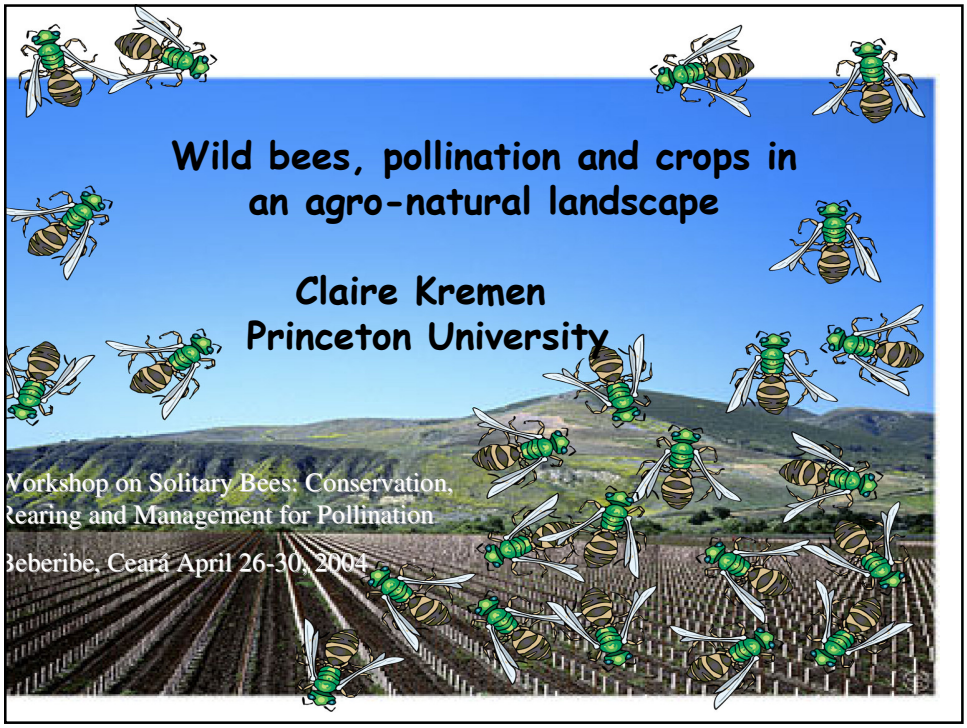



# Pollination services

- 15-30% of food production (McGregor 1976)
- 70% of 1300 crops (Roubik 1995)

## Bees pollinate 75% of crops.

(Nabhan and Buchmann 1997)

### Managed pollinators

*Apis mellifera* on almond

### Native pollinators

*Anthophora urbana* on tomato

## In the US, we rely on *Apis mellifera*, but there are problems.

Diseases

↓

50% decline in US colonies since 1950; 70% decline of feral


Hybridization with aggressive African strain

↓

Expected future declines

*Megachile rotundata* on alfalfa

**Honey bees are relatively poor pollinators of certain crops**

**(e.g. alfalfa, blueberries, cranberries, tomatoes, peppers…)**

What about wild bees?

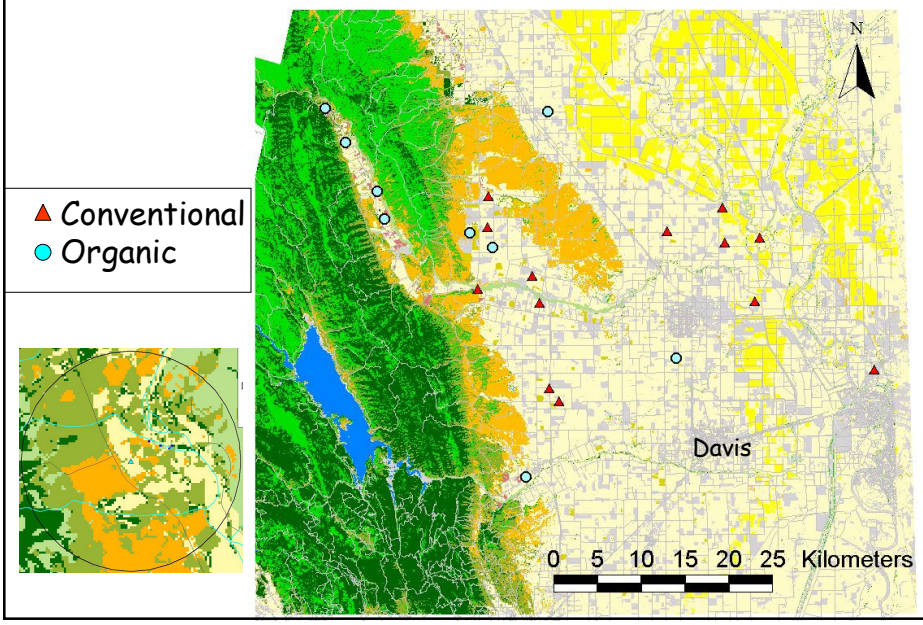

# Ecology of pollination services

- Role/value of wild bee species in crop pollination
- Effect of agricultural intensification on wild bee communities and pollination services
- Area requirements for supplying pollination services


