Pollinators: Learning the Value of their Protection and their Products

UCROSS
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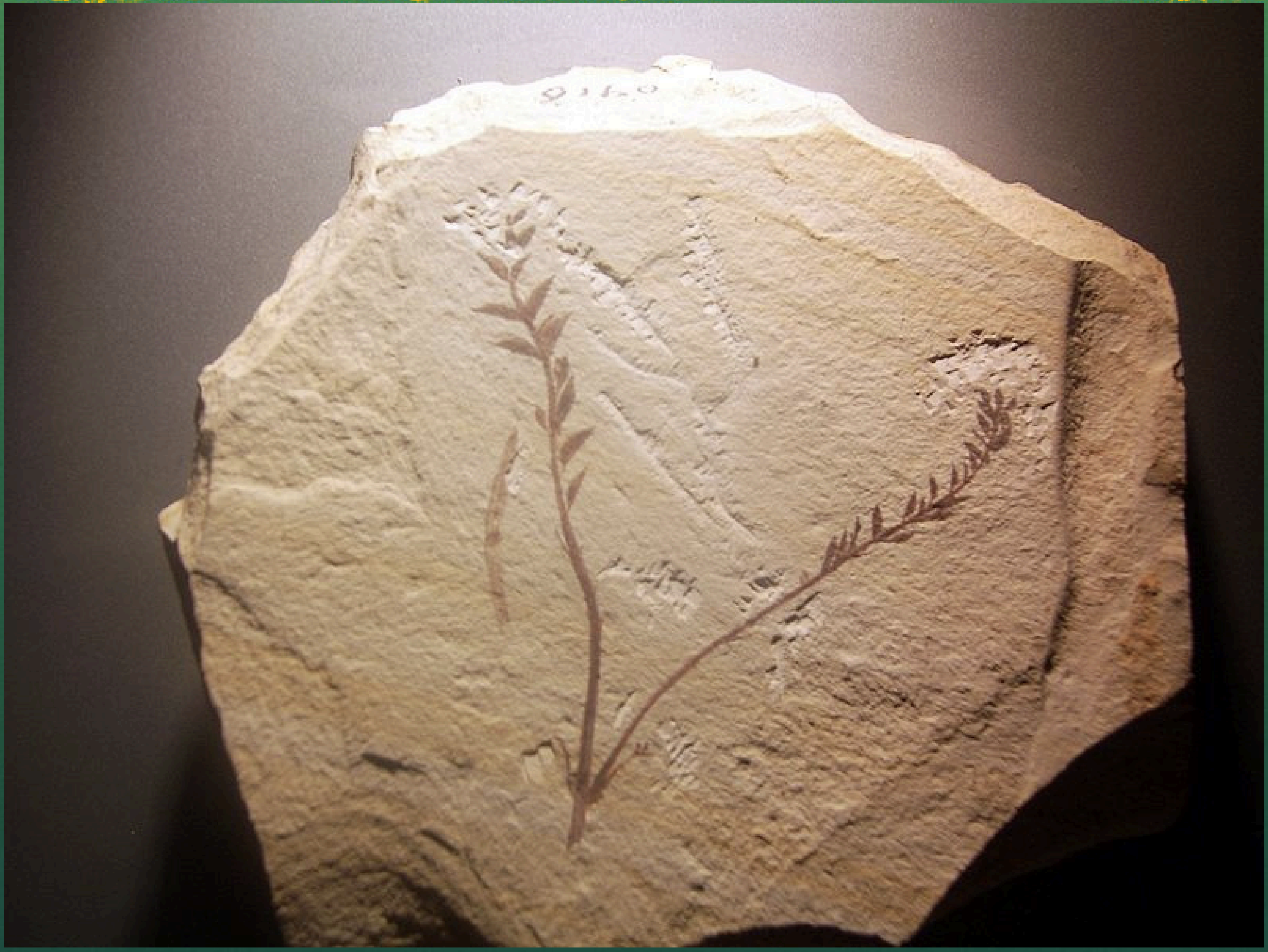
First things first: Flowering Plants

