Nutritional health of honey bees in a changing world

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Anthropogenic transformation of the globe
Fewer floral resources available for pollinators

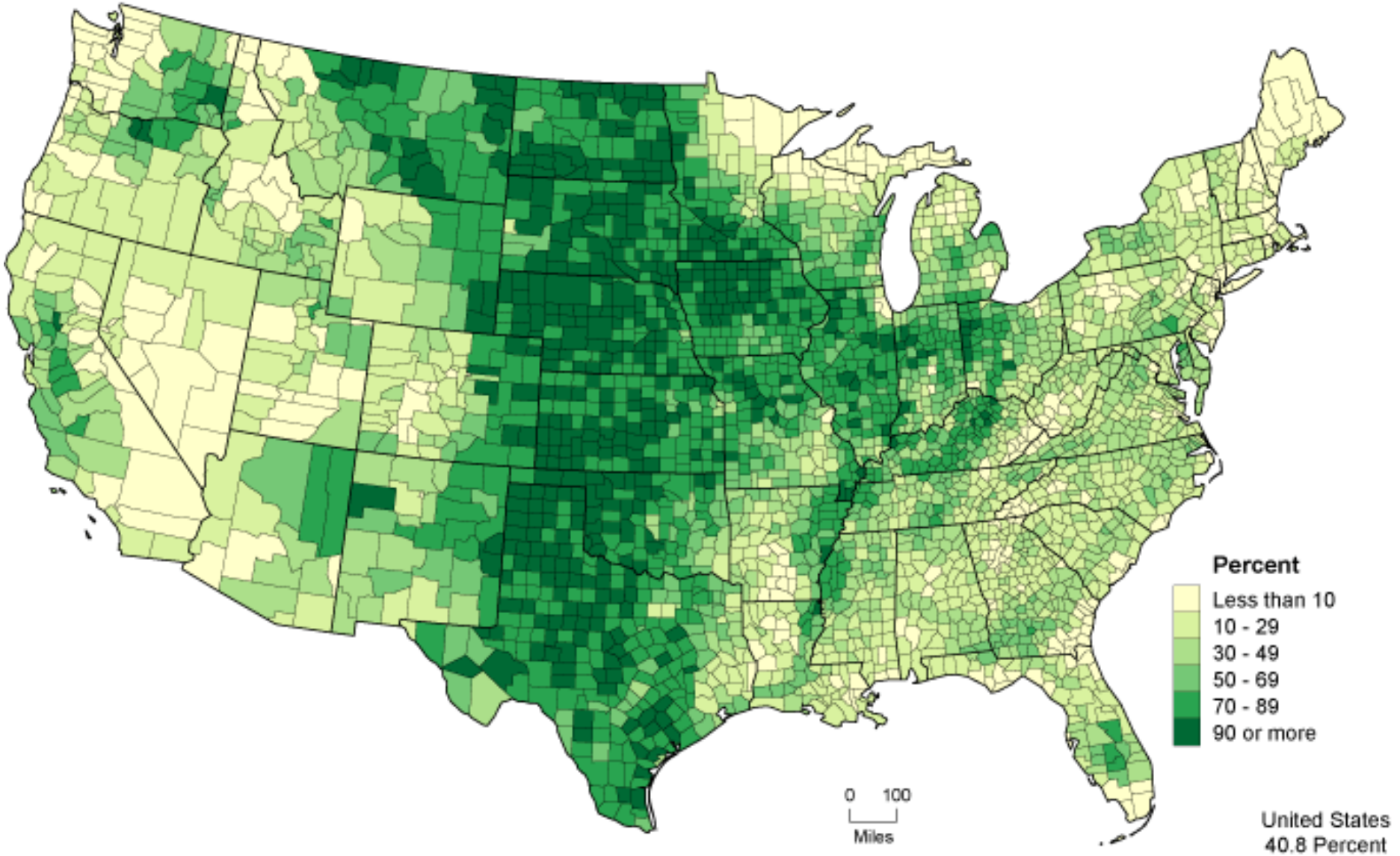
Animal Pastures

Urbanization

Monoculture crops

Gerstner et al. 2014
Foley et al. 2005

The USA: *40%* of land is under cultivation



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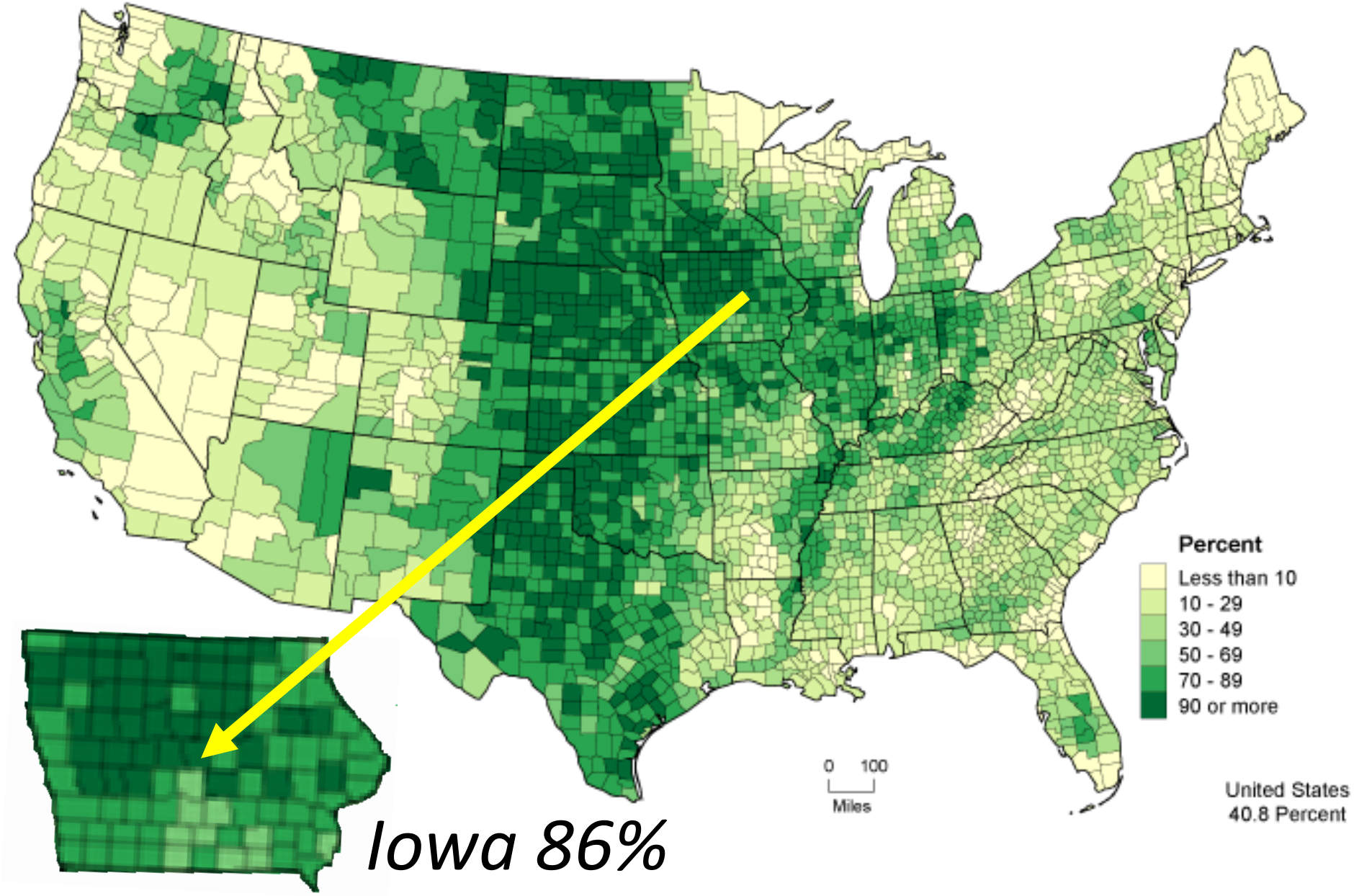
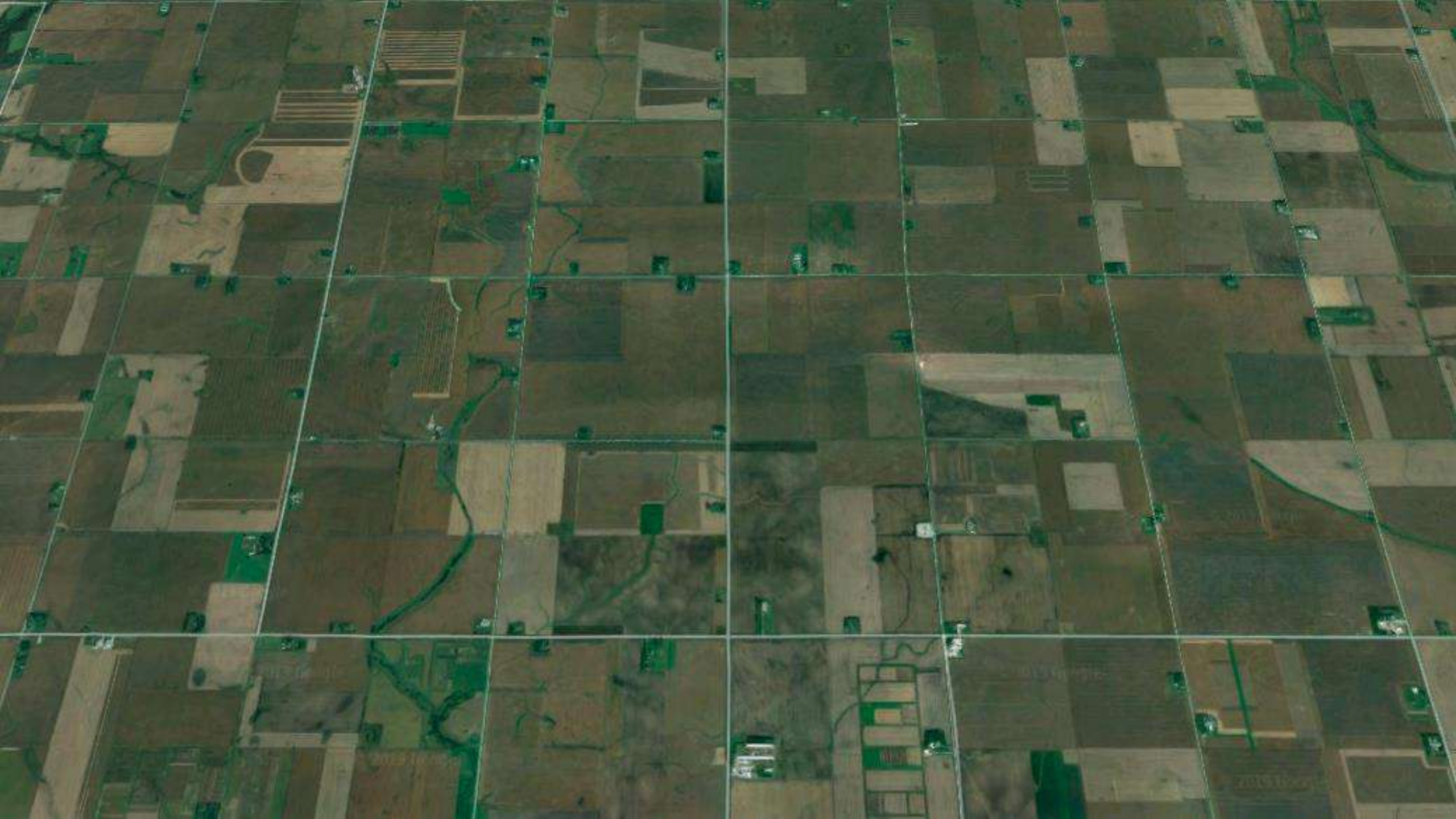
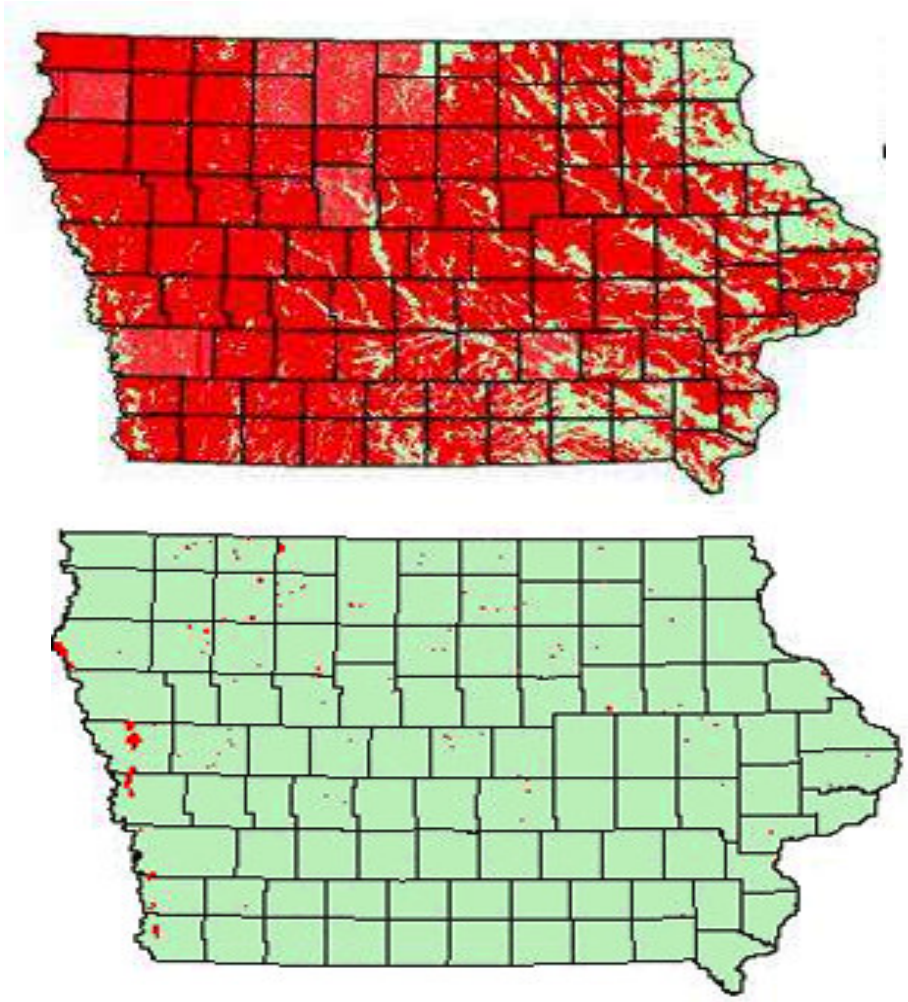