## Conservation Implications

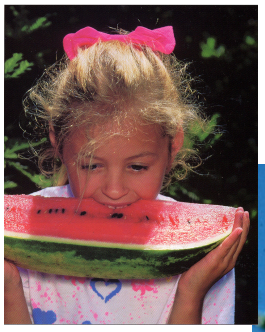

## Mosaic of Agricultural and Wild Lands

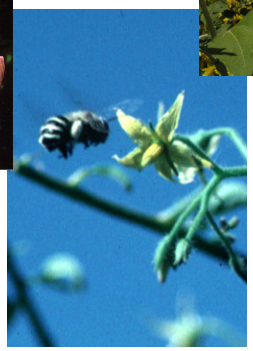

# Sites & Landscape Gradient




# Role/value of wild bee species in crop pollination

# Three crops with different pollination systems





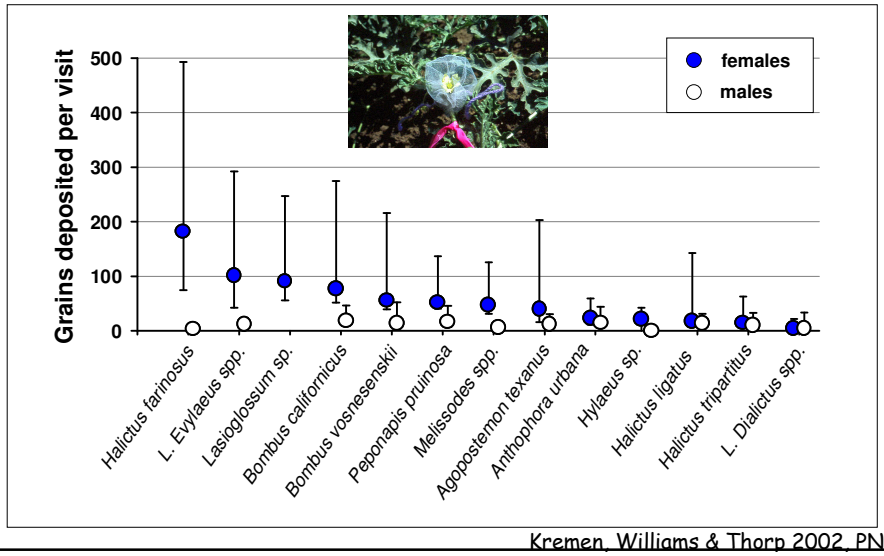
# Watermelon Pollination System

M

F

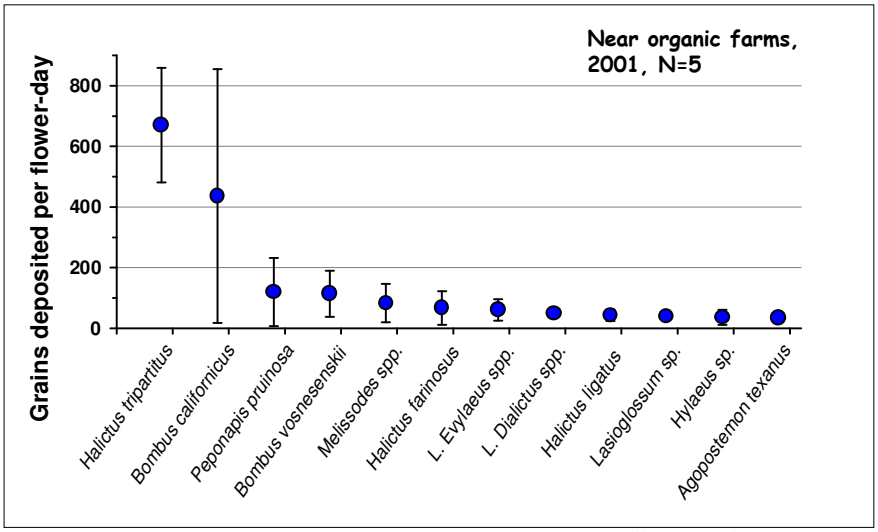
- requires insect vector, separate male and female flowers
- open during one day only
- needs lots of pollen (500-1000 grains)
- visited by 36 native bee species