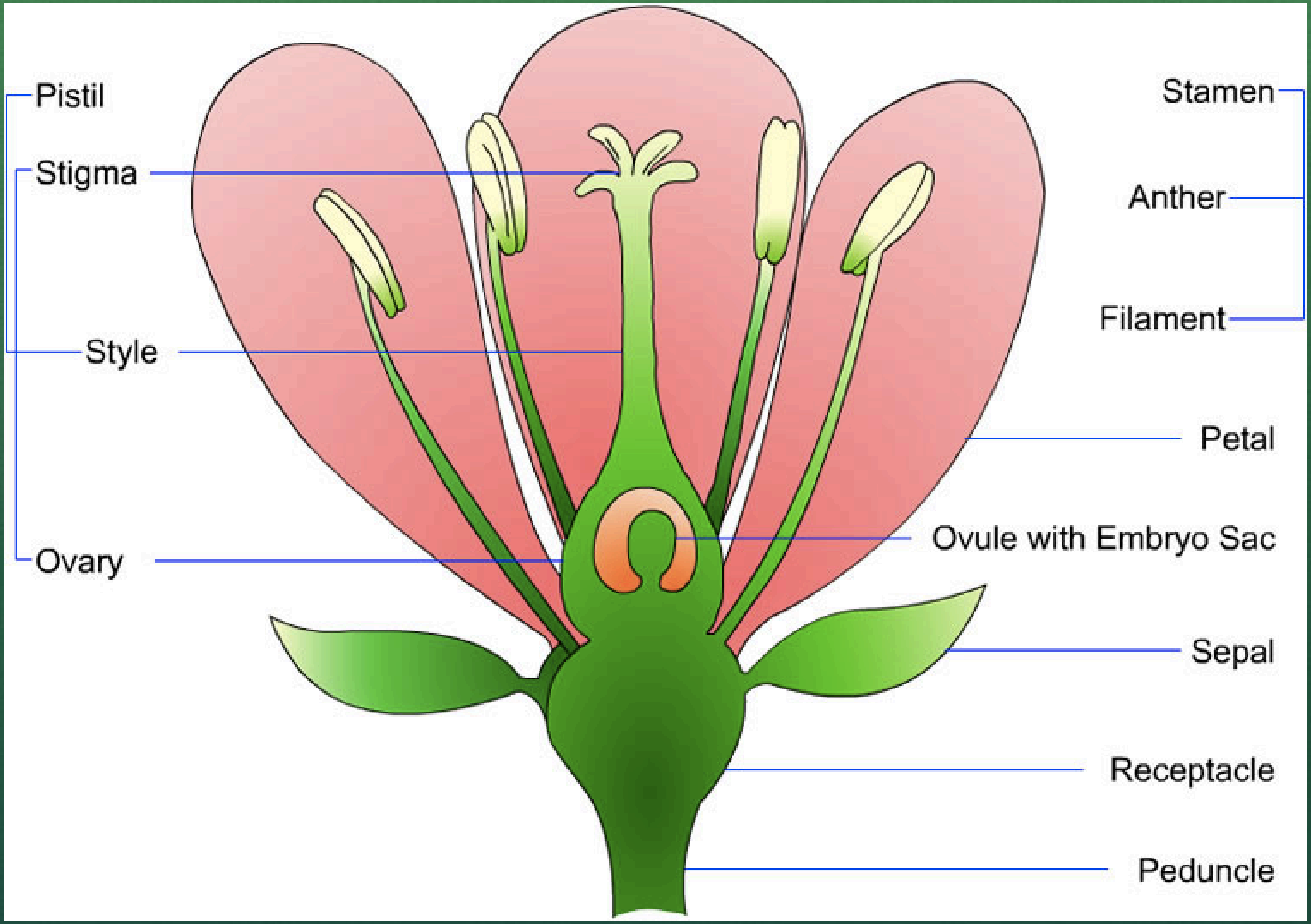


First things first: Flowering Plants

- **NOTE:** The notes used to guide Devin Routh's presentation and discussion have been included in this document. For each slide, the relevant notes appear on the following slide of the same title. For more information please contact devin.routh@gmail.com.

- Angiosperms versus gymnosperms
  - Angiosperms are the "new kids on the block"—evolving in the cretaceous period around 160 mya, they overtook gymnosperms (in terms of their number of species) some 60-100 mya; above is a fossil of Archaefructus
  - Angiosperms are the dominant form of (terrestial) plant life: between 250 and 400 thousand species (contrasted to ≈720 living species of gymnosperms in the world)
- Photo URL: http://en.wikipedia.org/wiki/Archaefructus_liaoningensis

Structure / Function of a Flower



Structure / Function of a Flower

- Pollination = the process of transferring the pollen (containing the male reproductive cells) from the stamen to the pistil.
- Consider: male versus female parts of the flower
- Genetics of outcrossing/selfing—there are evolutionary benefits associated outcrossing, i.e. genetic variation and diversity
- Visitation does not equal pollination (will revisit later in the presentation)
- Image URL: http://teachart.msu.edu/pila/images/flower.jpg

Variations in Flower Structure

Variations in Flower Structure

- Variations in flower structure reflect differing ecological relationships with various types of pollinators
- Consider: Inflorescences versus single flowers
- Consider: Temporal variation across a season; spatial variation within a habitat
- Left Image URL: http://saintelia.com/wp-content/uploads/2013/04/types-of-flowers.jpg
- Right Image URL: http://www.flowerstolebanon.com/multimedia/image/FTL/lebanese-flowers.jpg

Types of Pollinators






Types of Pollinators

- Consider: Pollination syndromes; convergent evolution
- Consider: Invertebrates versus vertebrates; native versus non-native
- Transition subject: we know a bit about the basics of pollination, but why is it important?
- Bee image copyright 2014 Dan Routh
- Butterfly Image: http://4.bp.blogspot.com/_u0DWEykBMWA/SwFZV8TVJiI/AAAAAAAABjQ/kISj6PM8_Kg/s1600/butterfly_thistle.jpg
- Hummingbird Moth Image: http://4.bp.blogspot.com/-2GP5ehcoQ9U/UcoTYsAWLmI/AAAAAAAAJho/gaUlZsTy9oM/s1600/hummingbird+moth.jpg
- Bat Image: http://www.fs.fed.us/wildflowers/pollinators/pollinator-of-the-month/images/long-nosedbat/lesser_long-nosed_bat_lg2.jpg
- Hummingbird Image: http://3.bp.blogspot.com/-YvmLPy02iV8/UGQbUVJsCqI/AAAAAAAAAto/a4YN02-fxSs/s640/Violet+Sabrewing+Hummingbird+.jpg
- Beetle Image: http://web.williams.edu/Biology/explodingflower/images/longhorn.jpg

Why is Pollination Important?

- Worldwide economic value ≈$241 billion
- Amounts to 9.5% of the total value of the world's agricultural production
- Pollinator disappearance would result in a loss to consumer surplus anywhere from $298 billion to $487 billion

Why is Pollination Important?

- Consumer surplus: An economic measure of consumer satisfaction, which is calculated by analyzing the difference between what consumers are willing to pay for a good or service relative to its market price. A consumer surplus occurs when the consumer is willing to pay more for a given product than the current market price.
- Last bullet point reference: Essentially the cost of half of the half of the American Recovery and Reinvestment Act
- References: Helmholtz 2008; Gallai et al 2009
-