I can see why they call it “fly-over” country…

Iowa: Nearly totally transformed landscape
Landscape of the future?



Fletcher & McNeely Iowa State University

~80% of Iowa in native tallgrass prairie, pre-colonization

Now < 0.1% in prairie, ~80% in farmland, vast majority in vast monocultures of corn and soy

Samson and Knopf 1994, Smith 1998

A drastic change for bees

High diversity floral landscape

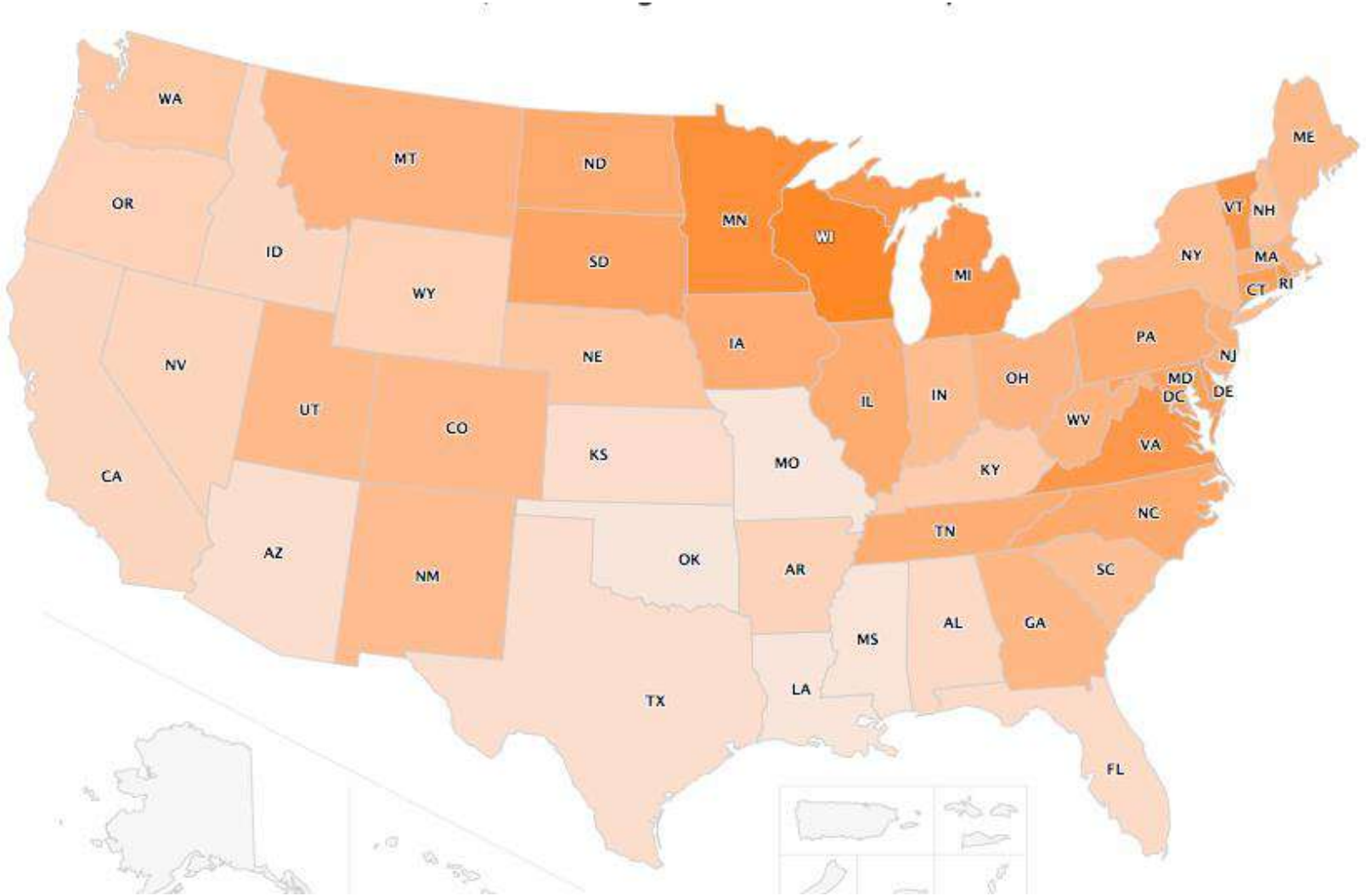
Low diversity floral landscape

Soy: produces nectar for a short period of time (1 month)

Corn: produces pollen, poor nutritional value and not favored by bees

Annual colony losses are especially high in the Upper Midwestern USA

Iowa: 60% Average Annual Colony Loss in 2017-2018



Bee Informed Partnership

Why? Multifactorial stresses

Pesticides

Poor foraging resources

Parasites and pathogens

Goulson et al. 2015

Nutrition is fundamental

- “You are what you eat.”
- Nutritional stress can lead to other health problems
- Honey bee diet is deceivingly simple, and subtly complex
  - Nectar -> honey (carbohydrates, phytochemicals), pollen (amino acids, lipids, micronutrients)
  - Bees forage for a diverse diet composed of multiple species of plant nectar and pollen