## Pollen deposited during single visits by bee species $P_i$ ( median ± quartiles )



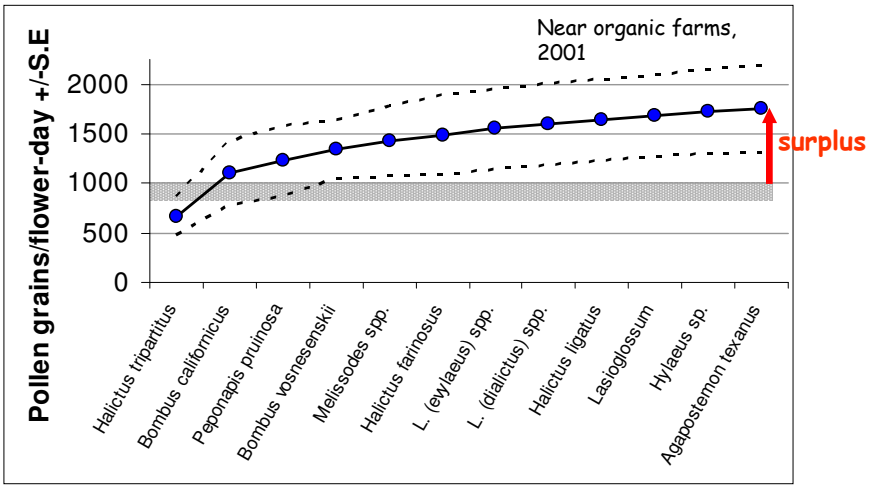

Kremen, Williams & Thorp 2002, PNAS

## Mean daily contributions to pollination per species, $V_iP_i$




Kremen, Williams & Thorp 2002, PNAS

## Cumulative daily pollen deposition by native bees $\Sigma V_i P_i$




Kremen, Williams & Thorp 2002, PNAS

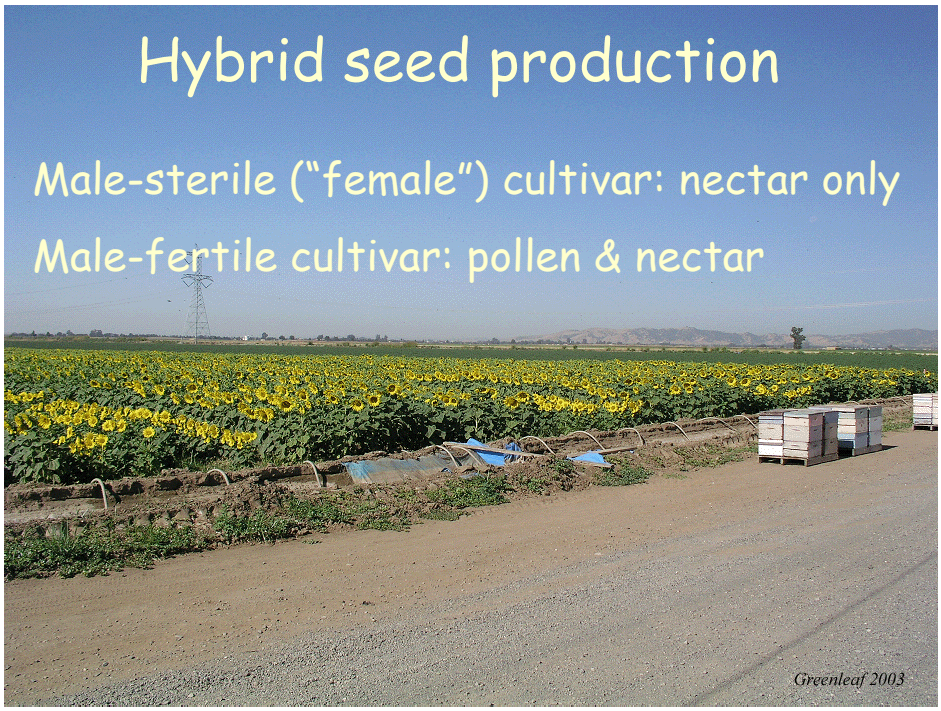
## Hybrid seed production: sunflower

- Male sterile/male fertile varieties
- Requires pollinator for seed set
- 31 native species visit
- Farmers always use honey bees but still don't get enough pollination