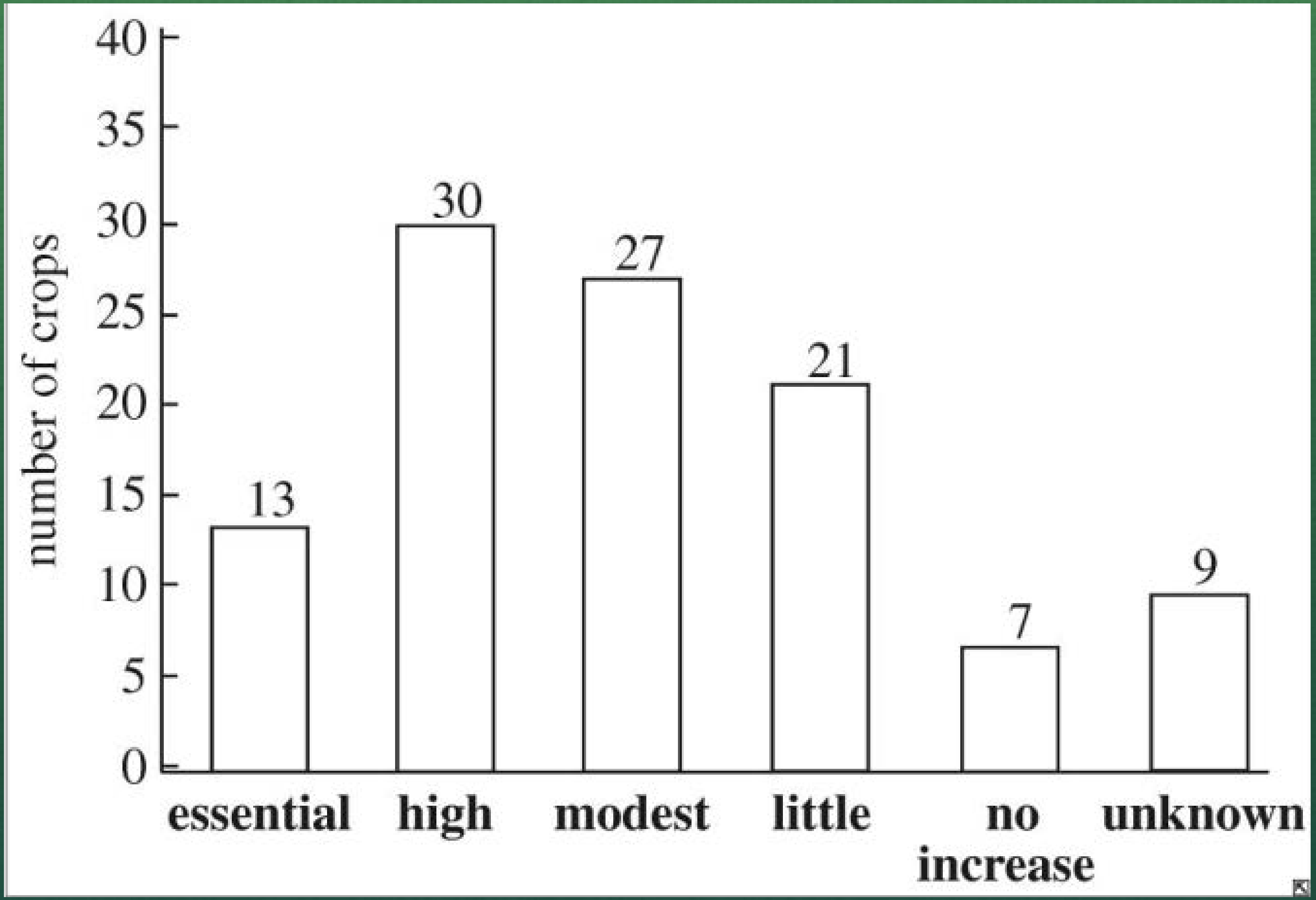
Vulnerability to Pollinator Loss

Crop category	Average value of a production unit	Total production economic value (EV)	Insect pollination economic value (IPEV)	Rate of vulnerability (IPEV/EV)
2014	Dollars per metric ton	Billion Dollars ($ US 2014)	Billion Dollars ($ US 2014)	%
Stimulant crops	$1,927.84	30	11	37%
Nuts	$1,997.08	20	7	32%
Fruits	$711.33	345	80	23%
Edible oil crops	$605.89	378	61	16%
Vegetables	$736.51	658	80	12%
Pulse	$810.48	38	2	4%
Spices	$1,578.47	11	0	3%
Cereals	$218.75	491	0	0%
Sugar crops	$278.55	422	0	0%
Roots and tubers	$215.60	154	0	0%

Vulnerability to Pollinator Loss

- Vulnerability ratio—ratio between the economic value of pollination and the current total crop value
- This ratio varied considerably among crop categories and there was a positive correlation between the rate of vulnerability to pollinators decline of a crop category and its value per production unit
- References: Gallai et al 2009; Klein et al 2007

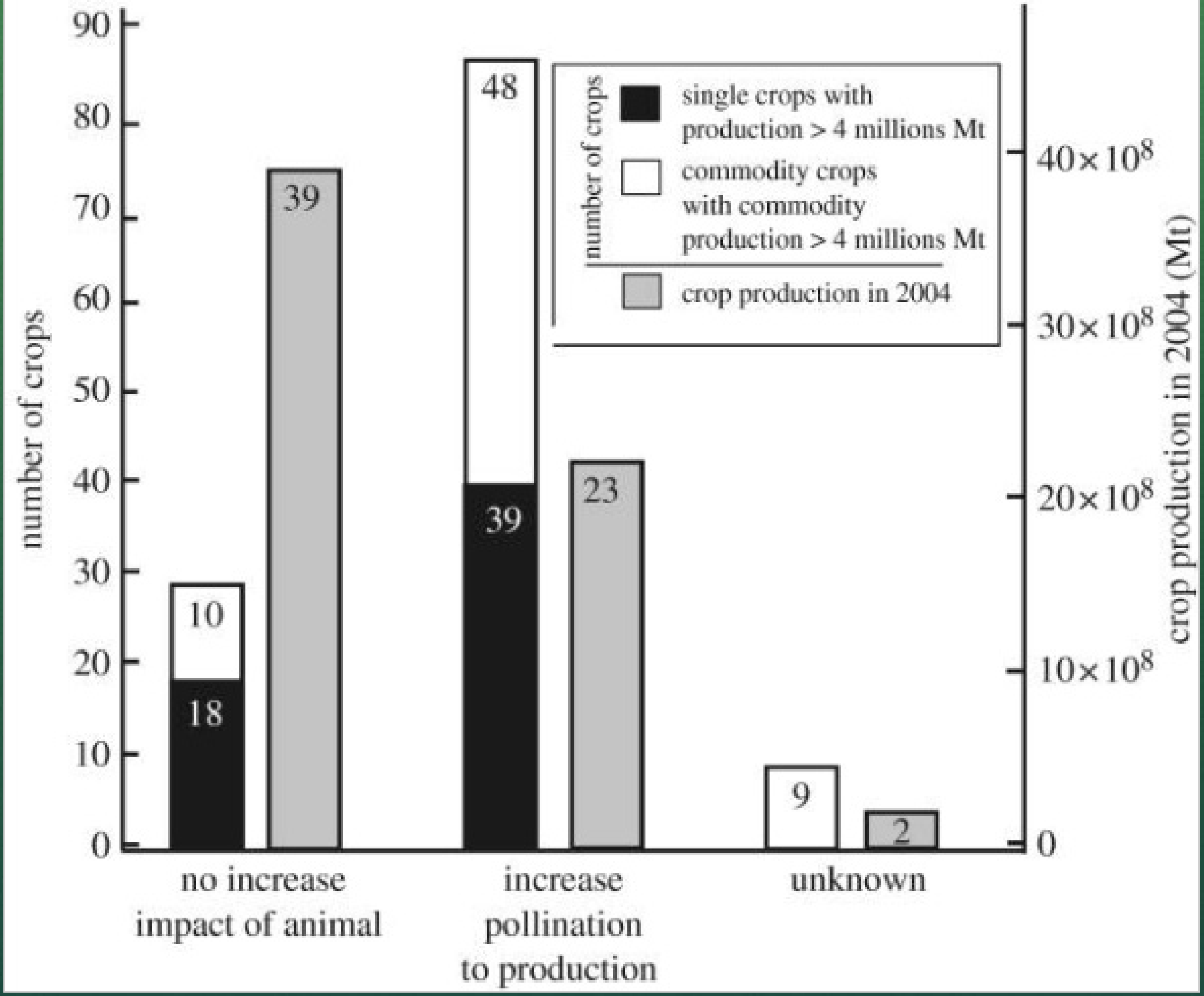
Vulnerability to Pollinator Loss



Vulnerability to Pollinator Loss

- Data from 200 countries revealed that fruit, vegetable or seed production from 91 of the leading global food crops is dependent upon animal pollination, while 28 crops do not rely upon animal pollination
- Pollinators are essential for 13 crops, production is highly pollinator dependent for 30, moderately for 27, slightly for 21, unimportant for 7, and is of unknown significance for the remaining 9
- References: Klein et al 2007