Research questions

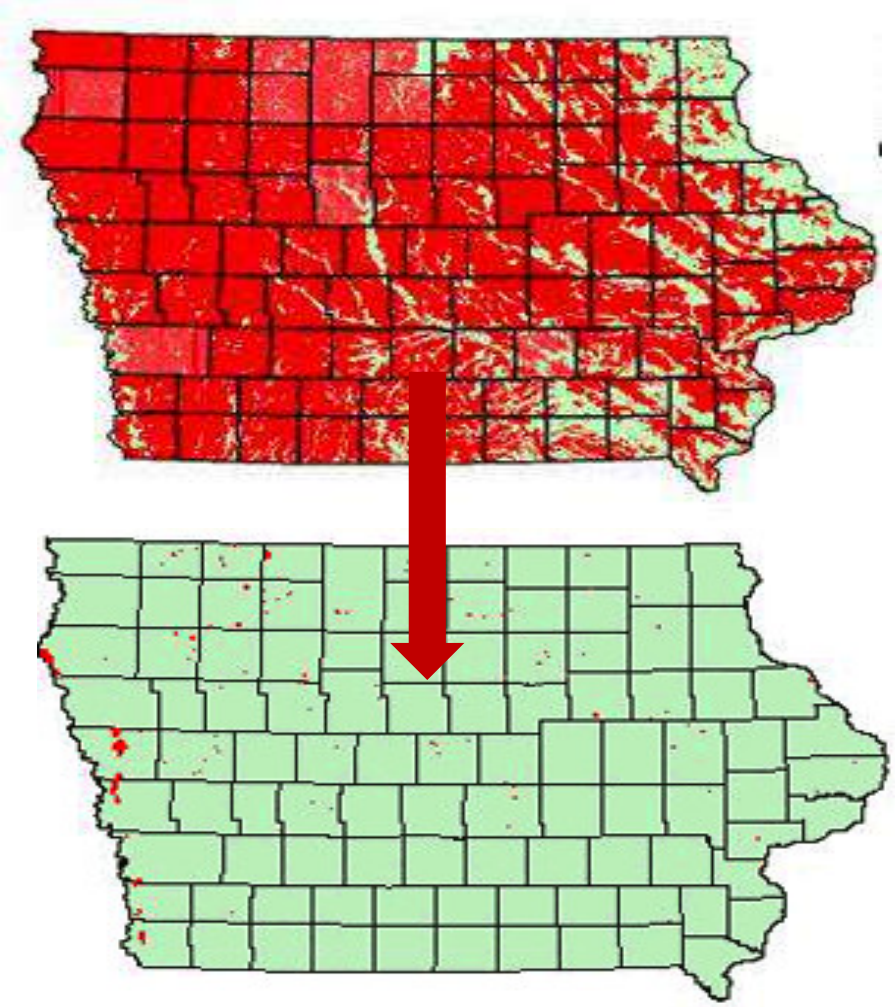
Lessons from an Extreme Land…

1. Can a good diet protect bees from other forms of stress?

2. What is the connection between agricultural land development and honey bee nutritional state?

3. Is there a nutritional critical period for bees?

4. What are some possible real-world solutions?

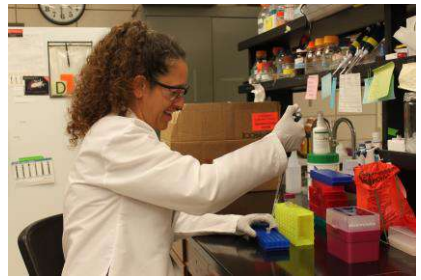


1. Can a good diet protect bees from other forms of stress?

Viral disease… a rising problem

Deformed Wing Virus

Sacbrood Virus



Jimena Carrillo-Tripp

Adam Dolezal

Bryony Bonning

Israeli Acute Paralysis Virus

Black Queen Cell Virus

Artificial infection experiments
Mixed inoculum: SBV, IAPV, BQCV, DWV

IAPV is the main cause of mortality from this mix (Carrillo-Tripp et al. 2016 *Scientific Reports)*

What is the interaction between diet and nutritional stress?

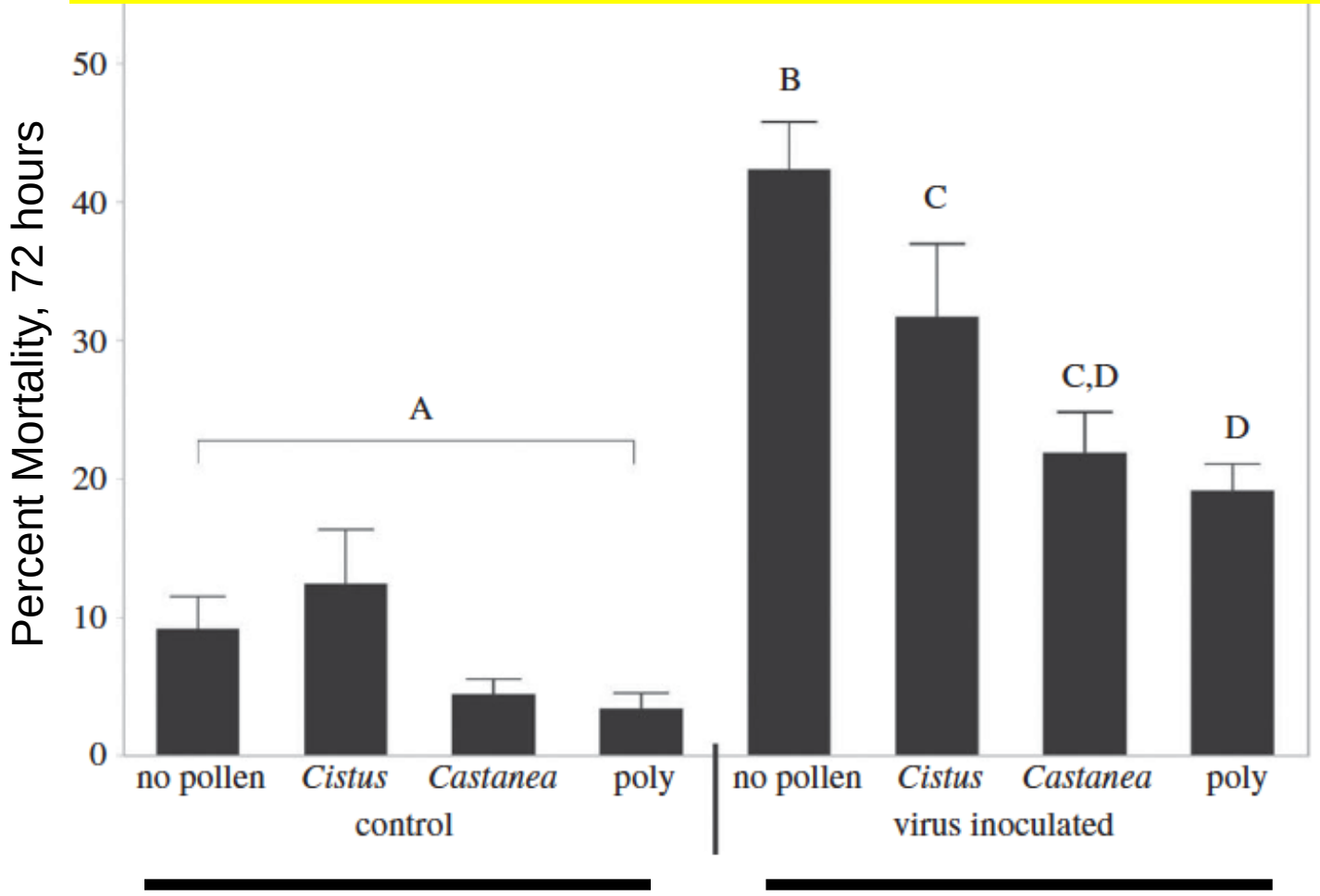
* DiPasquale et al. 2013

	No pollen (Sugar only)	Monofloral *Castanea* Chestnut “good”*	Monofloral *Cistus* Rockrose “bad”*	Polyfloral (>10 species)
Virus +				
Virus -				

Hypothesis: Bees that eat mixed pollen or high quality pollen will show “nutritional resilience” against viral infection

High quality pollen diet protects bees from virus-mortality

Why? Cistus is low in total protein, certain amino acids and anti-oxidants (DiPasquale et al. 2013) calcium and iron. Diverse pollen and micronutrients may support bee health.



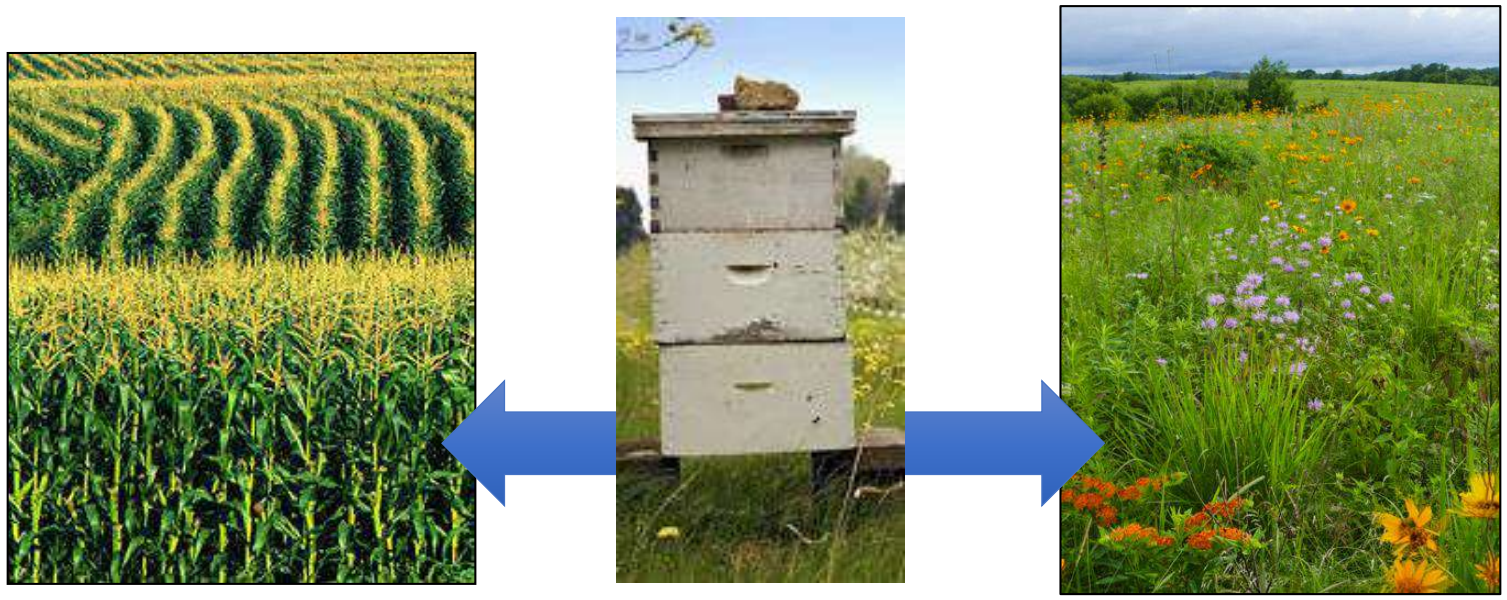
Mixed model ANOVA
Virus p<0.001
Diet p<0.001
Interaction p<0.001
N=15 cages/treatment