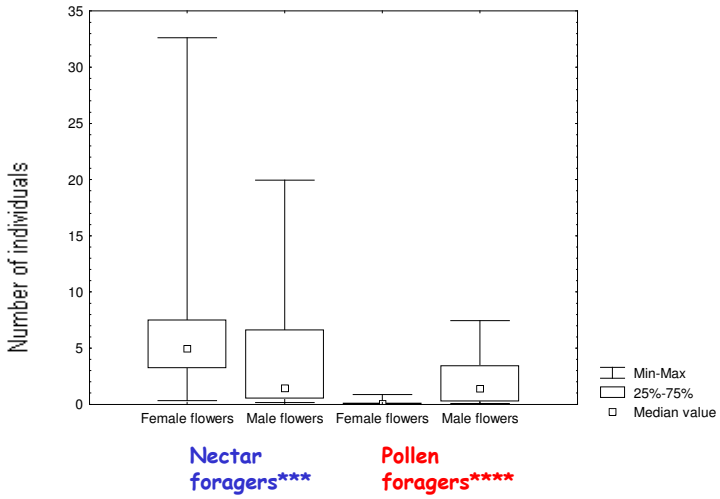
# Hybrid seed production

Male-sterile ("female") cultivar: nectar only

Male-fertile cultivar: pollen & nectar

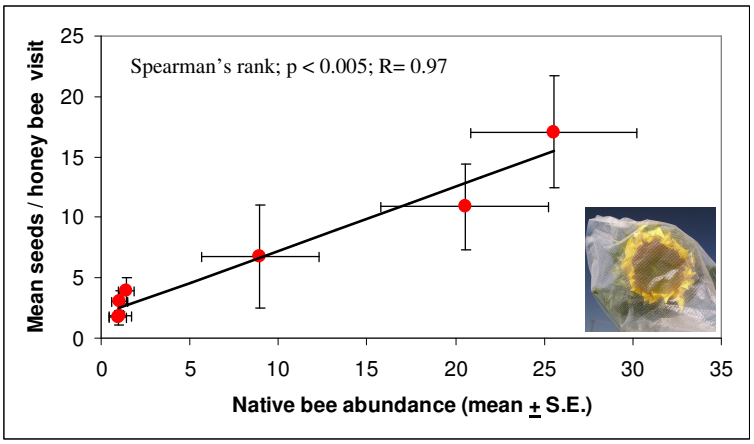



# Honey bee workers forage for either nectar or pollen




Greenleaf and Kremen

# Hybrid seed production by honey bees in sunflower




Greenleaf & Kremen

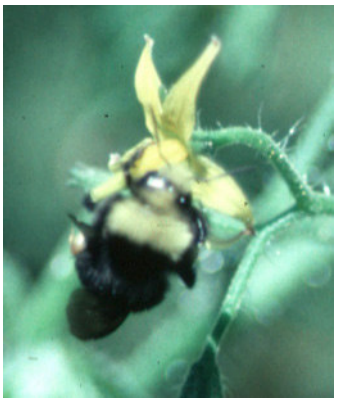
# H1: Native bees enhance honey bees efficiency by increasing transfers from "male" to "female" rows

| Interaction | Transfer M→M | Transfer M→F |
|---|---|---|
| Honey bee-honey bee | 60 | 4 |
| Honey bee-native bee | 42 | 11 |

Fisher's Exact Test, p = 0.008

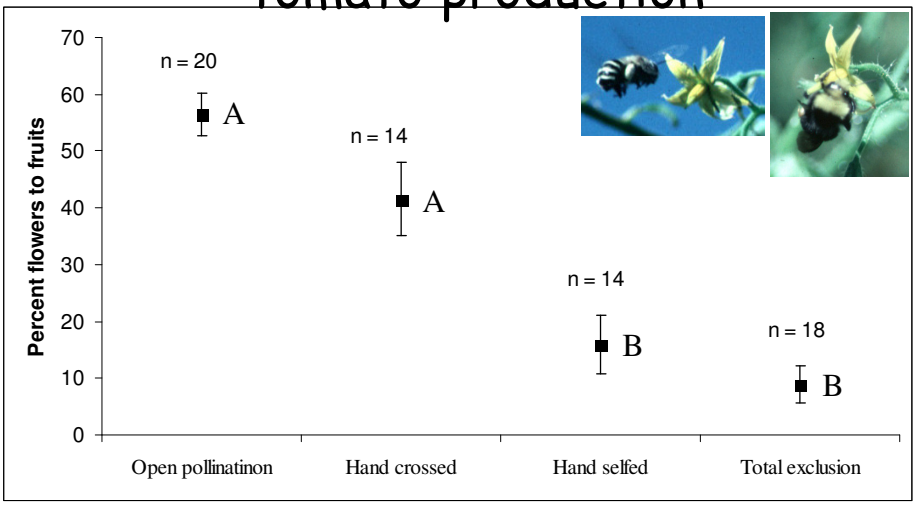
Greenleaf & Kremen

# Tomato pollination system



- Thought to be largely self-pollinated
- Flowers require vibration to release pollen
- Have no nectar
- Honey bees cannot release pollen, therefore rarely visit
- Visited by 5 native bee species

