Understanding sublethal impacts of neonicotinoid exposure on pollinators

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National Institute of Food and Agriculture

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5.5 million species of insects on earth (Stork 2017)

images: Wikimedia

~308,000 species of flowering plants (88% of global diversity) are visited by animal pollinators (Ollerton *et al*. 2011)

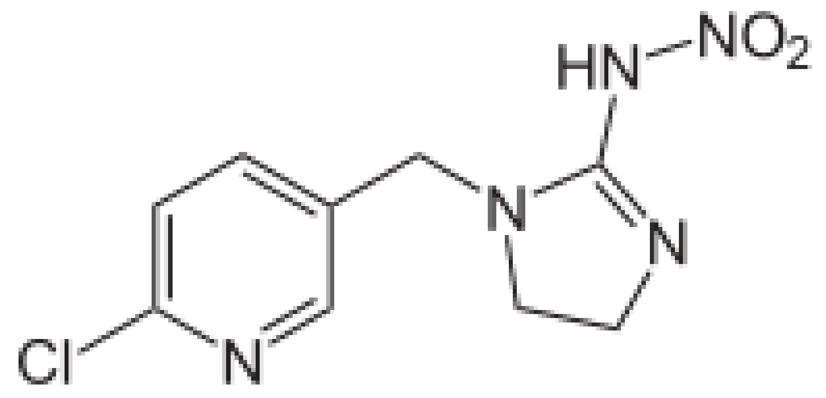
~1/3 of global food supply (and growing) comes from pollinator-dependent crops (Klein *et al.* 2007), including many important **crops in Wisconsin** (cranberry, apples, cherries, and many others!)

Pollination accounts for ***~25% of agricultural yield gaps***, and pollination is as important as all other plant quality management in some crops (Garibaldi *et al.* 2016)

Pollinator ***diversity is critically important*** for crop pollination (Garibaldi *et al.* 2013, Dainese *et al.* 2019)

photos: Wikipedia

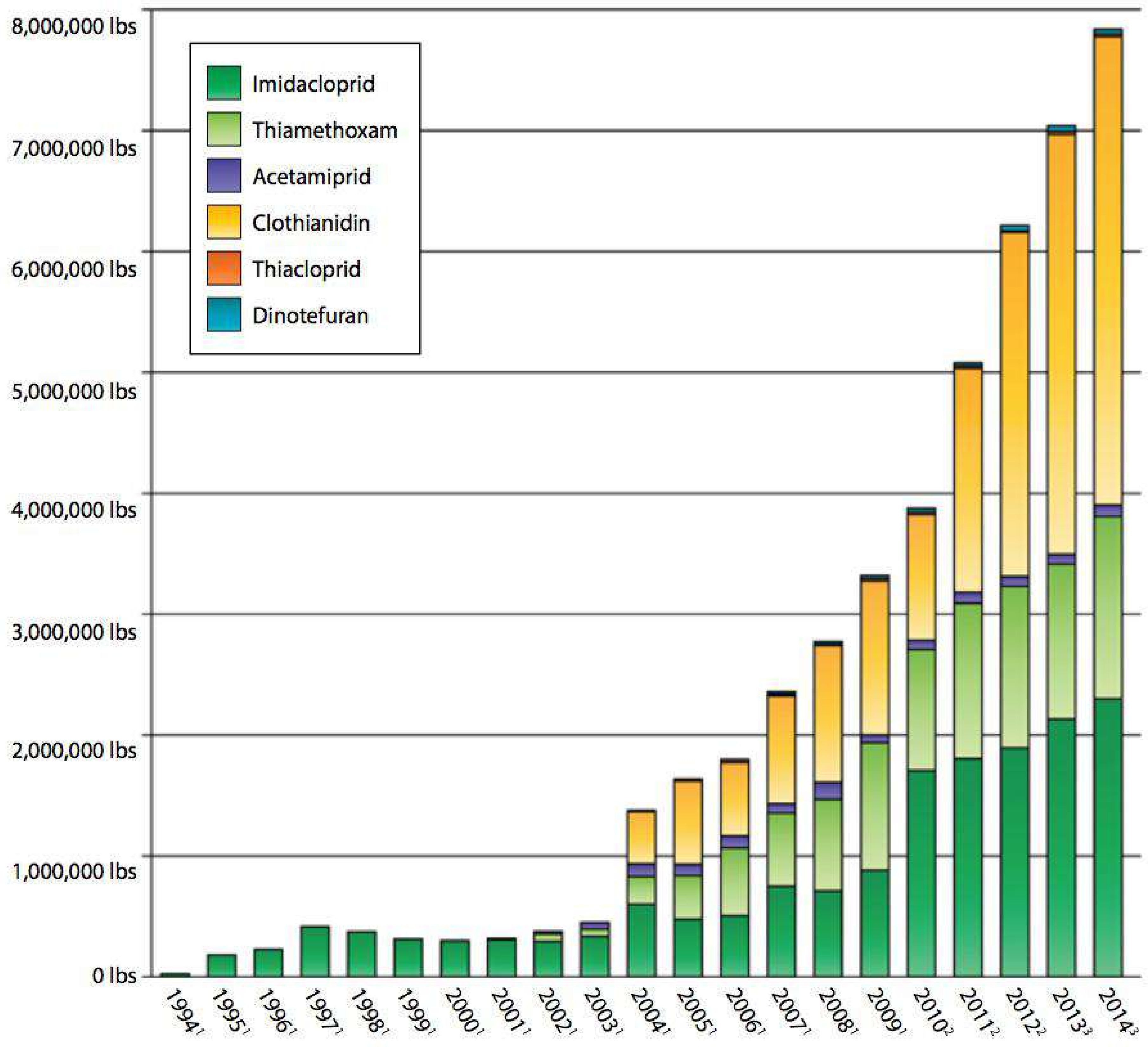
Neonicotinoid pesticides



Target ***nicotinic acetylcholine receptors*** (nAChRs), disrupting the primary excitatory neurotransmission system in the insect CNS

Neonics are ***persistent and widespread*** in the environment

FIGURE 3.2: Estimated Annual Agricultural Use of Neonicotinoids* in the United States: 1994–2014



Sources:

1. Stone (2013)[†]: http://pubs.usgs.gov/ds/752/
2. Baker and Stone (2015)[†]: http://pubs.usgs.gov/ds/0907/
3. Preliminary pesticide use estimates*[†]: http://water.usgs.gov/nawqa/pnsp/usage/maps/county-level/

Xerces Society, *How Neonicotinoids can kill bees*, 2016

Crall and Raine (*2023*). Advances in Insect Physiology

Global patterns of neonicotinoid exposure

~75% of global honey samples contain neonicotinoids

Mitchell et al. (2017, Science)