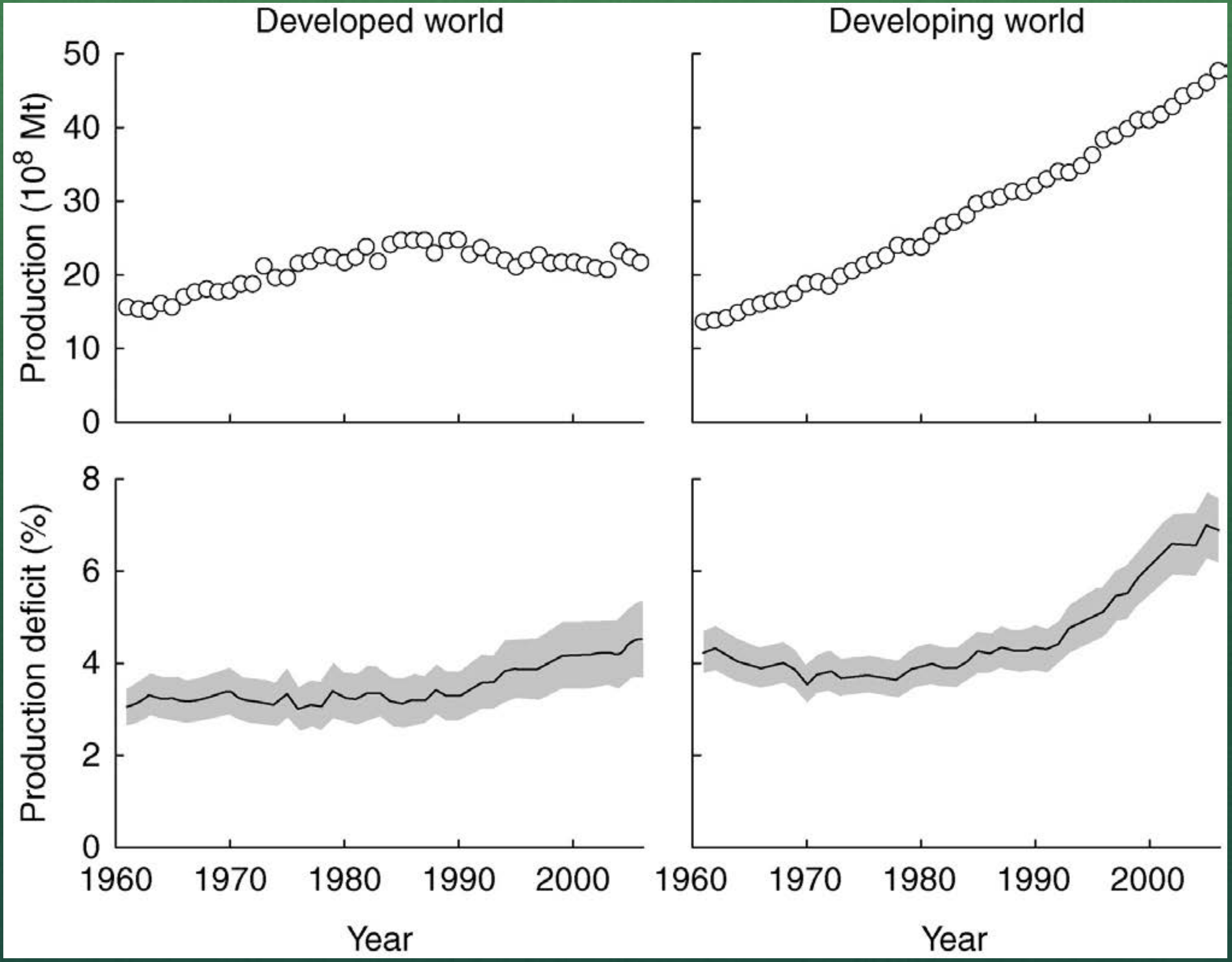
Bottom Line: Crop diversity depends on pollinators



Bottom Line: Crop diversity depends on pollinators

- Production of 39 of the leading 57 single crops increases with pollinating animals
- These crops account for 35% (23×108Mt) of global food production; 60% of global production comes from crops that do not depend on animal pollination; 5% are unevaluated
- Production of 48 of the 67 crops of the five leading global commodities increases with pollinating animals.
- References: Klein et al 2007