# Cross-pollination increases tomato production




ANOVA: $F(3,60) = 34.8$, $p < 0.0001$

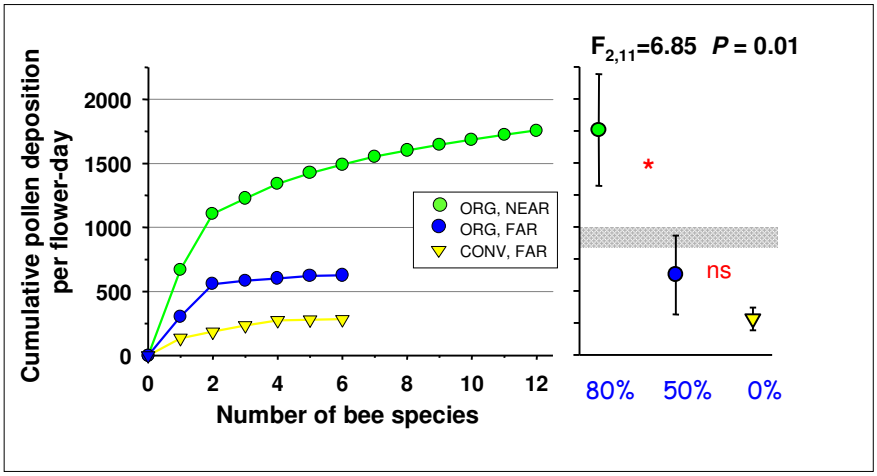
Greenleaf and Kremen

## Role/value of wild bees

- **Insect-dependent pollination system** (e.g. watermelon): replace or augment services provided by honey bees
- **Hybrid seed production** (e.g. sunflower): improve the efficiency of principal pollinator, honey bees
- **Self-pollinating** (e.g. tomato): increase number/size of fruits through cross-pollination
- ***Overall: provide these benefits and insurance in event of honey bee failure***

Effect of agricultural intensification on wild bee communities and pollination services