n=15
Steel-Dwass

Dolezal et al. 2019 *Royal Society Open Science*

2. What is the connection between agricultural land development and honey bee nutritional state?

Hypothesis: Bees from apiaries in highly cultivated landscapes will show nutritional deficits compared to apiaries in more lowly cultivated landscapes

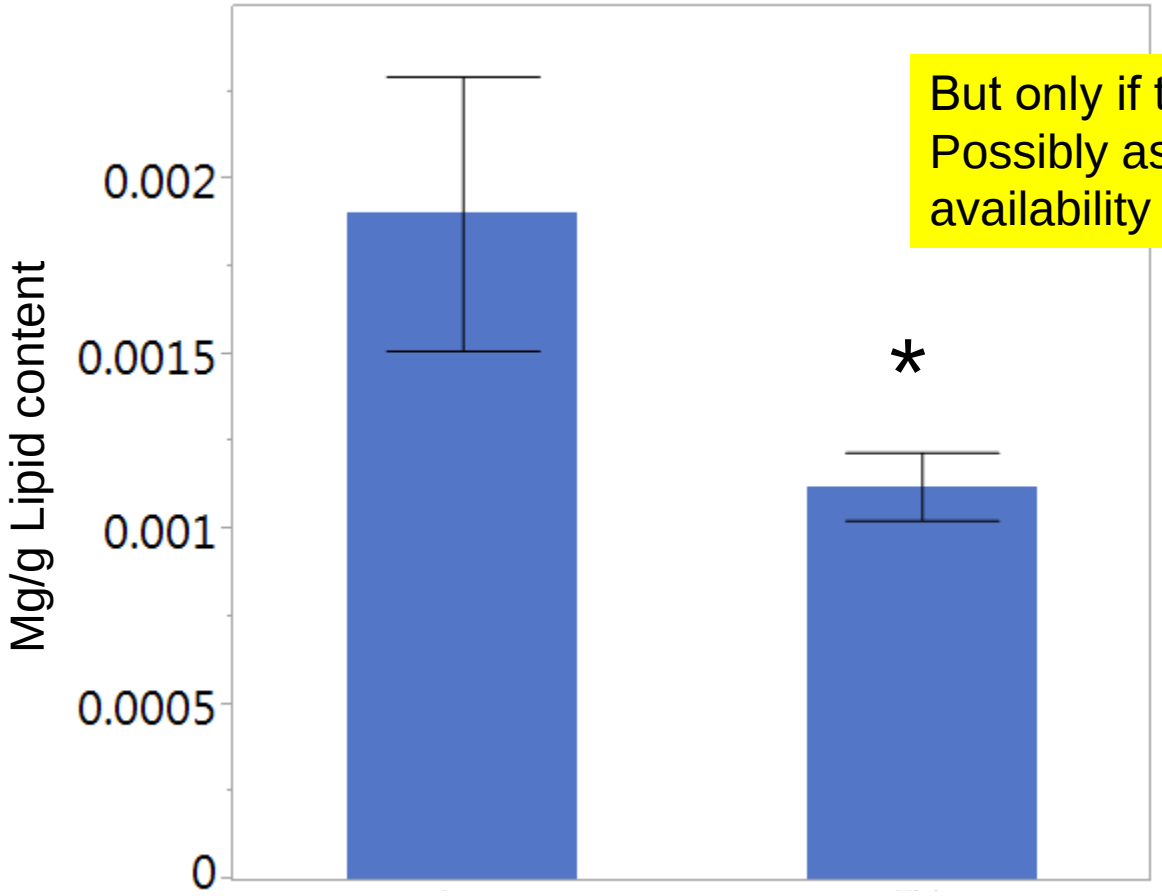


A collaboration with Iowa beekeepers

- 36 beekeepers collected live bees (n=~300) from colonies across the state of Iowa
  - Pre-overwintering time: related to probability of survival
  - Sent live by mail
- Bees processed in the laboratory to measure lipid content
  - Indicator of nutritional state
- Characterized surrounding landscape of apiaries using GIS

36 beekeepers sent samples from 110 hives

Bees in areas of lower cultivation have higher body lipid content



But only if they were mite ”free”. Possibly associated with floral resource availability in the landscape.

Dolezal et al. 2016
PLoS One

Low cultivation
N=13
(17-40% corn and soy)

High cultivation
N=13
(74-91% corn and soy)

3. Is there a critical period for bee nutrition?

Adam Dolezal

Ge Zhang

Matt O'Neal (ISU)

Ashley St. Clair

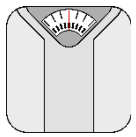
Monitor bee health from colonies located next to soybean fields
(n=2 years of data, 20 apiary sites, 80 hives)

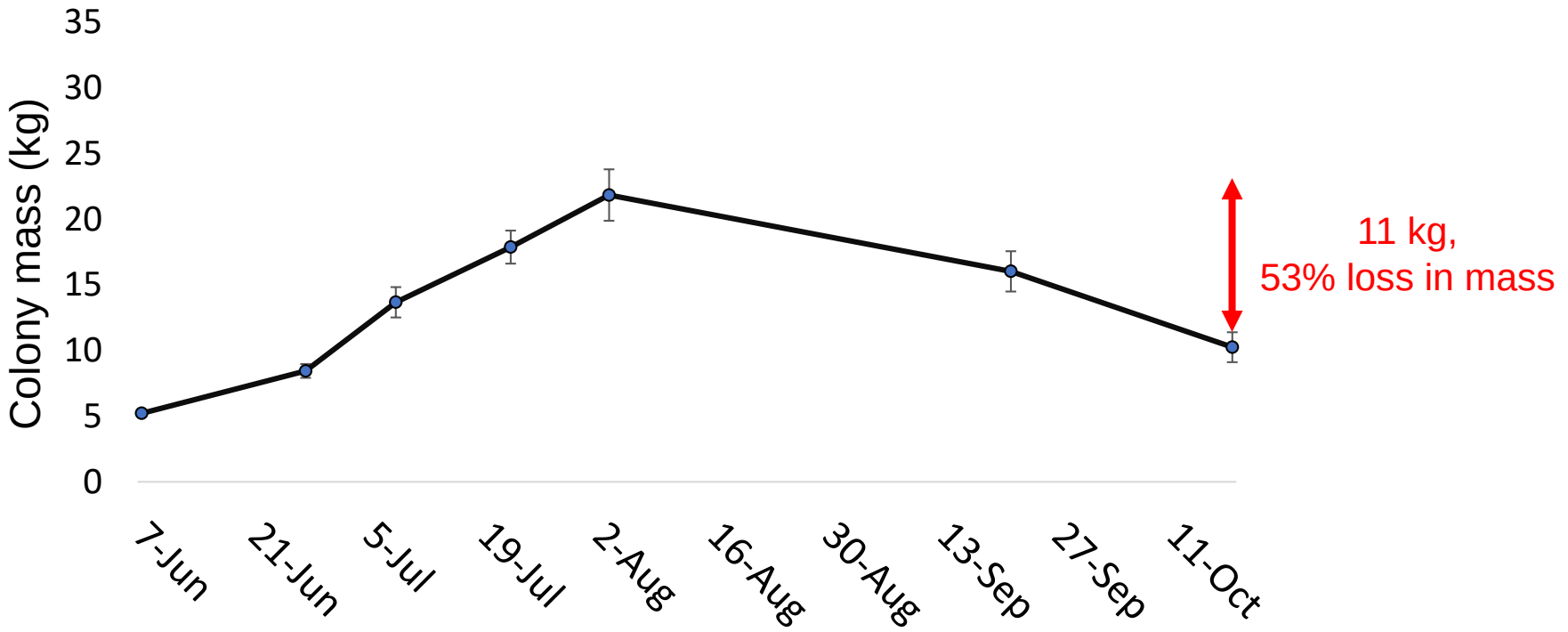
We already knew that bee behavior suggests a time of dearth in the fall

”Robbing season”

Hypothesis: Late summer/early fall is a time of nutritional stress for honey bees in highly cultivated landscapes

Large decline in colony mass in late summer/early fall





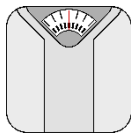
Similar patterns for capped brood, adult bee population