Neonicotinoid impacts in the field


LETTER

doi:10.1038/nature14420

Seed coating with a neonicotinoid insecticide negatively affects wild bees

Maj Rundlöf[1], Georg K. S. Andersson[1,2], Riccardo Bommarco[3], Ingemar Fries[3], Veronica Hederström[1], Lina Herbertsson[2], Ove Jonsson[4,5], Björn K. Klatt[2], Thorsten R. Pedersen[6], Johanna Yourstone[1] & Henrik G. Smith[1,2]

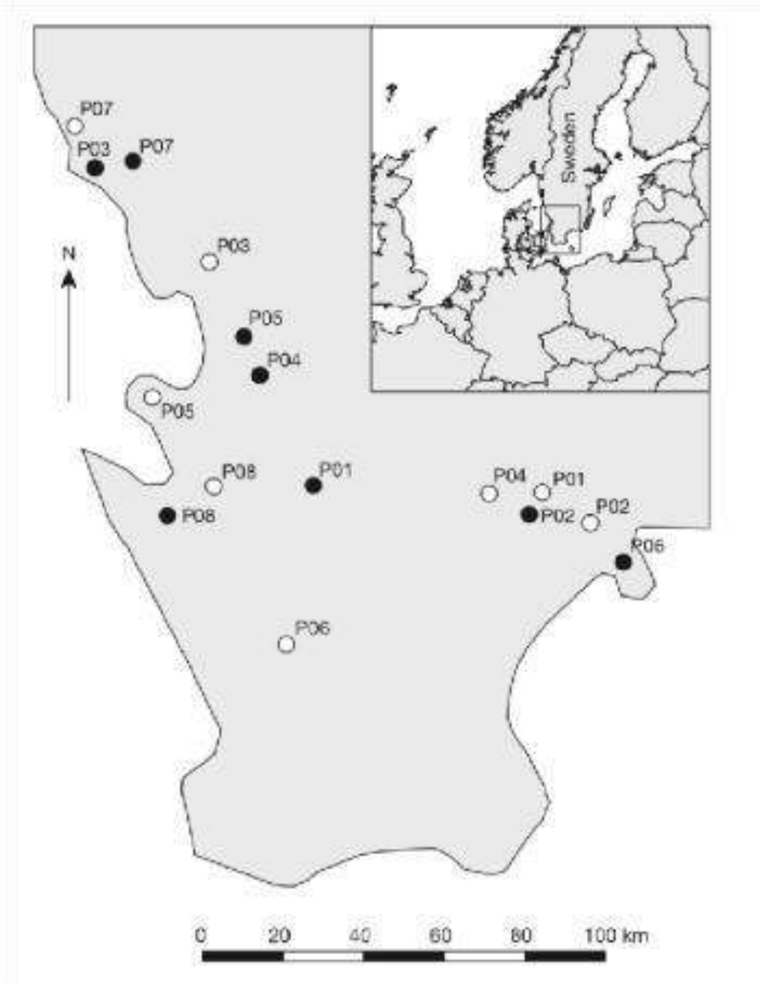
Strong evidence that field-realistic exposure to neonicotinoids **has negative effects on bees**

Stronger effects on solitary and bumblebees than honeybees

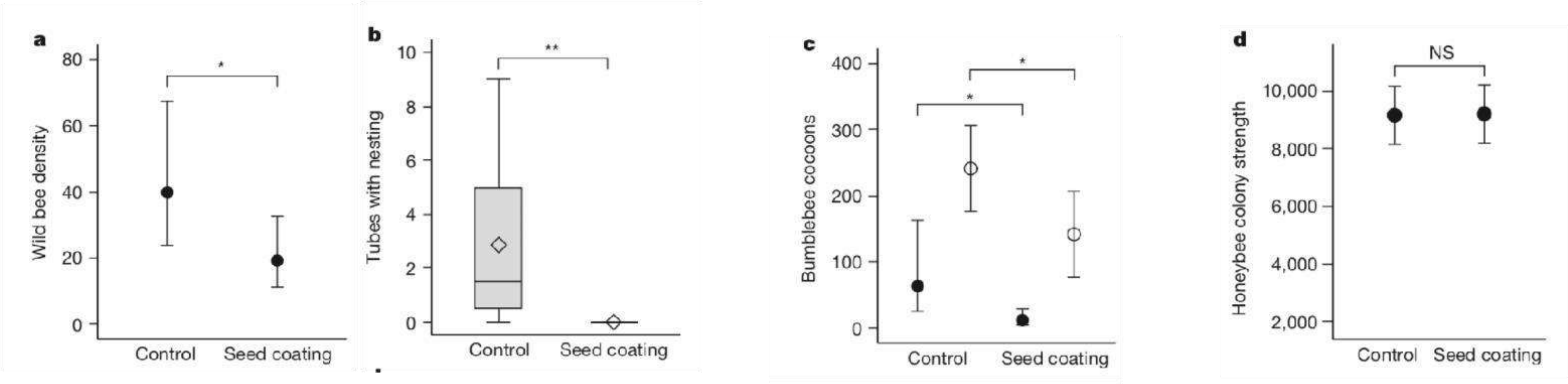
Solitary bees (~95% of all species)