# Agricultural intensification affects pollination function




Kremen, Williams & Thorp 2002, PNAS

# Pollen deposition and wild bee community attributes

Multiple regression: $r^2$=0.97, p < 0.0001

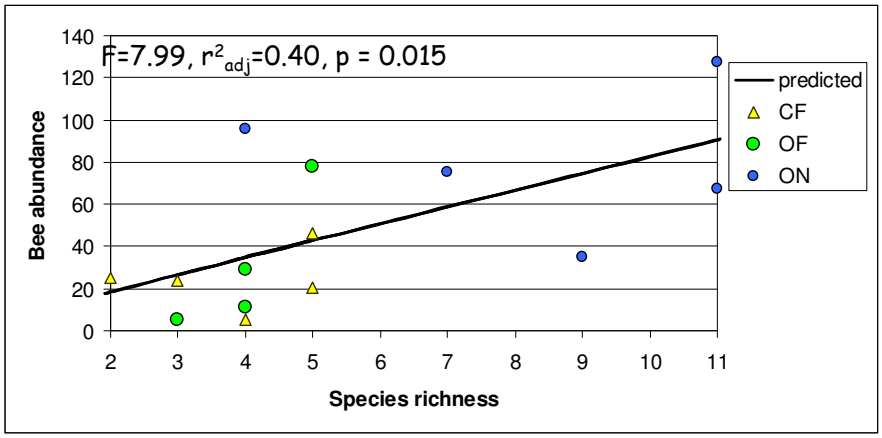
Richness: ns

Abundance****

Biomass****

Kremen 2004

# As species drop out, overall abundance declines




Similarly for biomass

# Local extinctions are ordered

| farm site | L. (Dialictus) | H. tripartitus | H. ligatus | L. (Evylæus) | A. texanus | Hylaeus spp. | Lasioglossum spp. | Melissodes spp. | B. vosnesenskii | P. pruinosa | B. californicus | H. farinosus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEEK8 | × | × | | | | | | | | | | |
| HERSH | × | × | × | | | | | | | | | |
| DURb | × | × | × | | | | | | | | | |
| RIC3 | × | × | × | × | | | | | | | | |
| DUR | × | × | × | | | × | | | | | | |
| McA1a | × | × | | | × | | | | | × | | |
| RIV4a | × | × | × | | | | × | | | | | |
| VIC | × | × | × | × | | × | | | | | | |
| YAS33 | × | × | × | × | | | | × | | | | |
| PAC | × | × | × | × | × | | | | | | | |
| RIV3a | × | × | | × | × | | × | × | × | | | |
| FUL4a | × | × | × | × | | × | × | × | × | | | × |
| FUL2a | × | × | × | × | × | × | × | × | × | × | × | |
| TER1 | × | × | × | × | × | × | × | × | | × | × | × |

| Spearman's rank | Extinction order |
|---|---|
| Abundance | - 0.34 n.s. |
| Body size | 0.83 **** |
| Efficiency | 0.69 ** |

**Nestedness temperature: 10.93°, randomized 48.63°, Monte Carlo p = 0.00002**

## Effects of agricultural intensification

Current land management practices reduce pollination services from native bees by:

- reducing species diversity,

➢ which results in reduced overall and individual species abundance and biomass

➢ and loss of functionally important species.