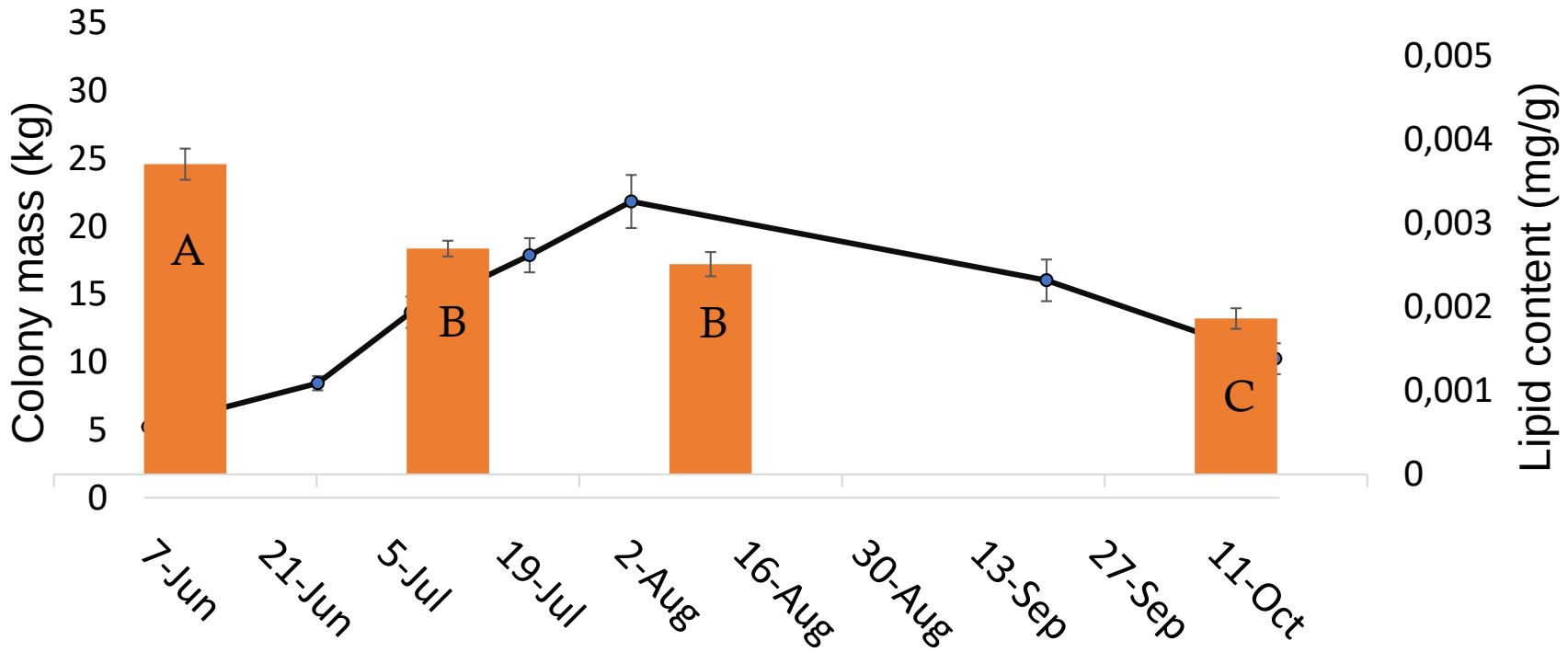
Some mass decline is typical, but this loss is extreme

Mixed model ANOVA; $p<0.05$
N= 80 colonies, 20 sites, 2 years

Dolezal, St. Clair et al. In revision

Declining nutritional state of individual bees



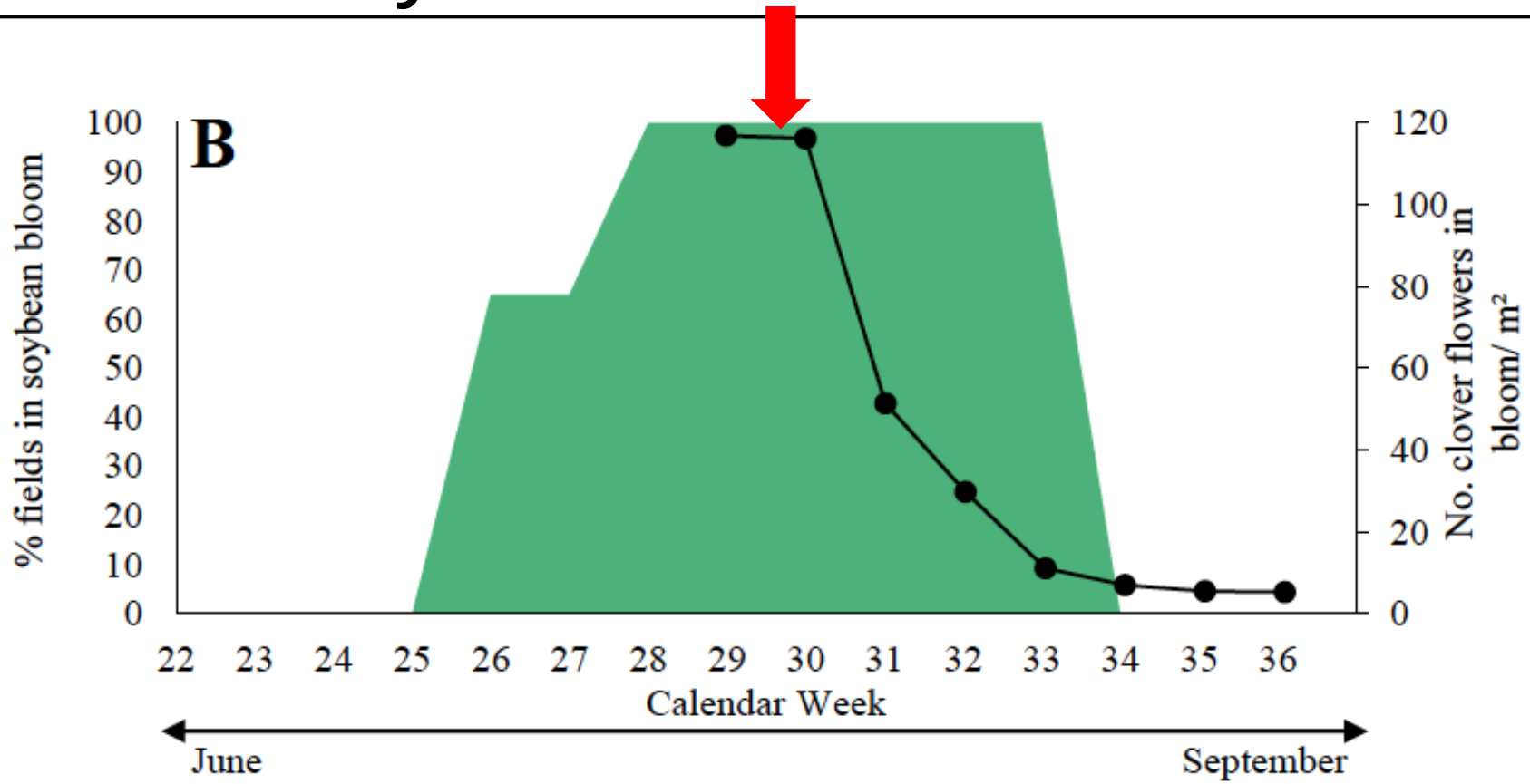


ANOVA, Tukey HSD; $p<0.05$
n=10/timepoint

Colonies and individual bees show declining nutrition at end of season

Harbingers of winter losses (colonies below 10kg almost never survive)

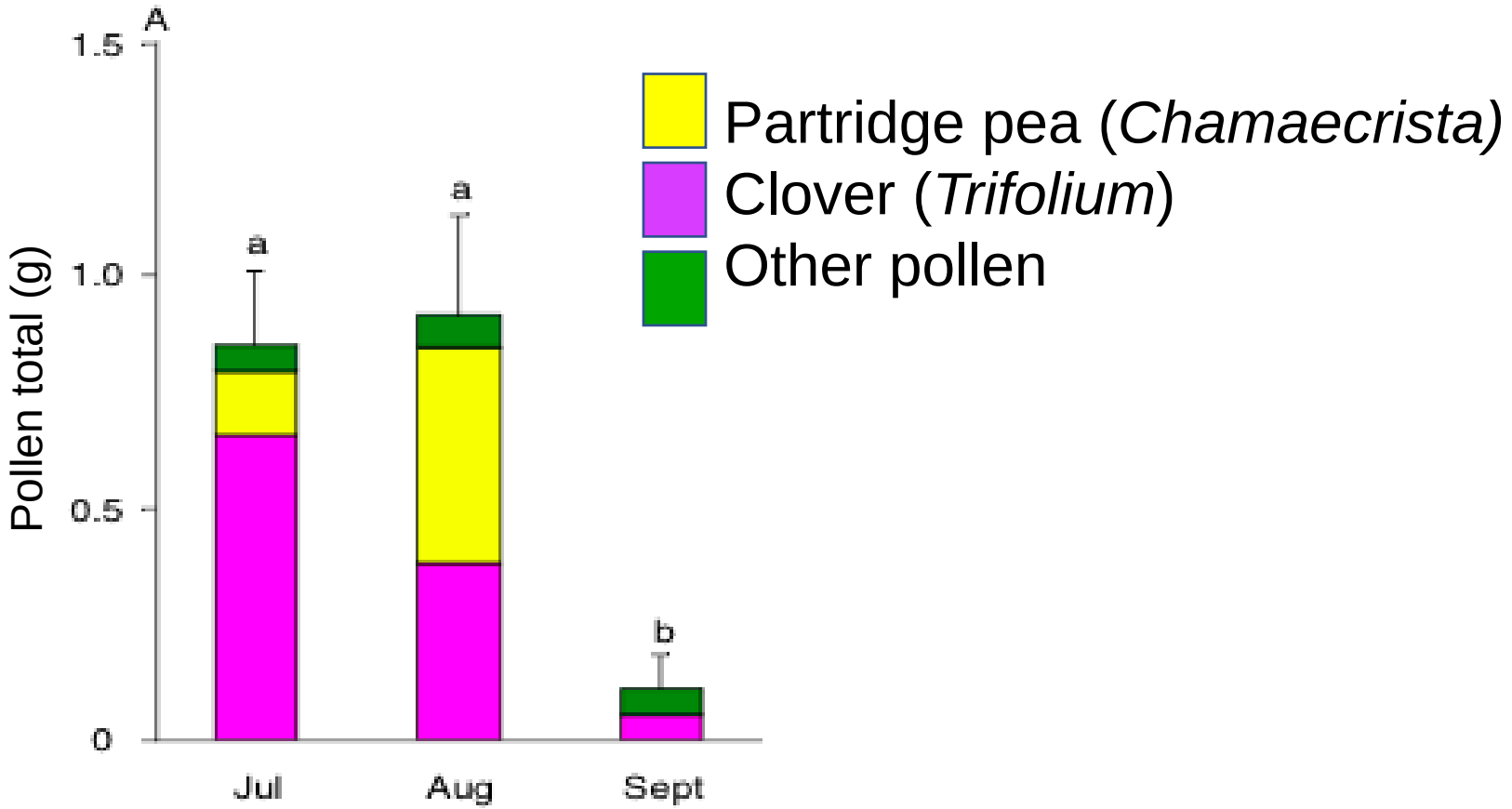
Colony decline coincides with the cessation of clover and soybean bloom