Bumblebees

Honeybees



Field Studies in Sweden

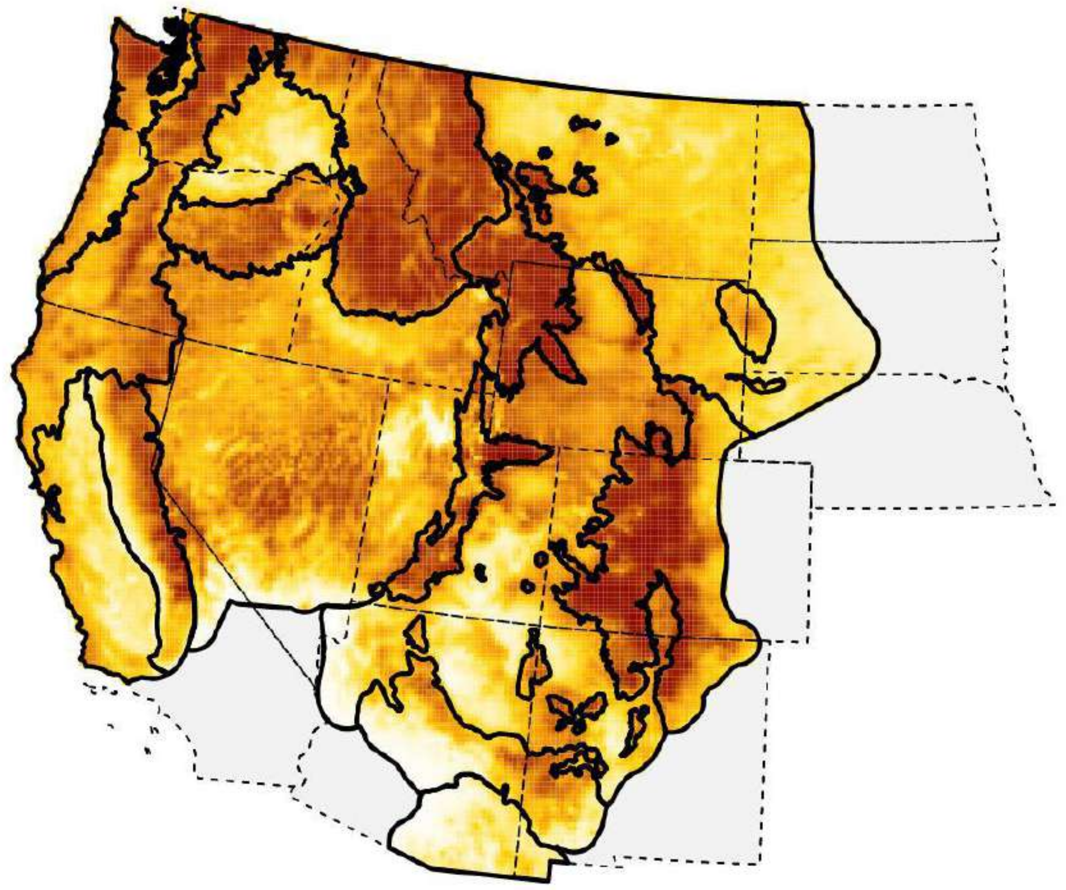


Neonicotinoids and pollinator population declines

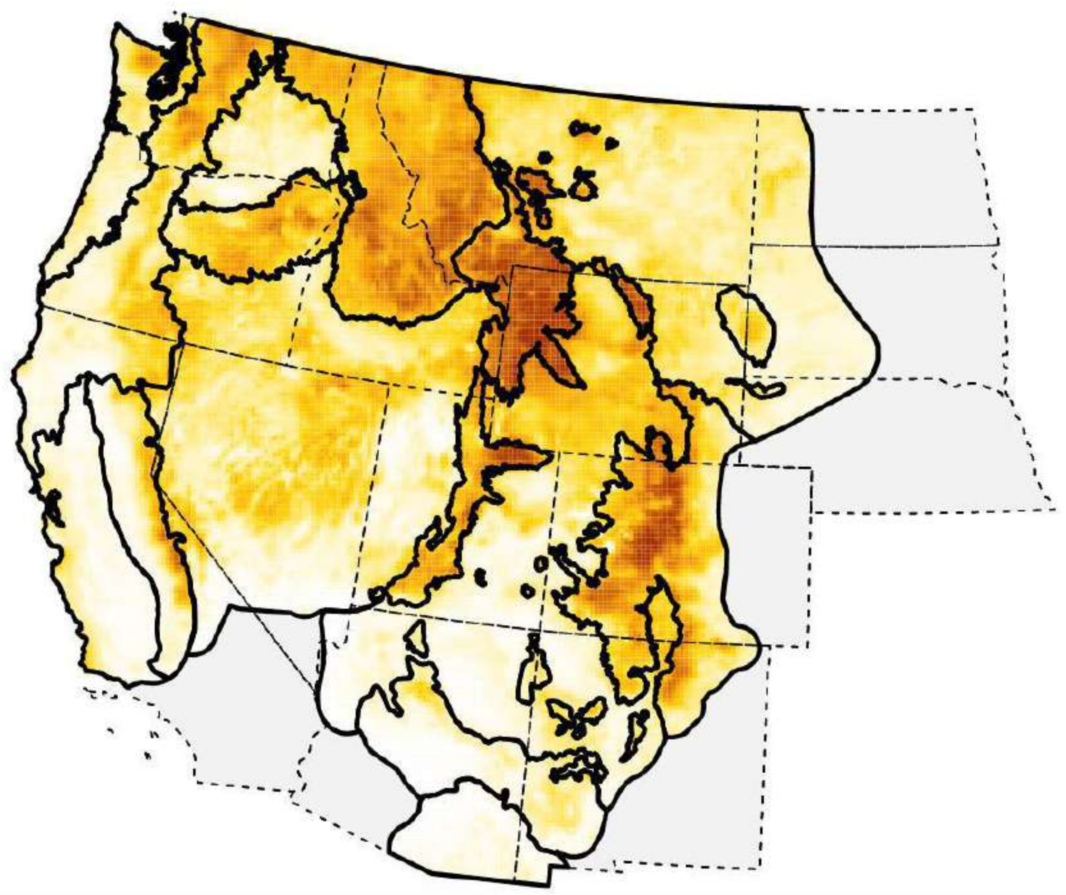
Recent and future declines of a historically widespread pollinator linked to climate, land cover, and pesticides

William M. Janousek[a,1,2], Margaret R. Douglas[b], Syd Cannings[c], Marion A. Clément[d], Casey M. Delphia[e], Jeffrey G. Everett[f], Richard G. Hatfield[g], Douglas A. Keinath[d], Jonathan B. Uhuad Koch[h], Lindsie M. McCabe[h], John M. Mola[i], Jane E. Ogilvie[j], Imtiaz Rangwala[k], Leif L. Richardson[g], Ashley T. Rohde[h], James P. Strange[l], Lusha M. Tronstad[m], and Tabitha A. Graves[a,1]