Area requirements for supplying pollination services

# Landscape & local factors

**Variables:**

Upland habitat***

Riparian habitat*

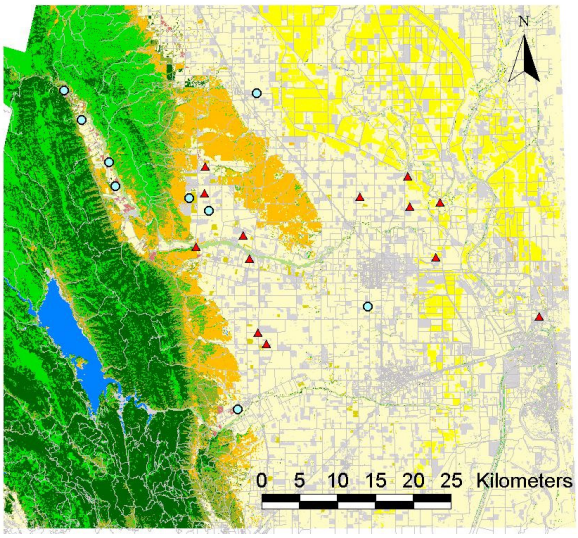
Farm management type*

Insecticide level

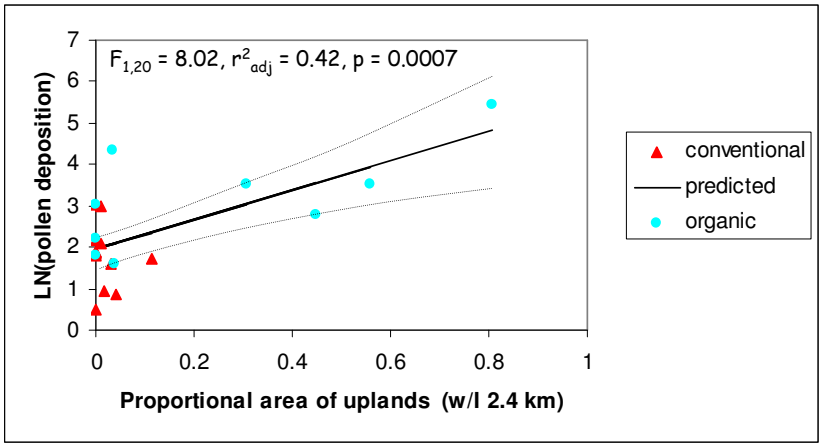
Plant sp. richness

Field size

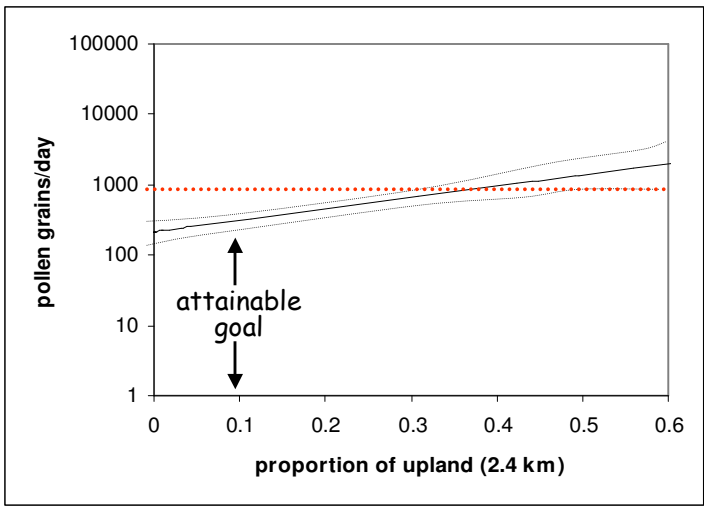
Honey bee density




# Relationship with upland habitat area



## Restoration: how much land is needed?




## Conservation Implications

- Wild bees provide important crop pollination services that augment those of honey bees directly or indirectly.
- They provide insurance if honey bees are in short supply.
- In California, some wild bees depend on wild habitat. Species richness & abundance decline with farming intensity; important species are lost first.
- Thus we may be endangering our insurance policy/food security by intensive agriculture.

# Protecting and promoting pollinators on farms

FLORAL RESOURCES

Restored patches

Flower gardens

Allowing weeds, crops, cover crops to flower

NEST SITES

Nest blocks

Bare soil

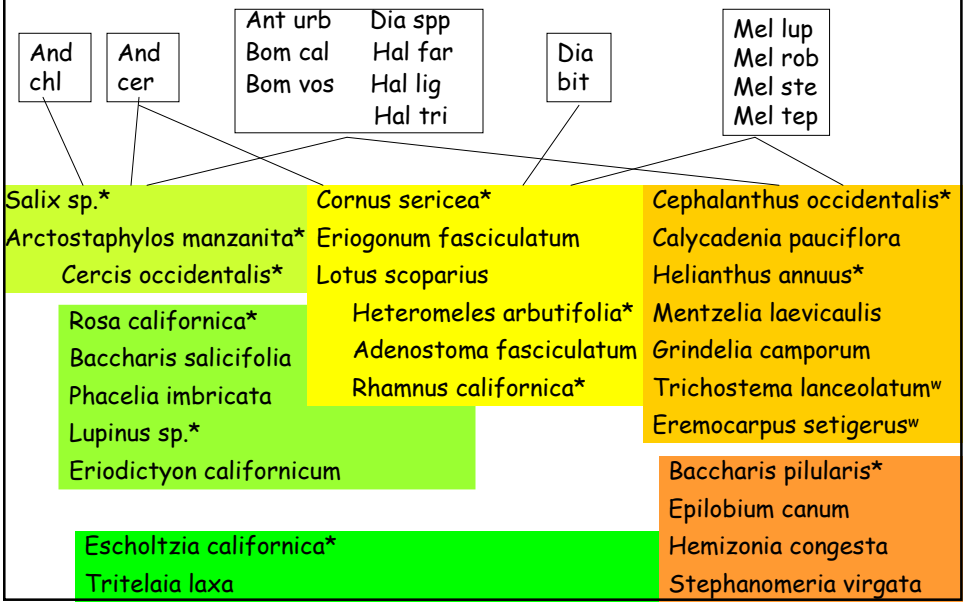
Best mgmt practices for pesticide use

# Restoration: bees & floral phenology

Bee-floral records (Williams, Kremen and Thorp)

- > 8600 records from 30 sites
- 171 bee species
- 125 plant species (natives, crops, weeds)
- 15 crop bees on native plants (700 records)

# Restoration: bees & floral phenology




# Conservation & Policy actions

**Local level**: farmer awareness program

The Xerces Society

- Values of wild bees
- Managing for wild bees
- Assessing what they already have; reducing costs of honey bee rentals

**National level**: Farm Bill pays for environmental stewardship (CSP, EQIP)

- Putting pollinators on the agenda (NAPPC)

# Acknowledgements


**•Collaborators:**
Robbin Thorp (Davis)
Neal Williams (Bryn Mawr)
Sarah Greenleaf (Princeton)
Bob Bugg (Davis)
Trond Larsen (Princeton)
John Fay (Stanford)
Bill Guthe (Princeton)