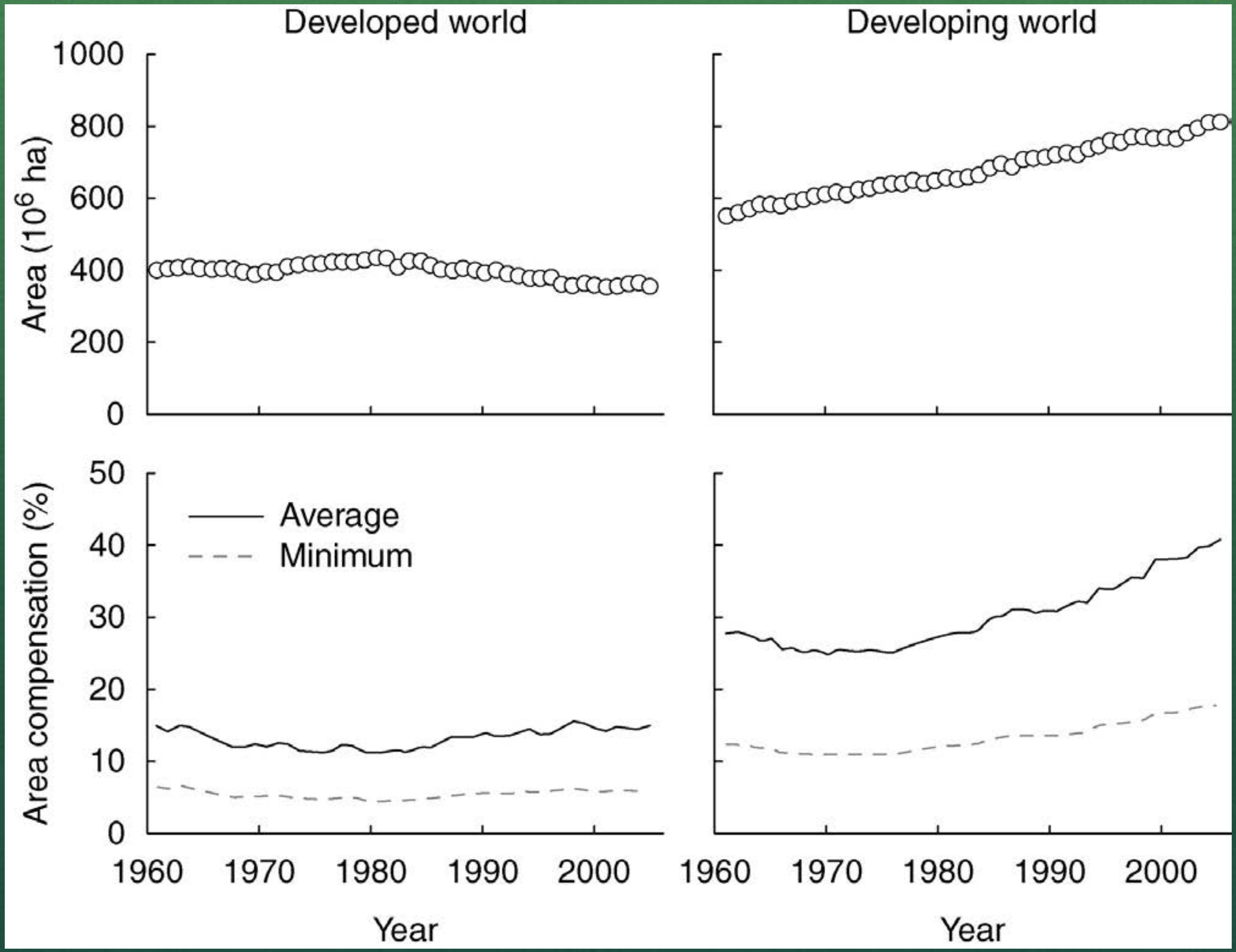
Compensating for Pollinator Loss



Compensating for Pollinator Loss

- Trends in total agricultural production and mean production deficits in the absence of animal pollination for the developed and developing world 1961–2006. The grey bands in the lower panels include the region delimited by the 2·5 and 97·5 percentiles of randomized distributions and depict uncertainty in the estimation of the production deficit.
- Consider: expanding diets in developing nations—more and more folks in developing nations would also like to consume animal pollinated products
- Results from previous studies demonstrate that pollinator-dependent crops represented a larger proportion of total agricultural production in the developing than developed world
- References: Aizen et al 2008

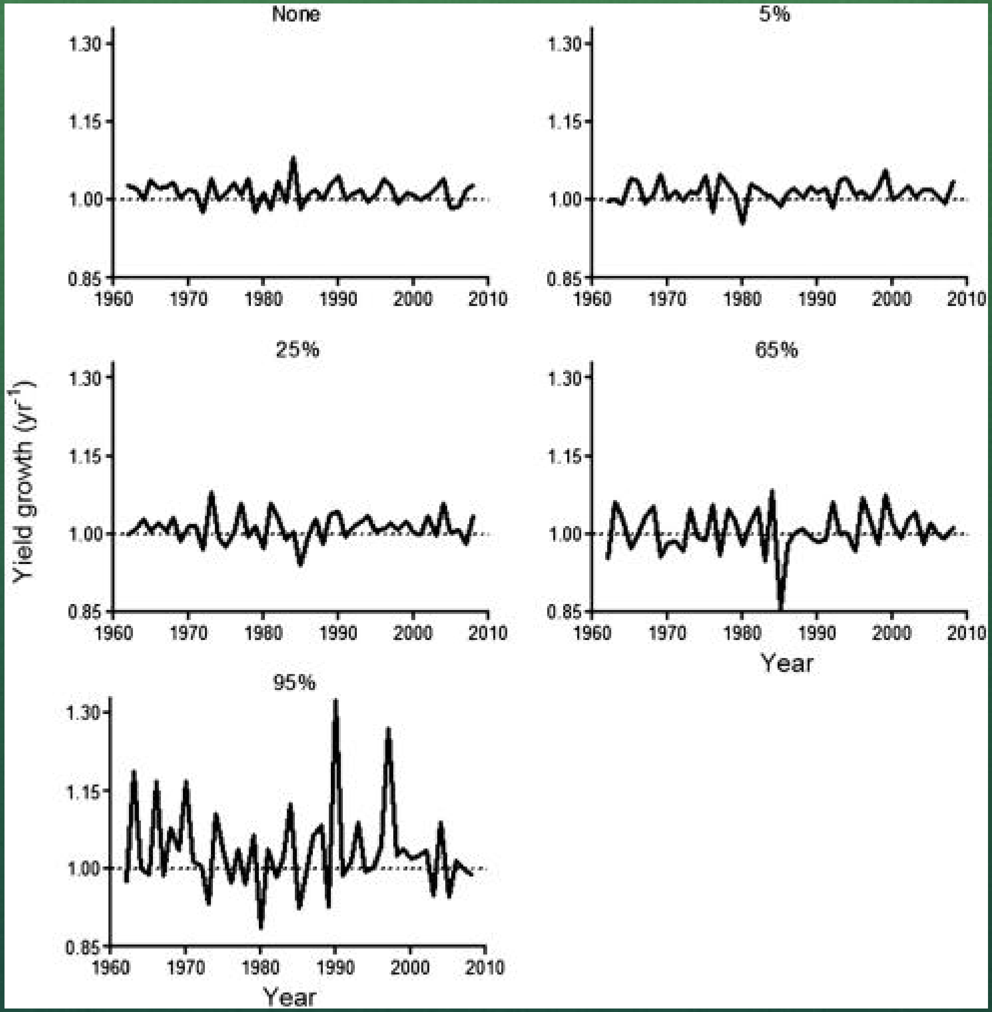
Compensating for Pollinator Loss



Compensating for Pollinator Loss

- Trends in total cultivated area and in the extra cultivated land required to compensate for the deficits in crop production in the absence of animal pollination (i.e. area compensation) for the developed and developing world 1961–2006.
  - Area compensation was estimated assuming that the pollinator dependence of individual crops was represented by the mid-value of the range defining its corresponding dependence class (average-area compensation) and by the lower limit of that range (minimum-area compensation).
- Note: The developing world already comprises 2/3's of the land devoted to crop production (globally); the area under cultivation needed to compensate for any pollinator collapse would be six times larger in the developing than in the developed world
- References: Aizen et al 2008; "How much does…"

Changes in Crop Yield



Changes in Crop Yield

- Consistency in yield growth declines with increasing pollinator dependence
- References: Girabaldi et al 2011

