollinator decline

As honey bees and native bees are declining

- Important to diversify pollinators for production agriculture
- Important to strengthen habitat
- Important to protect bees from pesticide exposure

Pollinator conservation: Provide resources

- Provide a variety of pollen/nectar sources
- Provide season long forage (min. 3 per season)

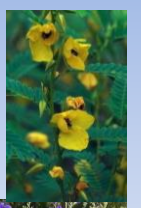


Photos: Matthew Shepherd (Xerces Society)

Plants for Wisconsin

Native flowers

- Lupine
- Spiderwort
- Penstemon
- Milkweed
- Beebalm
- Joe Pye weed
- Blazing star
- Goldenrod
- Asters
- Prairie clover
- Purple cone flower
- Leadplant
- Cup plant



The Xerces Society

Photos: Eric Mader

Plants for Wisconsin

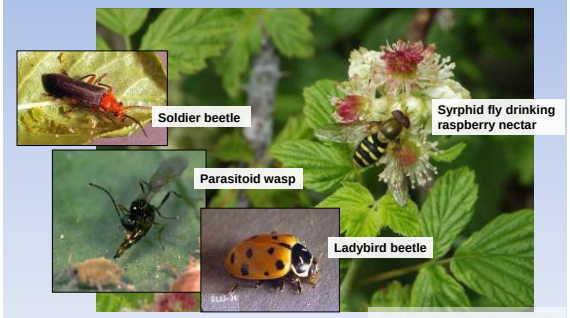
Woody plants

- Redbud
- Apple
- Plum
- Basswood
- Wild rose
- Pussy willow
- Hawthorn
- Ninebark
- Raspberry
- Blueberry

The Xerces Society

Pollinator conservation

Conservation biological control



Pollinator conservation: Prevent diseases

- Avoid locating honey bees near conservation areas
- Diseases can be spread through pollen

Pollinator conservation: Pesticide protection

- Pesticides not tested on native pollinators
- Use the lowest risk/lowest concentration
- Avoid dusts and micro-encapsulated products
- Avoid products with long residual (systemic)
- Time applications to avoid bees
- Spray in the evening when bees are not active

Pollinator conservation: Provide nesting habitat

Provide bare soil for ground nesters

- Cut/burn limited areas avoiding peak bloom
- Retain bare land/untilled areas
- Clear away some plants from well drained slopes
- Use cover crops that serve as forage

Pollinator conservation: Provide nesting habitat

Provide cavities for cavity nesters:

- Prefer wood
- Provide artificial nesting holes

Pollinator conservation: Provide nesting habitat

Retain or create nest sites for bumblebees:

- Plant native bunch grasses
- Maximize "wild" areas
- Artificial nests are <u>not</u> effective

Photos: Matthew Shepherd; NRCS/Lynn Betts

Questions?

Plant flowers!