**Yolo Co. farmers/ranchers**

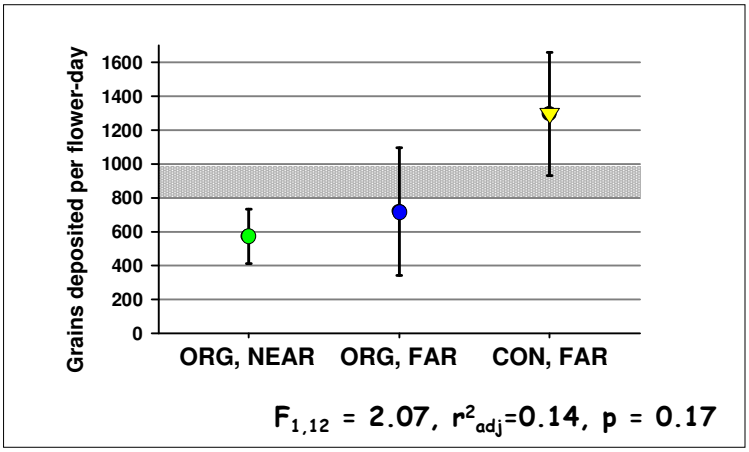
**Students/Assistants**:
Nikki Nicola, John Kim, Rich Hatfield, Sarah Adelman, Wendy Knight, and many others

**Funding:**
McDonnell Foundation
National Fish & Wildlife Foundation
Organic Farming Research Foundation
Mead Foundation

HoneyBee Research Facility, UC Davis
Entomology Museum, UC Davis


Muito obrigado!!!!!

## Honey bee contributions to watermelon pollination




Kremen, Williams & Thorp 2002, PNAS

## Does competition with honey bees explain reduction in pollination services?

1. no relationship between HB abundance and aggregate NB abundance or diversity
2. few interactions between HB and NB (< 1/hr)
3. no difference in proportion of interactions won by HB, NB or neutral

Kremen, Williams & Thorp 2002, PNAS

## Ecology and Management

FLORAL RESOURCES

ECOLOGY OF POLLINATION SERVICES

MANAGEMENT of POLLINATION

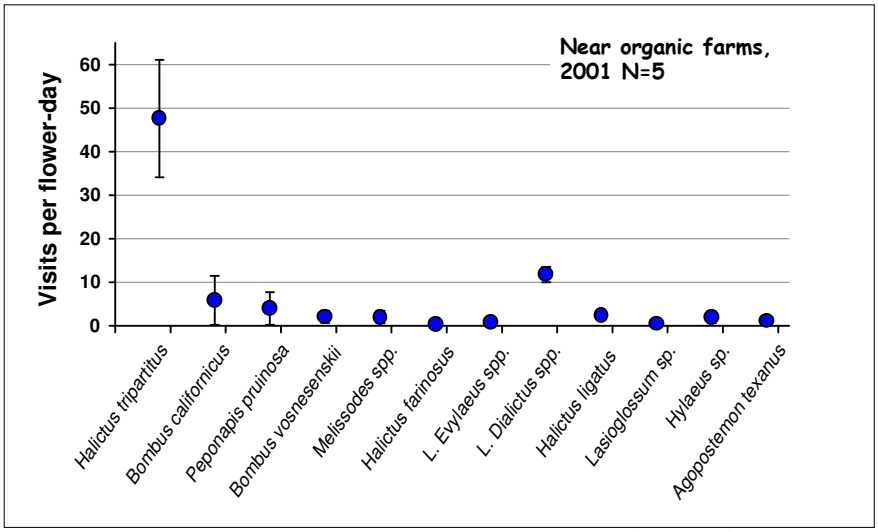
NEST SITES

# Value of managed pollination

- US: $US 5 billion/year
- EU: €4.3 billion/year
- UK: £137.8 million/year
- Canada: Can$443 million /year

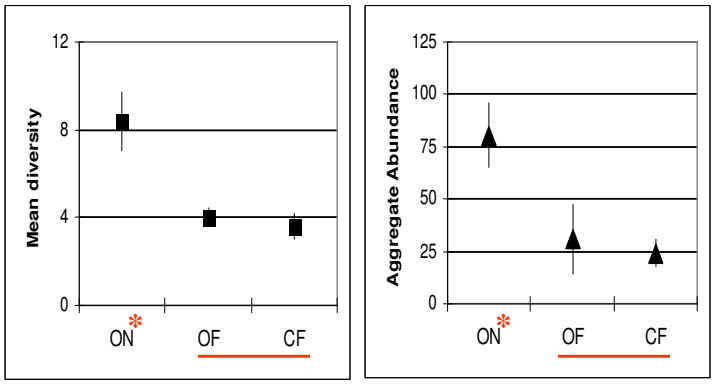
Value of unmanaged pollinators: Unknown

## Daily visits per flower by native bees $V_i$ (mean + S.E.)




Kremen, Williams & Thorp 2002, PNAS

# Both diversity and abundance of native bees decline with agricultural intensification




Kremen, Williams & Thorp 2002, PNAS