Bees using soybean nectar as forage (but not pollen)
Clover well-known to be a favored source of pollen and nectar forage by bees
Both in steep decline by late August, when colonies lose weight

Clover dominates bee-collected pollen in this landscape, greatly reduced in late season

Ge Zhang



Intensively farmed landscape is deficient in foraging resources and fails to support the nutritional health of bees at the end of the season

4. What are some possible solutions?

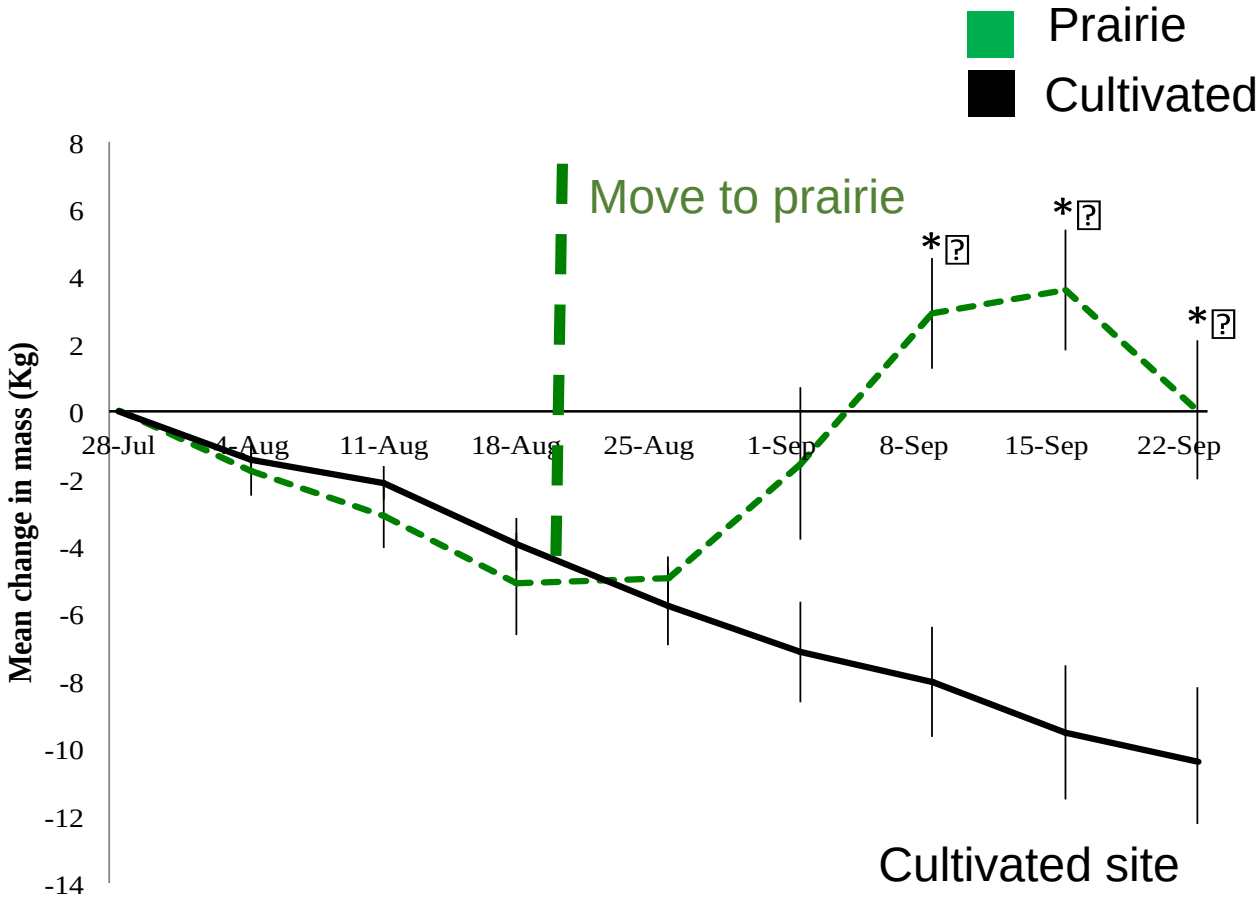
Native prairie: Greater floral biodiversity, flowering across the season

Hypothesis: Prairie habitat will prevent late season decline of hives previously located in soybean fields

Prairie habitat can “rescue” late season colony decline

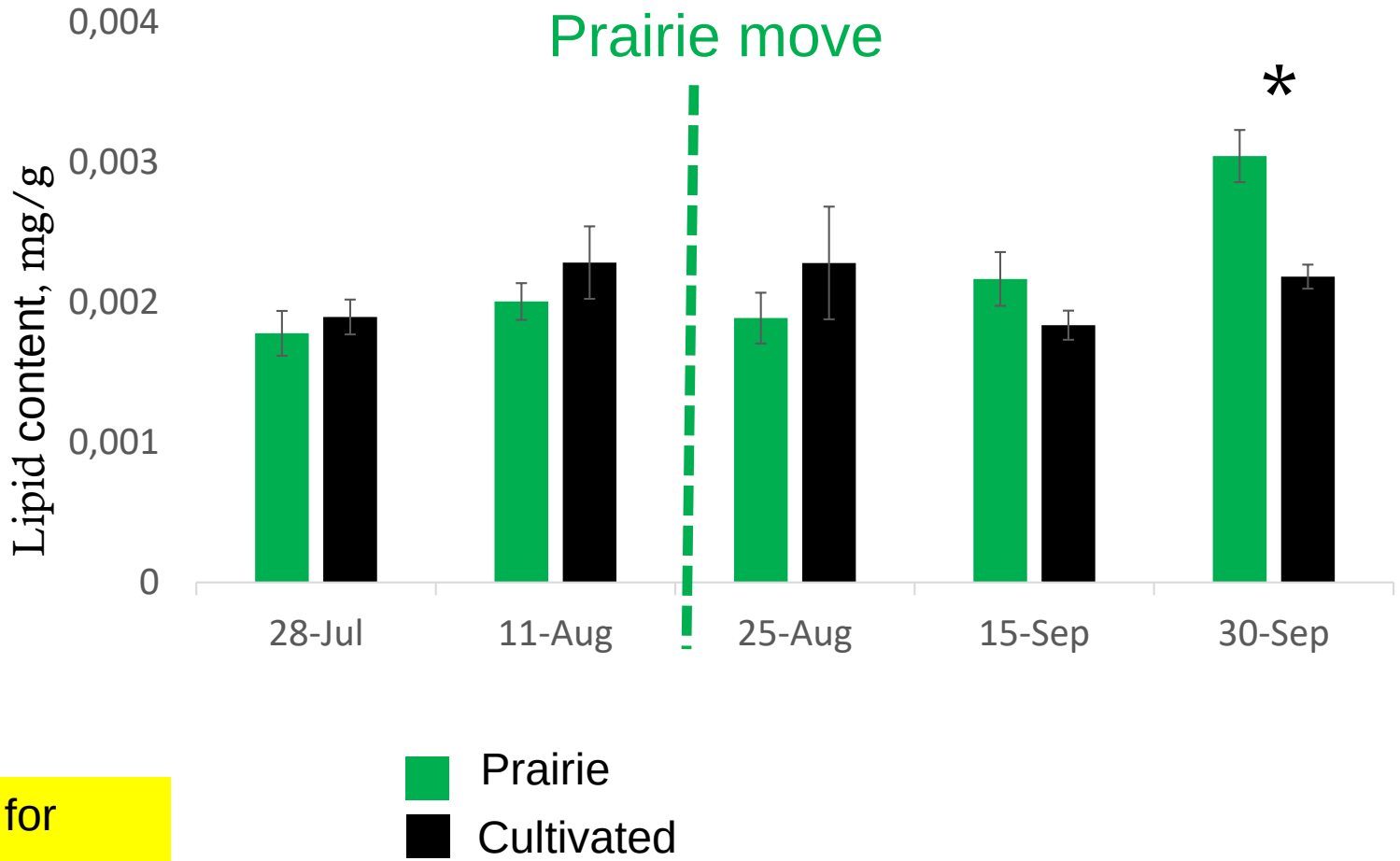
- Colonies kept at a highly cultivated site until start of weight decline (late August)
- Transport colonies to a prairie in the “critical period”, when steep colony decline begins