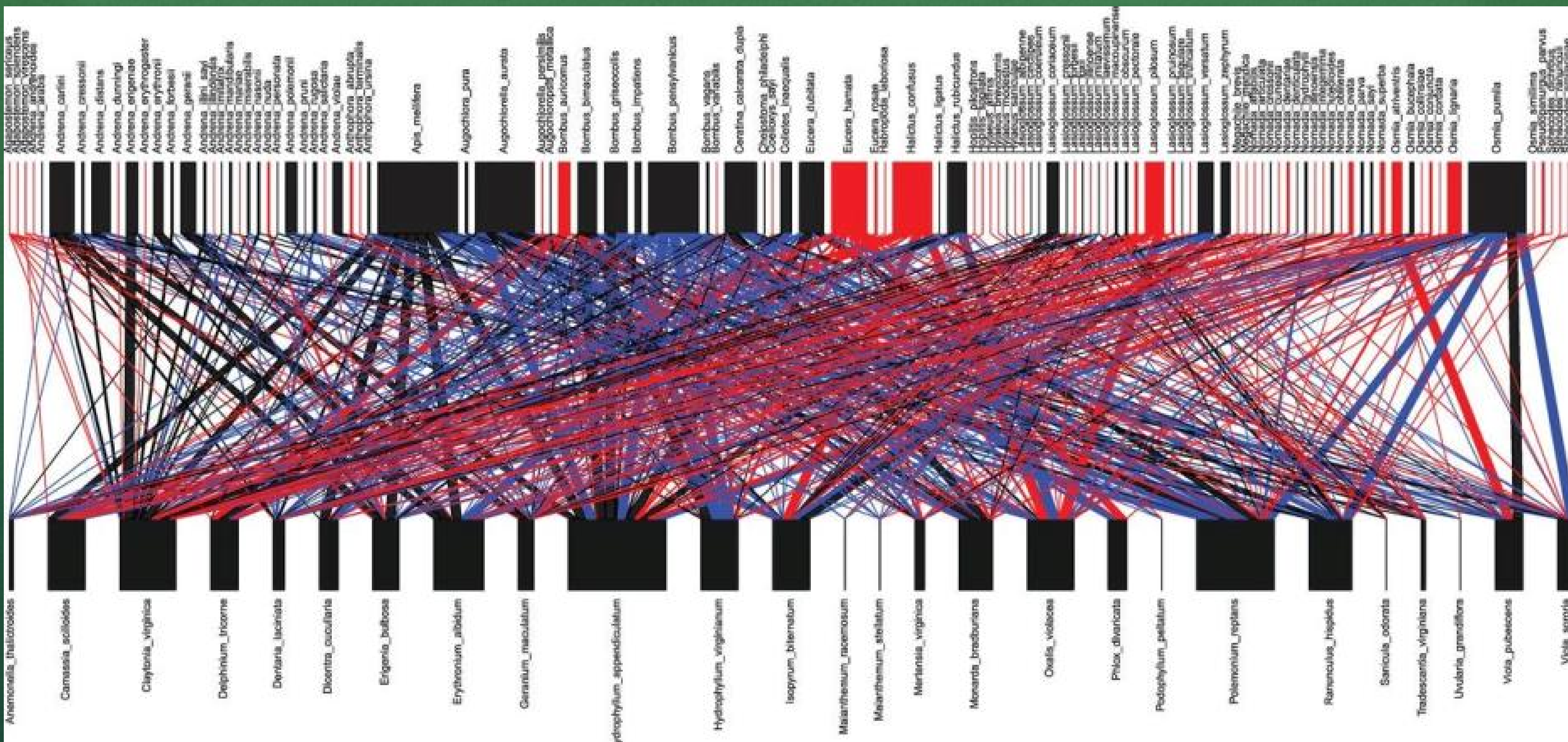
Honey-bees and Wild Pollinators

- Honey bees (*Apis mellifera*) represent the most commonly recognized and used species for large-scale pollination; but how do honey bees and wild pollinators interact in agricultural systems?
- Fruit set increased significantly with wild insect visitation in all crop systems (Garibaldi et al 2013)
  - Fruit set increased with flower-visitor richness independently of honey bee visitation (ibid)
  - Results indicate that integrated management policies could improve future agricultural yields

Honey-bees and Wild Pollinators

- These results challenge land-sparing conservation approaches advocating the protection of biodiversity outside of farmed areas / the further intensification of agricultural areas
- Pollinator visitation does not equal pollen deposition (the latter of which results in fruit set); wild pollinators increased incidences of pollen deposition
- Studies of uncropped field margins (6 m wide field margins that are not sown with crops or treated with agrochemicals) have found that they support approximately six times as many flowering plant species, ten times as many flowers, and attract ten times as many foraging bumblebees as equivalent cropped field margins
- Consider: what are the effects of habitat alteration?
- References: Garibaldi et al 2013

Habitat Alteration



Habitat Alteration

- Intensification of farming practices during the latter half of the 20th century can be partially blamed for native pollinator habitat loss
- Changes include the loss of unimproved flower-rich grasslands (formerly valued as pasture and for hay production), loss of hedgerows, and the widespread use of insecticides and herbicides (the latter removing food sources for insects)
- Figure explanation: “In the late 1800s, Charles Robertson meticulously collected and categorized insect visitors to plants, as well as plant and insect phenologies, in natural habitats near Carlinville, Illinois, USA. Over the next century, this region experienced severe habitat alteration, including conversion of most forests and prairies to agriculture, and moderate climatic warming of 2°C in winter and spring. In 2009 and 2010, researchers revisited the area studied by Robertson and re-collected data on the phenologies and structure of a subset of this network—26 spring-blooming forest understory forbs and their 109 pollinating bees. Hence, they could quantify changes in network structure, local bee diversity, and phenologies of forbs and bees.”
    - In the intensive resurvey over 2 years, researchers found less than half (54 of 109) of those bee species
    - Only 24% of the original interactions (125 of 532) were still intact. However, they observed 121 novel forb-bee interactions in the contemporary data, such that the absolute difference of interactions lost was 46% (246 of 532)
    - Of the 407 lost interactions, 45% (183) were lost because bee species were extirpated from the study region; all 26 forbs remained present
- References: Goulson 2003; Burkle et al 2013

Bees – Paragons of Pollination

- Roughly 90% of world's plant species are pollinated by animals, most of which are bees
- Roughly 18,000 bee species have been described, with the true total number of species likely near 20,000
- Bee biodiversity peaks not in the tropics but in arid temperate areas

Bees – Paragons of Pollination

- Sociality may help explain the exceptionally high bee diversity observed in deserts as well. One hypothesis is that social species, which have long flight periods and require continuous bloom, are excluded from deserts, where bloom in temporally patchy. This makes floral resources available for a greater variety of less abundant, solitary species
- Oligolectic (single food species source) species may be able to time their emergence to the temporally erratic bloom of their host plant species better than polylectic (multiple food species source) species, thus creating selection for dietary specialization on the part of desert bees, and subsequently high diversity
- Image copyright 2014 Dan Routh Photograph
- References: Winfree 2010

Bumble Bees

- Bumble bees (the genus *Bombus*) are the best-studied bee taxon and the only taxon that has been globally assessed for its endangerment status.
  - Half of the *Bombus* species historically known from Britain are either extinct, or in danger of extinction
  - Of the 60 *Bombus* species known from west and central Europe, 30% are now threatened throughout their range according to IUCN criteria, and 7% went extinct in this region between 1951 and 2000
  - The main cause of *Bombus* decline in the UK and western Europe is widely agreed to be the agricultural intensification that took place in the 20th century
  - Three formerly common North American species in the subgenus *Bombus* (*B. affinis*, *B. terricola*, and *B. occidentialis*), have declined dramatically, while a fourth which was always rare, *B. franklini*, is now close to extinction

Bumble Bees

- One working hypothesis proposed to explain these declines is parasite infection from commercially reared congeners. In particular, the fungal pathogen Nosema bombi may have spread to wild North American bees from commercial B. occidentalis and B. impatiens raised for greenhouse pollination in Europe, and then imported into the United States. In support of this hypothesis, commercial Bombus are known to have higher pathogen burdens than wild bees, and to forage outside the greenhouse