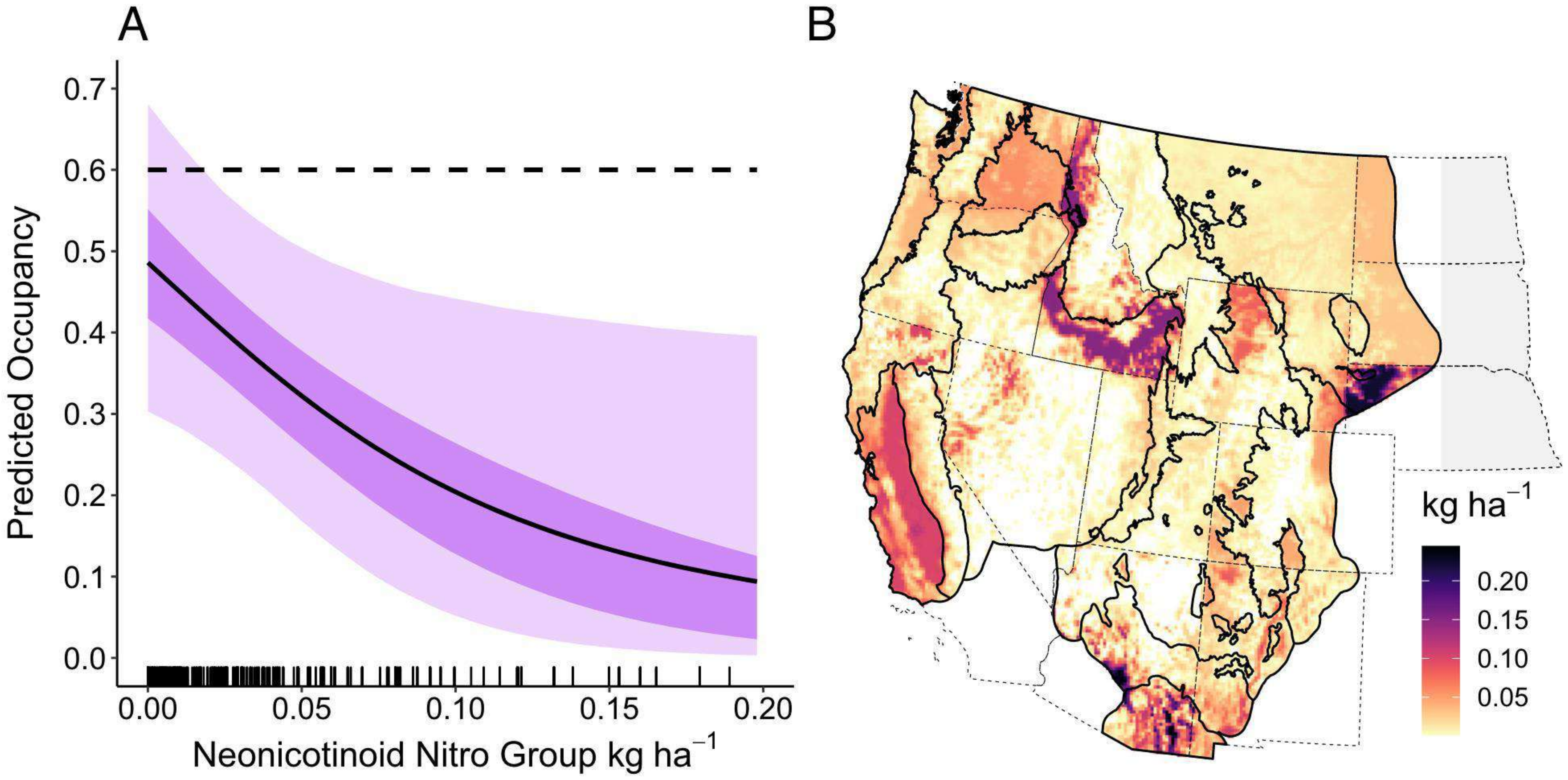
B Occupancy 1998



C Occupancy 2020



Neonicotinoids were an important (but not the only!) contributor to the decline of *Bombus occidentalis*



Neonicotinoids can negatively affect bees, even at concentrations below acute, lethal toxicity (i.e., **sublethal effects**)

But how do neonicotinoids affect pollinator health?

What can this tell us about how to **improve risk assessment**?

Key challenges:

Sublethal effects (e.g., on behavior, physiology)

Combined stressors (e.g., neonicotinoids + other agrochemical, nutrition, weather)