Ashley St. Clair



n=5, means +/- SE
T-test, p<0.05

Lipid levels of individual bees higher in colonies moved to prairie

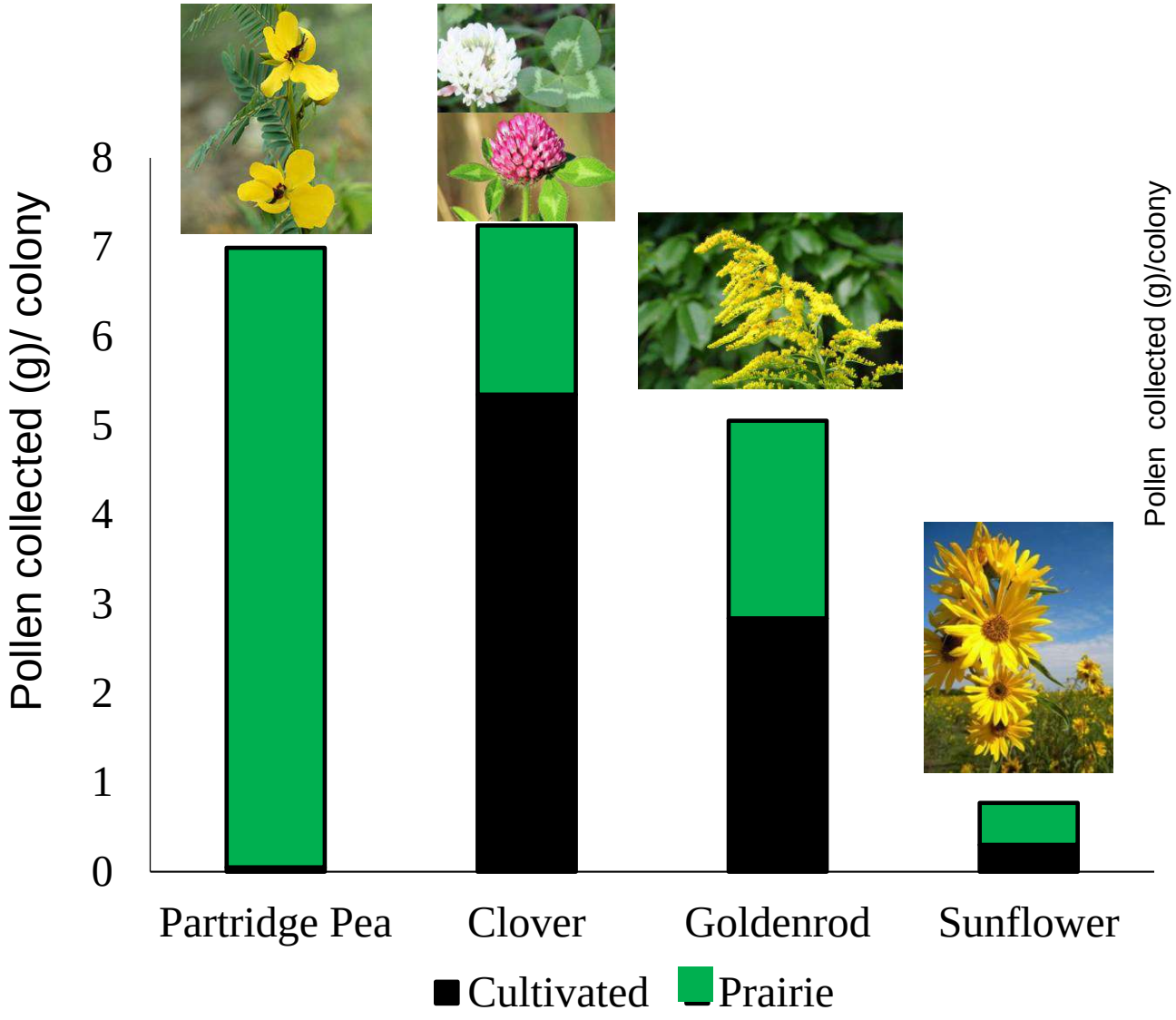


See talk by Randall Cass at 1:30 today for updates on this project!

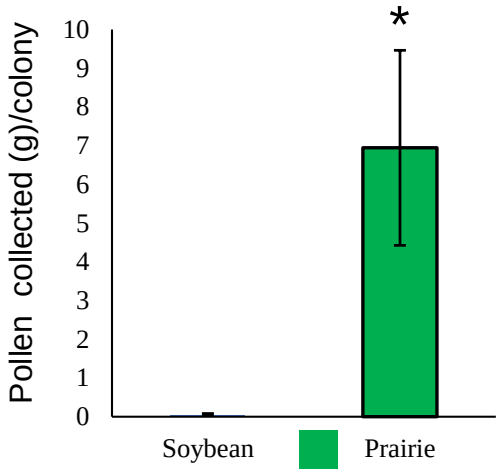
n=5, means +/- SE
T-test, p<0.05

Bee-collected pollen from prairies: honey bees use native plants

Ge Zhang



Chamaecrista
Partridge Pea



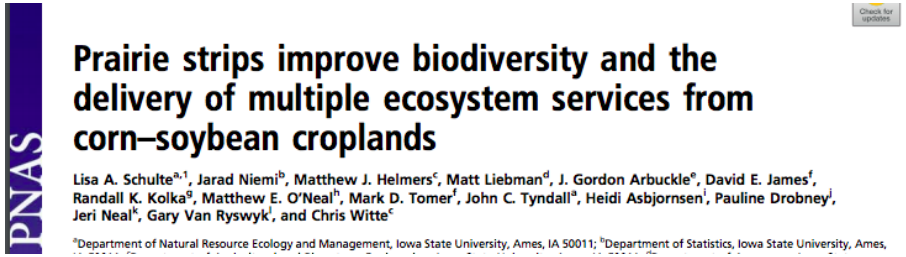
A sustainable solution for agricultural production and bees?

Prairie STRIPS (Schulte-Moore et al. *PNAS* 2017)

- **S**cientific **T**rials of **R**ow-Crops **I**ntegrated with **P**rairie **S**trips
- 10% of crop field taken out of production and seeded with prairie plants
- Shows large benefits for erosion, soil quality, and biodiversity

- What about bees (ISU Team)?

  Lisa Schulte-Moore (PI)
  Matt O'Neal (Entomology)
  John Tyndall (Economics)
  Joel Coats (Toxicology)
  Ge Zhang (MVP)



PNAS

Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands

Lisa A. Schulte[a,1], Jarad Niemi[b], Matthew J. Helmers[c], Matt Liebman[d], J. Gordon Arbuckle[e], David E. James[f], Randall K. Kolka[g], Matthew E. O'Neal[h], Mark D. Tomer[f], John C. Tyndall[a], Heidi Asbjornsen[i], Pauline Drobney[j], Jeri Neal[k], Gary Van Ryswyk[l], and Chris Witte[c]

[a]Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA 50011; [b]Department of Statistics, Iowa State University, Ames,

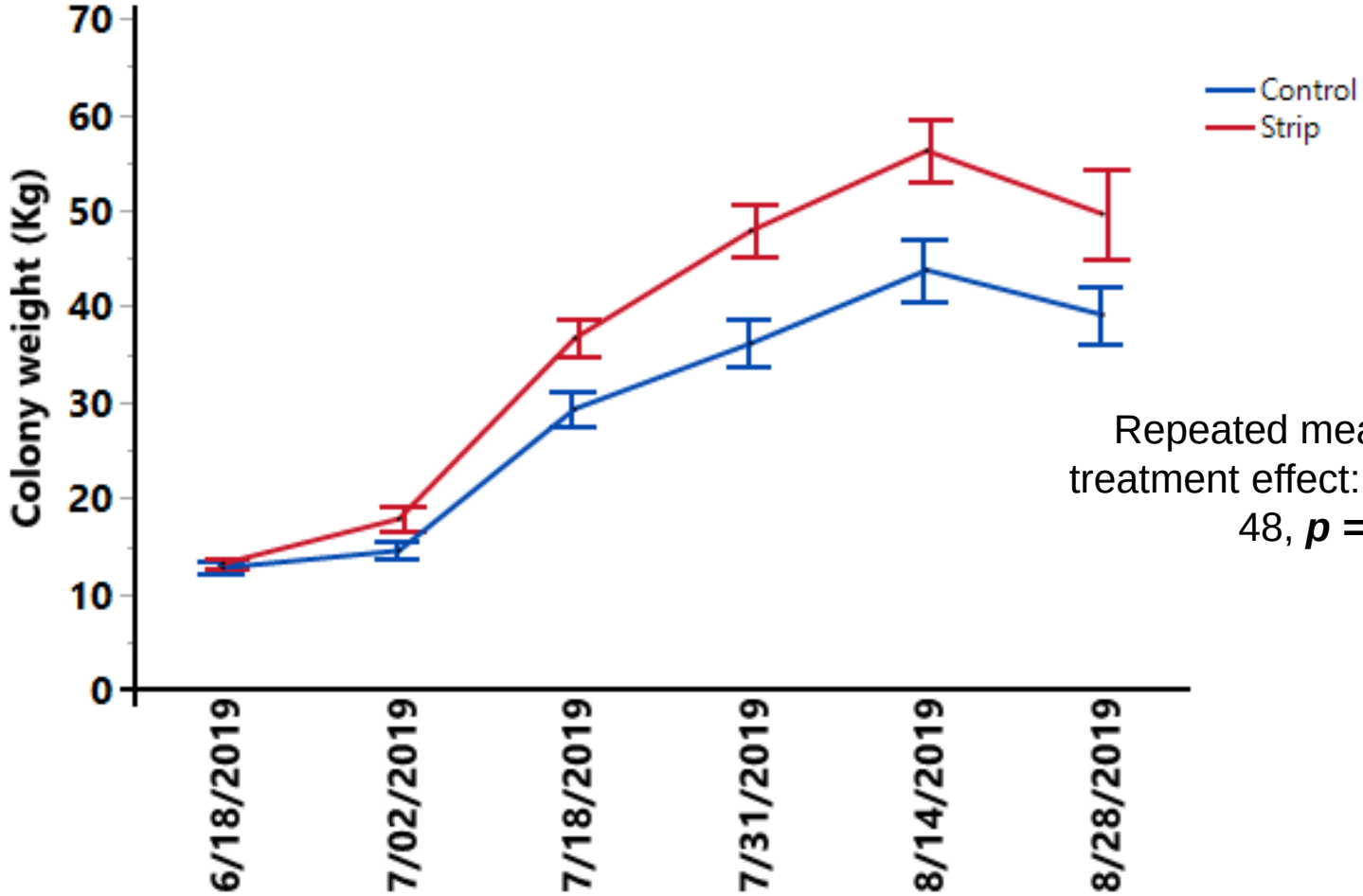
Photos by Ge Zhang, August 2019

STRIP sites (n=9 , 36 colonies, over 2 years)