- B. affinis, which was once common across much of eastern North America, disappeared from 42 of 43 sites between the early 1970s and mid 2000s
- comprehensive analysis of 527 European bee species suggests depending on the climate change scenario, Europe could lose 14–27% of its bee species by 2050 due to climate change (Climate change could cause widespread extinctions of bees, as it could for other organisms, if bees are unable to migrate fast enough to keep up with the regions within their thermal tolerances)
- Few studies have compared pesticide toxicity in non-Apis species to Apis, and the results have been variable. Laboratory colonies of Bombus impatiens fed spinosad-contaminated pollen at concentrations they are likely to encounter in the wild experienced few lethal effects, but showed impaired foraging behavior
- References: Winfree 2010
-

Honey Bees

- Worldwide the number of honey bee hives have increased by ~45% since 1961, however, the proportion of agricultural crops depending on pollinators is increasing much more rapidly (>300%)

- There are currently ≈2.5 million hives in the U.S., decreased from ≈6 million some 60 years ago

- USDA reports that “Currently, the survivorship of honeybee colonies is too low for us to be confident in our ability to meet the pollination demands of U.S. agricultural crops”

Honey Bees

- Demand for pollination services could outstrip the increase in hive numbers
- References: Potts et al 2010; Walsh 2013
- Image copyright 2014 Dan Routh Photography

Honey Bees – Colony Collapse Disorder

- Colony Collapse disorder (CCD), which has received attention from the press since 2006, isn't a single issue—it's an umbrella term for a larger phenomenon
- Problems include: mites (e.g. *Varroa destructor*), viruses, bacterial pathogens, pesticides, and a variety of other issues

Honey Bees – Colony Collapse Disorder

- Beekeepers in the United States have seen honey bee colony loss rates increase to an average of 30% each winter, compared to historical loss rates of 10 to 15%
- References: Walsh 2013

Pesticides: Neonicotinoids

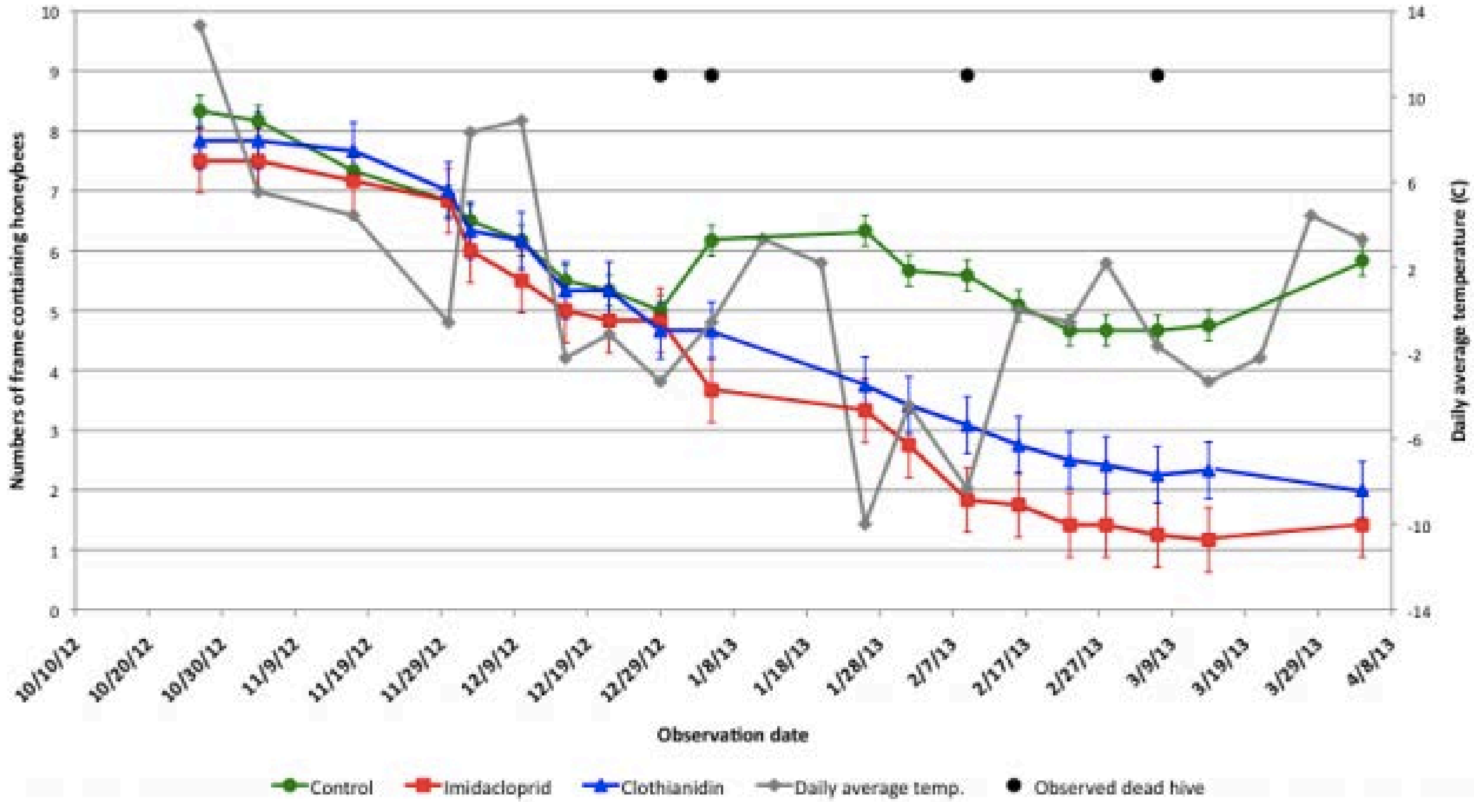
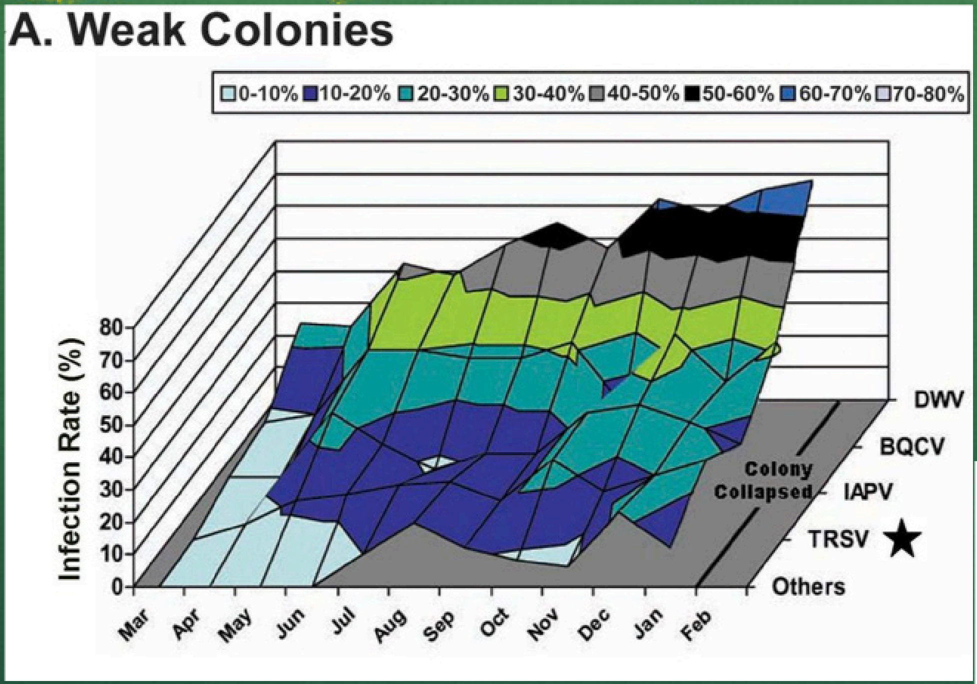