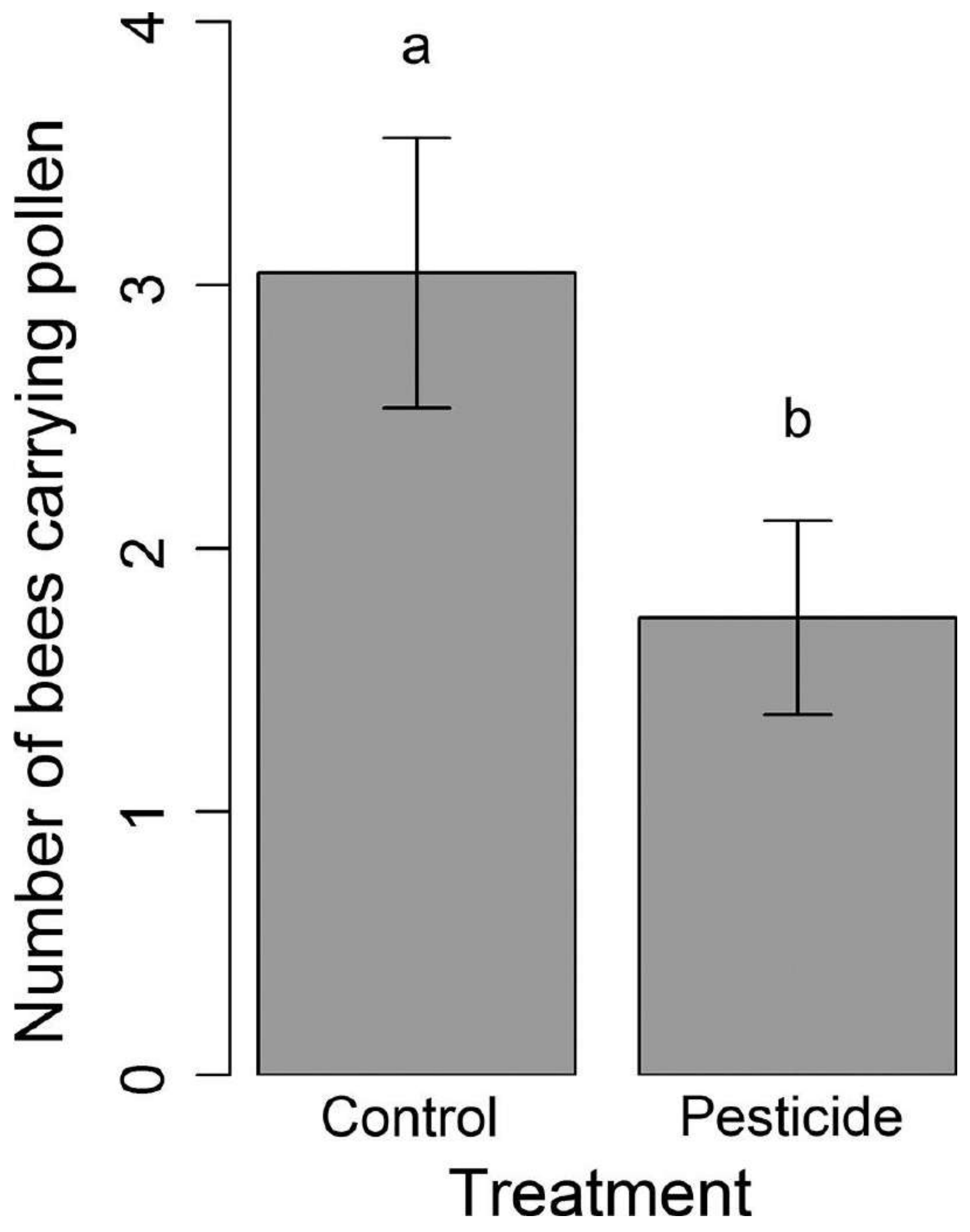
Tetragonsica *spp*, photo: Alex Wild

Crall et al. (2018). Nature Communications

Neonicotinoid impacts on foraging

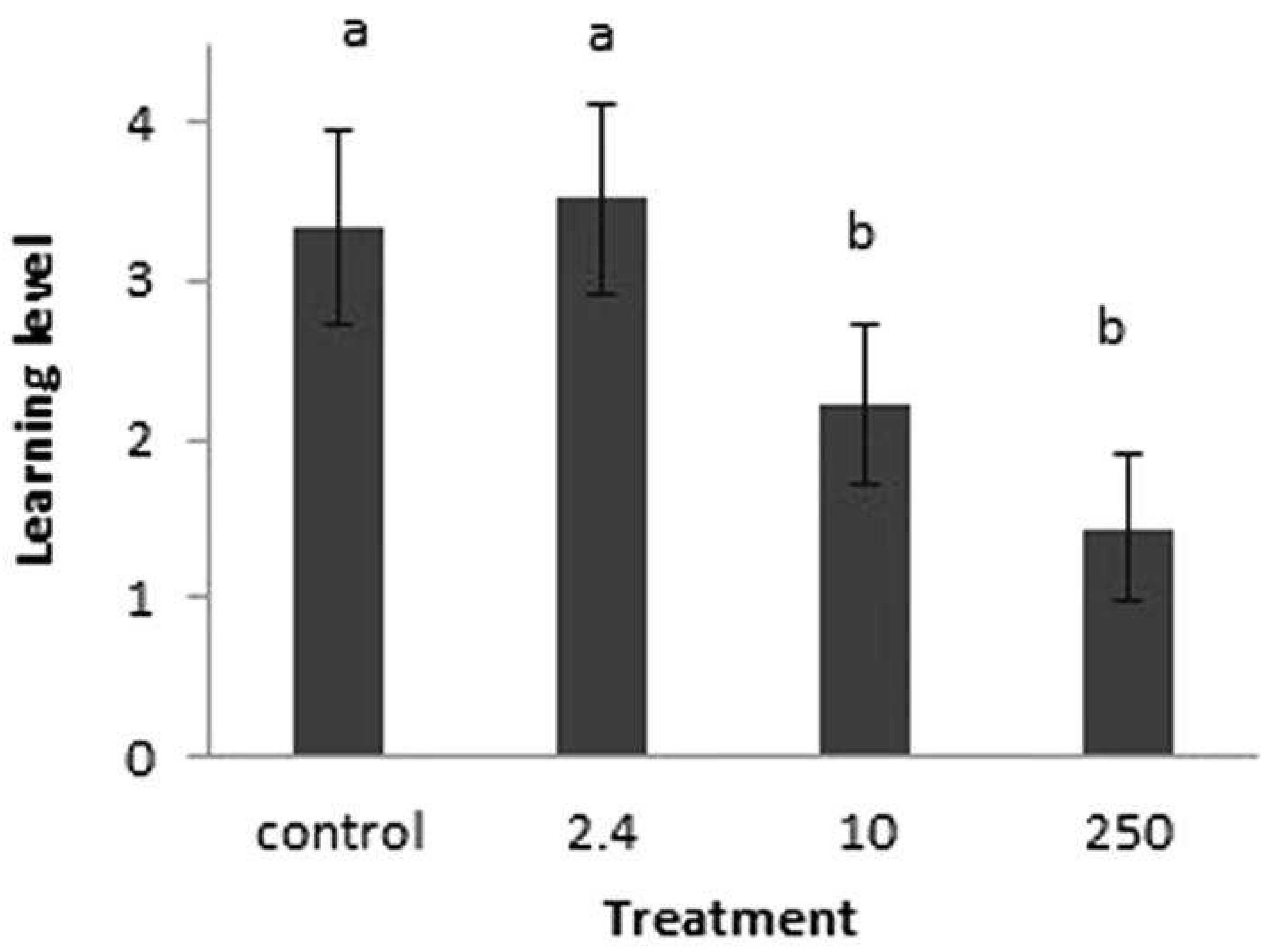
Exposure to **neonicotinoids can disrupt….**