Control sites (n=9 , 36 colonies, over 2 years)

Colonies gain more weight at STRIPS sites

Ge Zhang

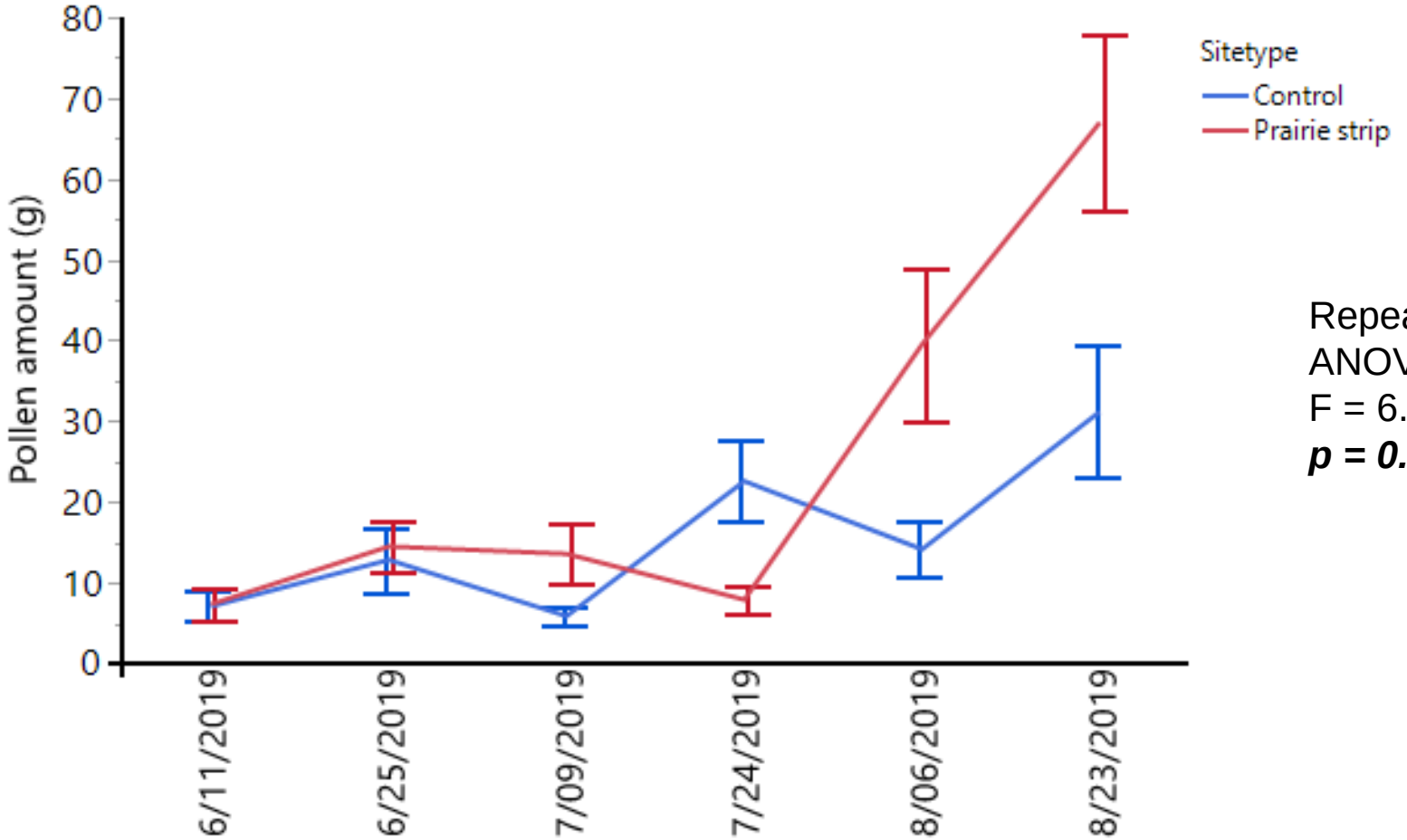


Repeated measures ANOVA, treatment effect: F = 13.83, df = 1, 48, ***p = 0.0005***.

((Now finishing season, analyzing lipids, and tracking winter survival))

Bees collect more pollen from STRIPS sites

Ge Zhang



Repeated measures ANOVA, treatment effect: F = 6.60, df = 1, 13.7, ***p = 0.0277***.

Suggests prairie strips may provide tangible benefits for both farmers and beekeepers

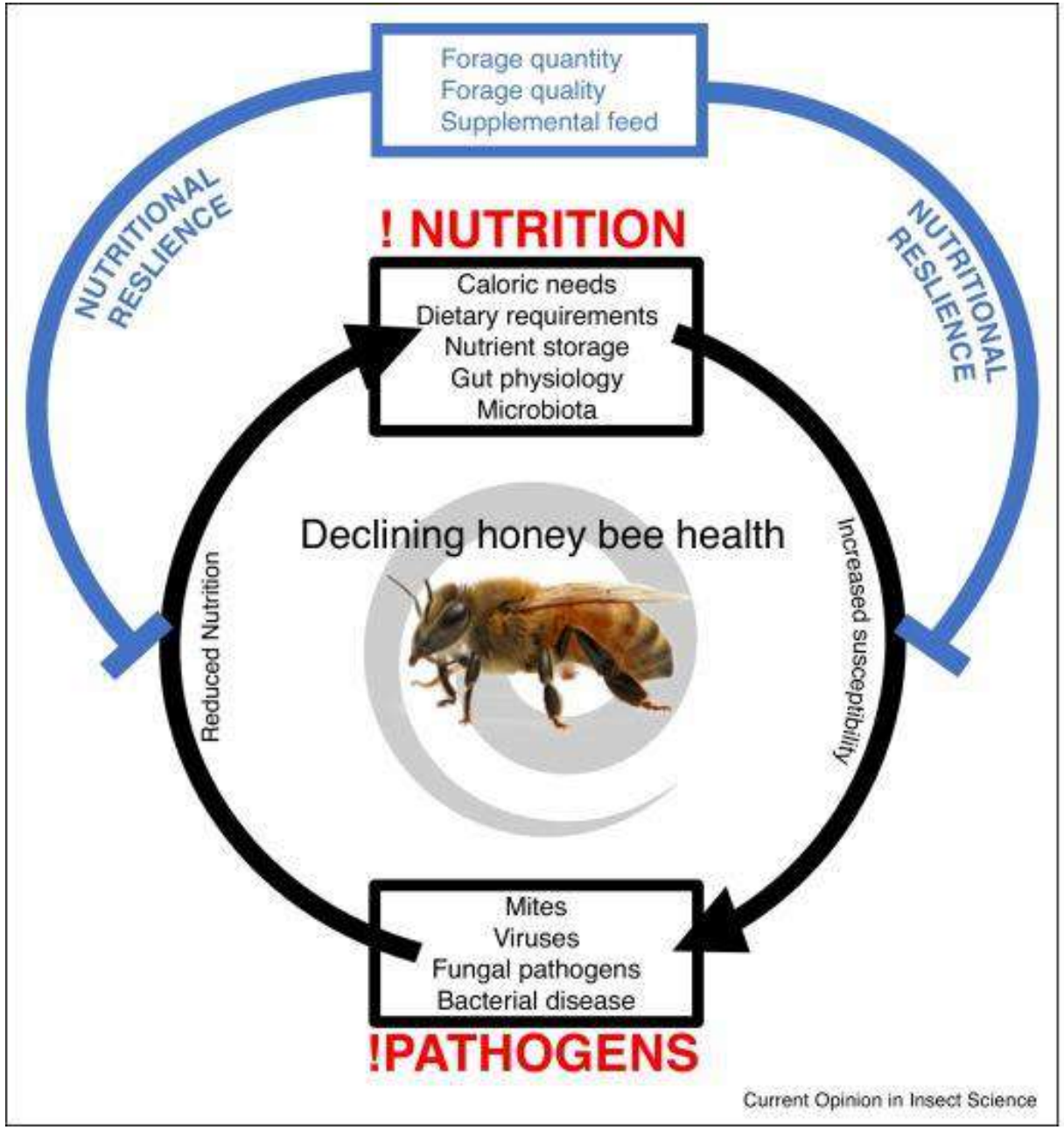
Summary: Nutrition is fundamental

- Good nutrition (diverse pollen, pollen with a full complement of micronutrients) may protect bees from other forms of stress (e.g. viruses)
- Simplified landscape of intensive cultivation does not support nutritional health throughout the season, of colonies nor individual bees
  - A critical period for nutrition in the end of the season with forage dearth, right when bees need to “bulk up” for overwintering
  - The decline is *not* inevitable!
- Landscapes with diverse forage can negate these effects
  - More diverse agro-ecosystems (re-integration of native habitat into the landscape) can provide “stacked benefits” for agriculture, biodiversity, and bees

Final word: *Nutrition is fundamental*

Global change = stress

If we want to improve bee health, boost bees' "nutritional resilience"



Dolezal and Toth, 2018

It takes a colony…

BEETEAM

Ashley St. Clair
Ge Zhang
Randall Cass
Dr. Harmen Hendriksma
Dr. Jimena Carrillo-Tripp
Dr. Alex Walton
Erin McCall
Kate Hunter
Giselle Narvaez
Amy Geffre
Zoe Pritchard
Maria Cline
David Stein

Collaborators
Adam Dolezal (Illinois)
Matt O'Neal (ISU)
Lisa Schulte-Moore (ISU)
Erin Hodgson (ISU)
Bryony Bonning (Florida)

Funds

USDA- NIFA
Foundation for Food and Agricultural Research
United Soybean Board
Leopold Center for Sustainable Agriculture

Millions of bees!!!