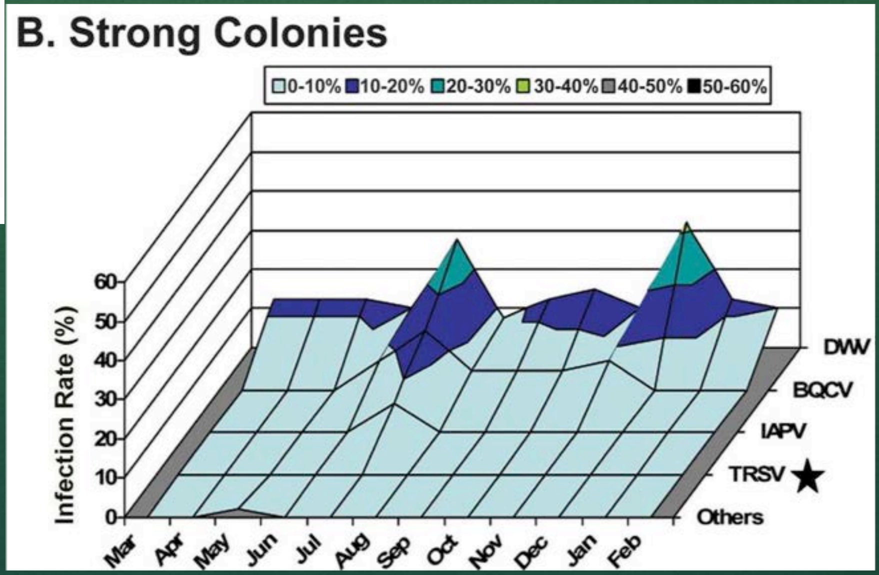
Figure 1. Average numbers of frame (standard deviations shown as error bars) containing honeybees for control-, imidacloprid-, and clothianidin-treated colonies and the corresponding daily average temperature at Worcester regional airport in Worcester MA recorded from October 2012 to April 2013. The daily average temperature readings were obtained from the NOAA website (http://cdo.ncdc.noaa.gov/qclcd/QCLCD).

Pesticides: Neonicotinoids

- Sub lethal exposure of neonicotinoids (including imidacloprid or clothianidin) affected winterization of colonies, leading to colony collapse
- Imidacloprid is currently the most widely used insecticide in the world; can be applied by soil injection, tree injection, application to the skin of the plant, broadcast foliar, ground application as a granular or liquid formulation, or as a pesticide-coated seed treatment
- 18 colonies were studied separate into 3 groups (control, imidacloprid treated [4 died], clothianidin treated [2 died]); no difference in colonies until the arrival of winter; brood rearing in neo-treated colonies did not resume in the spring; half of the treated colonies were lost as opposed to 1 out of 6 control colonies
- E.U. announced a two year ban on neonicotinoids as of mid-2013
- The U.S. has yet to take any such action—USDA withholds judgment and the EPA is conducting five year study
- Consider: the precautionary principle
- References: Walsh 2013; Lu et al 2013

Pathogens: Tobacco Ring Virus





Pathogens: Tobacco Ring Virus

- Li et al: Seasonal prevalence of TRSV (tobacco ringspot virus) and other honeybee viruses in honeybee colonies.
- (A) Weak colonies. The prevalence of TRSV along with deformed wing virus (DWV), black queen cell virus (BQCV), Israeli acute paralysis virus (IAPV), and two rarely detected viruses, sacbrood virus (SBV) and chronic bee paralysis virus (CBPV) was found in all season. The viral infections reached their peaks in winter before the colony collapsed. Of viruses detected in weak colonies, DWV was the most prevalent, followed by BQCV, IAPV, TRSV, and others (SBV and CBPV).
- (B) Strong colonies. Only DWV and BQCV were detected in healthy colonies all year round, but the prevalence of the viruses in strong colonies was significantly lower in weak colonies. All strong colonies survived through the cold winter months.
- Bee colonies were classified as strong or weak based on the size of adult populations, amount of sealed brood, and presence of food stores, as previously described. Bee colonies that had more than ten frames covered with adult workers and more than six frames filled with brood and food stores were defined as strong colonies, while bee colonies that had a small number of foraging bees flying in and out, fewer than ten frames of adult bees, fewer than six combs with brood, and small patches of food stores were defined as weak colonies
- Note: RNA viruses have very high mutation rates, i.e. their genetic composition can change significantly from generation to generation
- TRSV was also found in Varroa mites, which suggests that Varroa might be partially the cause of TRSV spread
    - the virus seems to be able to successfully live both in bees and in plants (i.e. new example of pathogen host shifts
    - in plants, the virus causes “infected plants show discoloration, malformation, and stunted growth, accompanied by reduced seed yield or almost total seed loss due to flower and pod abortion”
- References: Wines 2014; Li et al 2014

New Efforts for Pollinators

the WHITE HOUSE *PRESIDENT BARACK OBAMA*

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For Immediate Release June 20, 2014

Presidential Memorandum -- Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators

MEMORANDUM FOR HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES
SUBJECT: Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators

Pollinators contribute substantially to the economy of the United States and are vital to keeping fruits, nuts, and vegetables in our diets. Honey bee pollination alone adds more than $15 billion in value to agricultural crops each year in the United States. Over the past few decades, there has been a significant loss of pollinators, including honey bees, native bees, birds, bats, and butterflies, from the environment. The problem is serious and

LATEST BLOG POSTS

New Efforts for Pollinators

- The White House will be creating a new "Pollinator Health Task Force"
- The Task Force will be assigned to implement National Pollinator Health Strategy
    - Pollinator Research Action Plan
    - Public Education Plan
    - Public-Private Partnerships
    - Increase and Improve Pollinator Habitat
- URL: http://www.whitehouse.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b

What can I do?

- Plant a wide diversity of flowers in your garden
- Contact your representatives
- Buy Honey
- Drink Mead
- Continue to inform yourself and your friends/family
- The Xerces Society—information for ranchers and land-owners
- Contact me!
  - Devin.Routh@gmail.com

What can I do?

- Scientific literature constantly reveals more and more evidence to an increased number of threats to pollinators
- Are there any "easy" or "simple" fixes?
- Consider: Pollinators are on the decline
- What do the terms "resilience" and "biodiversity" mean?
- What does the "precautionary principle" mean?
- Spreading information and encouraging citizen action
    - Xerces society
    - local beekeeping associations
    - honey products
- Pollinators are important for both "human" and "non-human" ecology
-

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