…foraging…



Stanley et al, 2016

…floral learning…

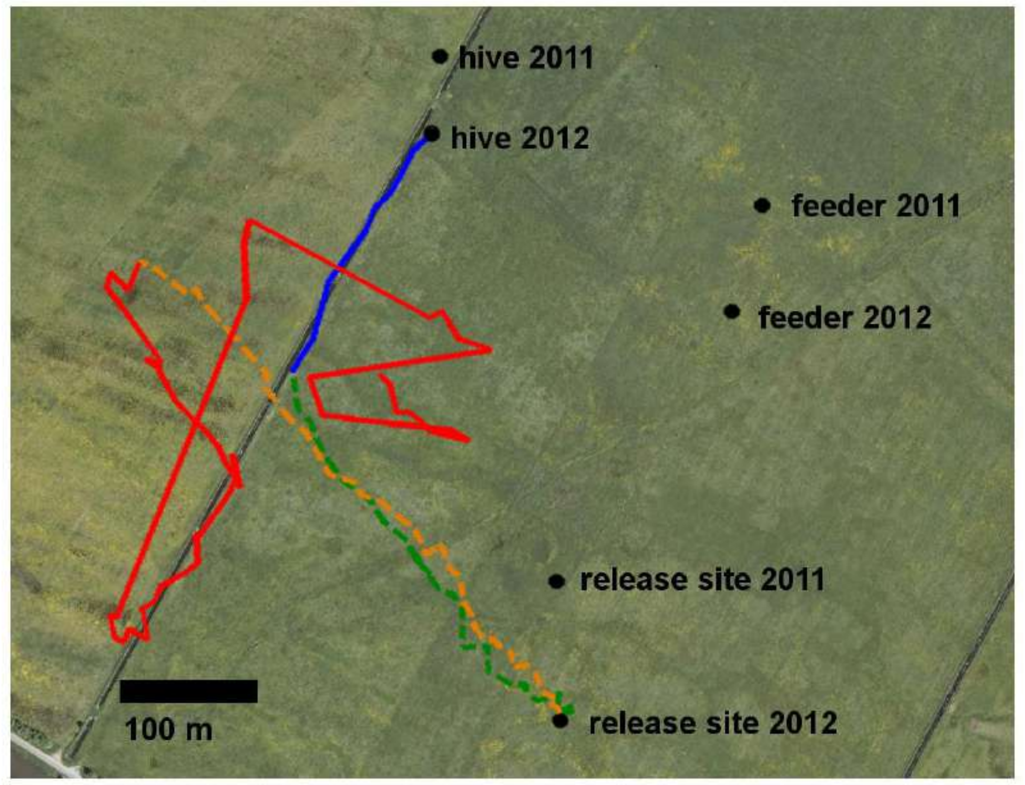


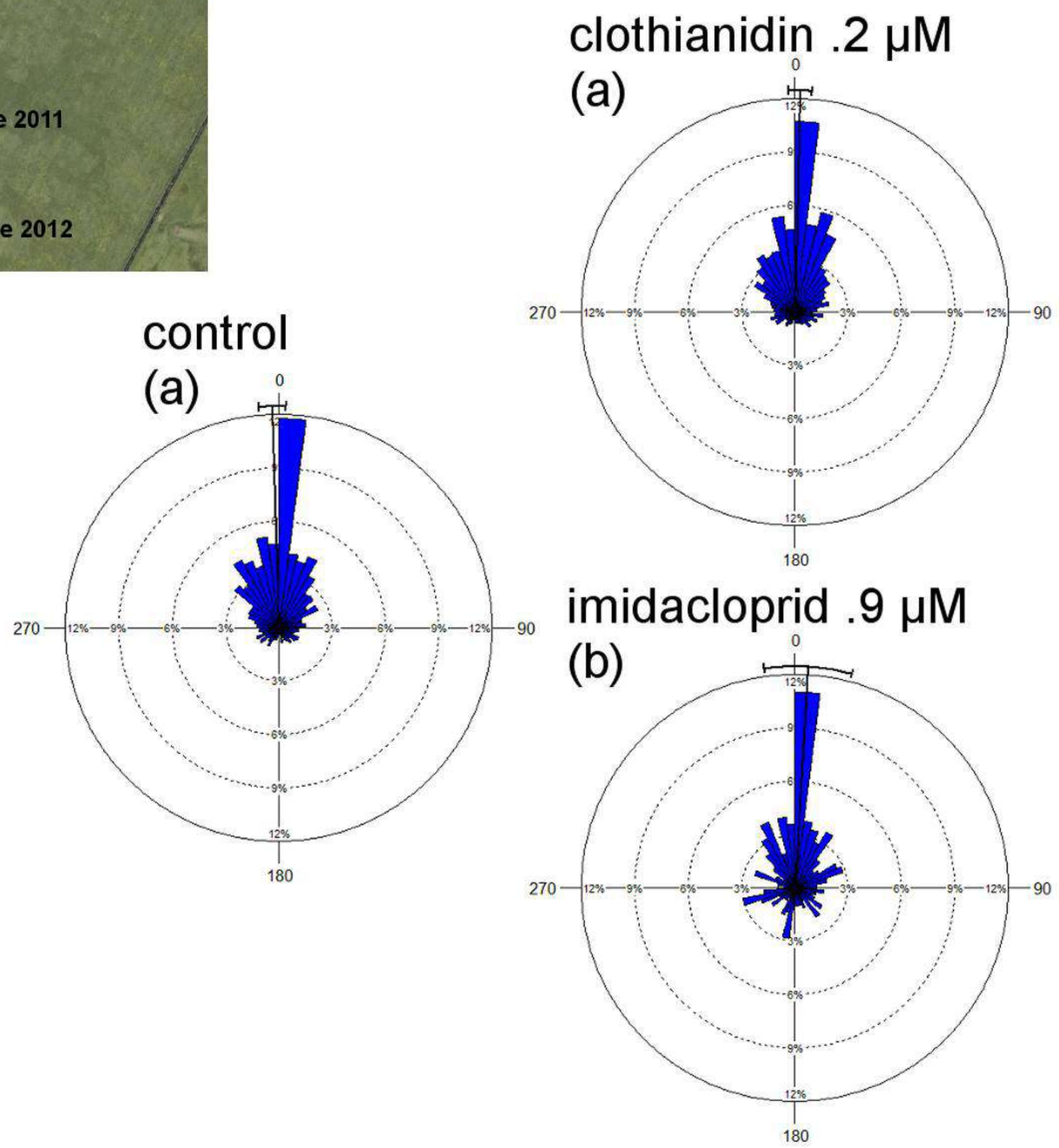
Stanley et al, 2015

Neonicotinoid impacts on foraging

Exposure to **neonicotinoids can disrupt….**

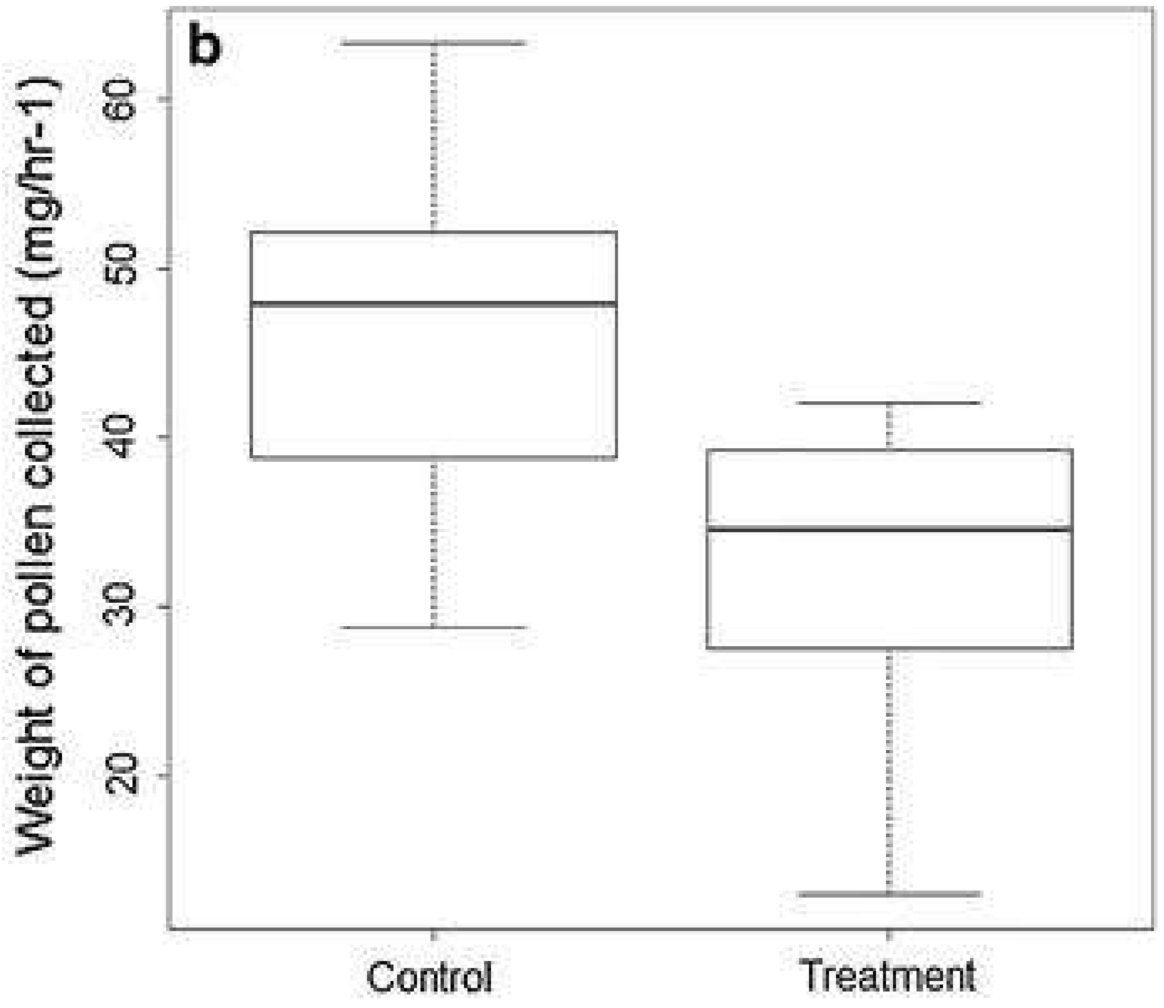
…and navigation…





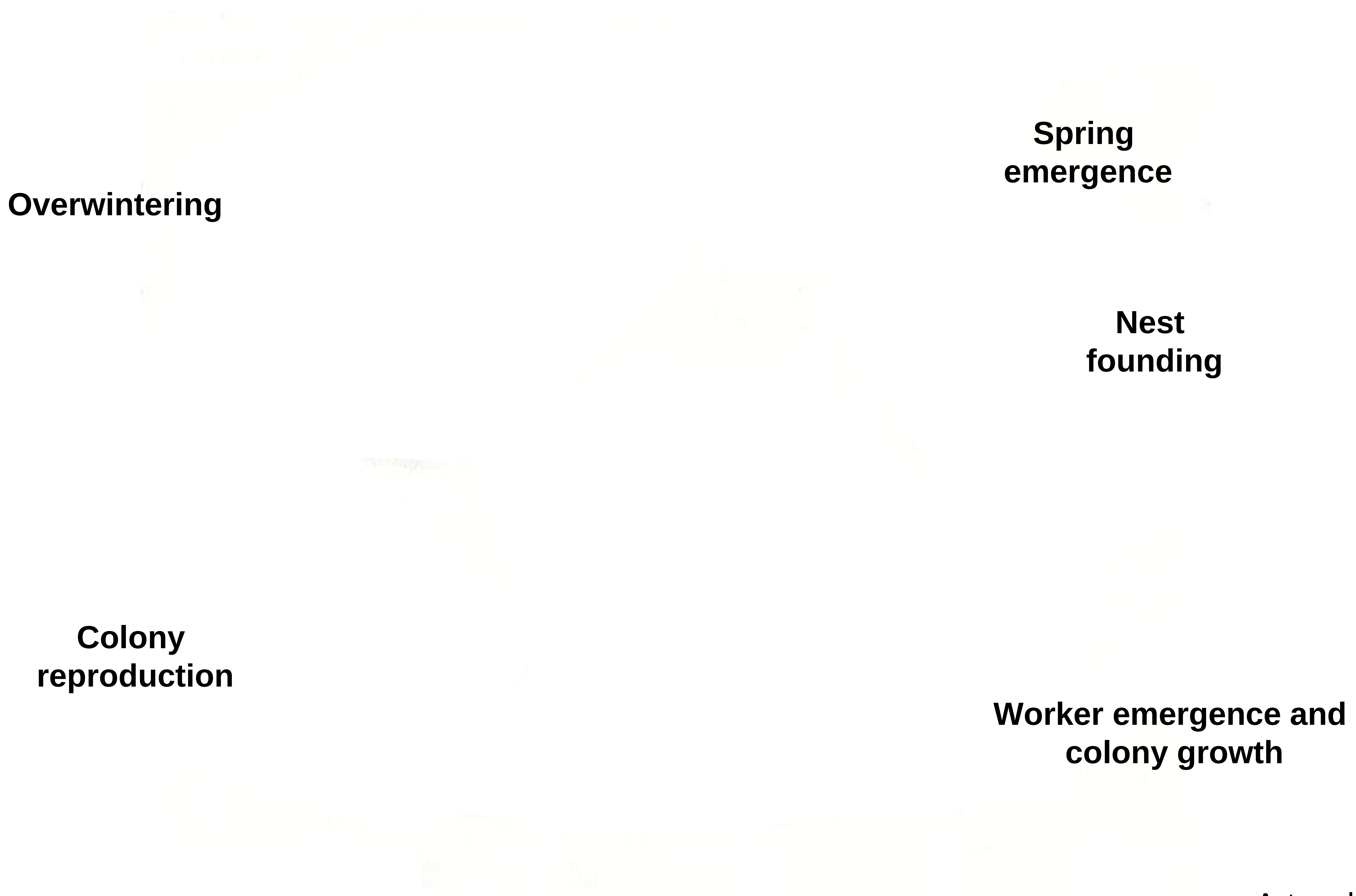
Fischer et al, 2014

… leading to reduced colony food intake



Feltham et al, 2014

Bumblebee colony life cycle



Artwork: Trenton Jung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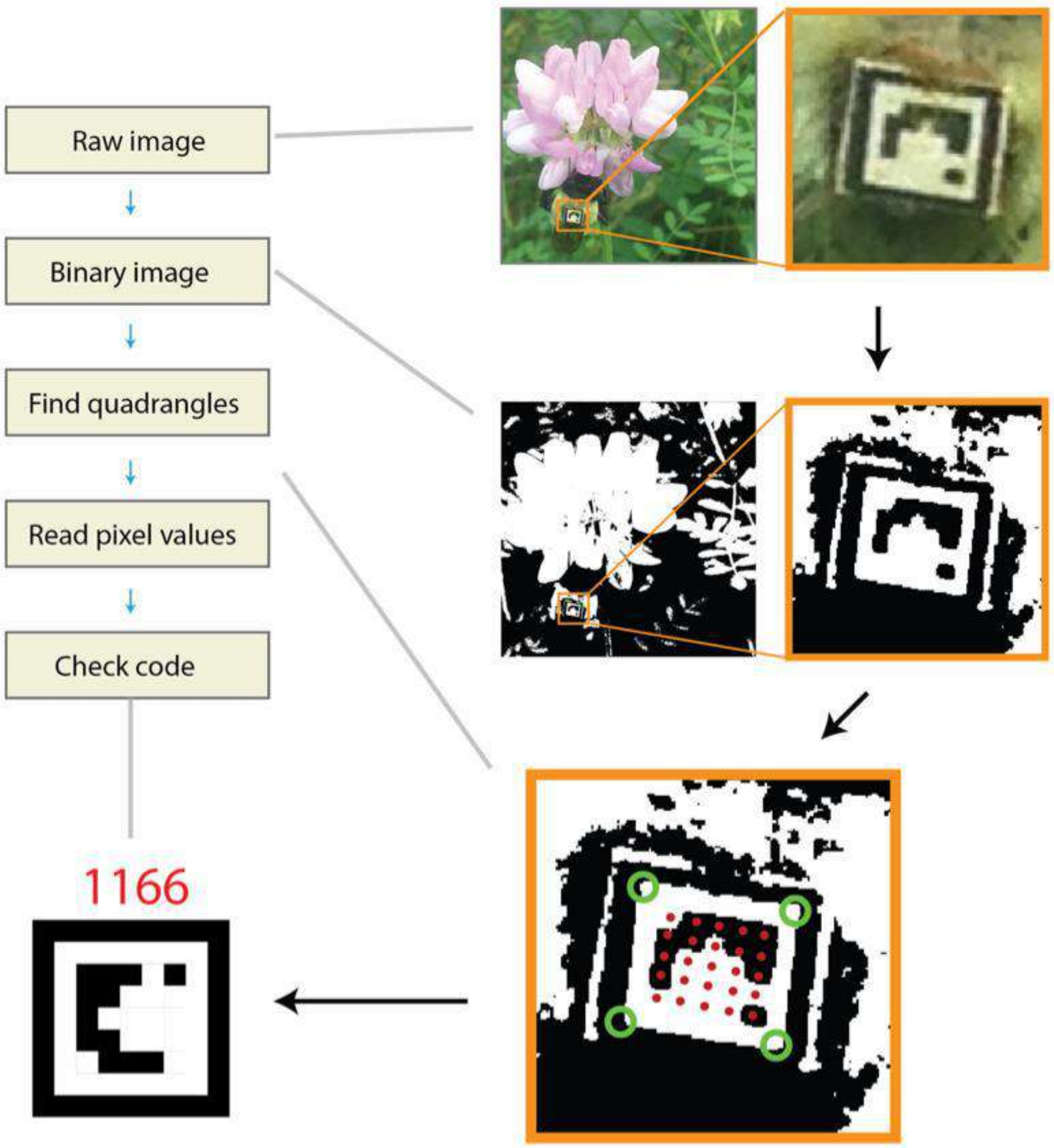

BEEtag

Crall et al. (2015) BEEtag, *PLOS One*


42
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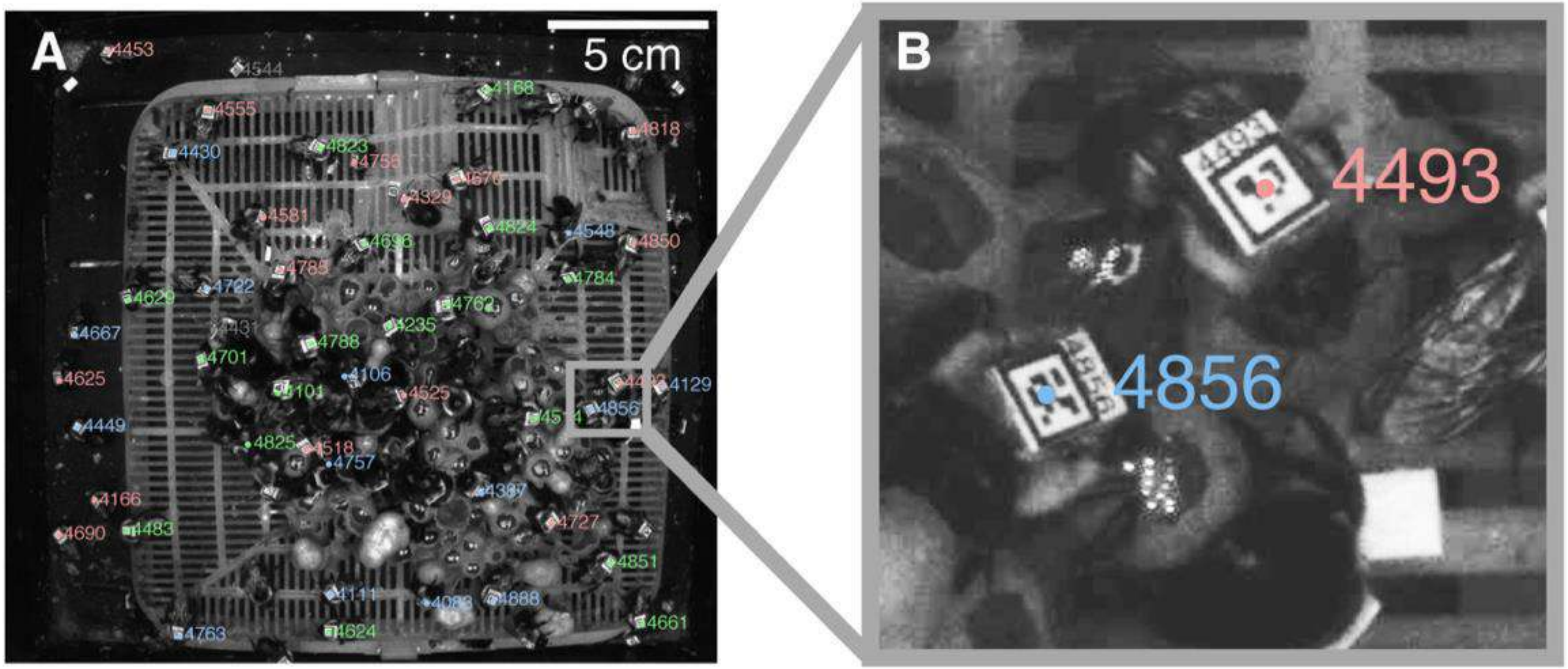
Impacts of neonicotinoid exposure

Orally dosing ***B. impatiens*** with **imidacloprid**

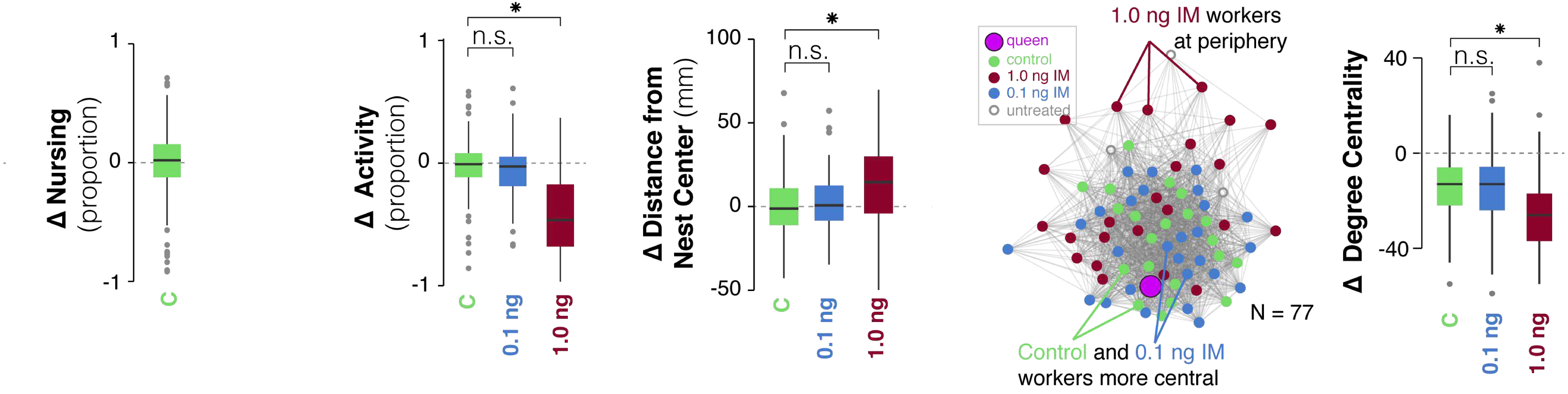
Acute neonicotinoid exposure within colonies



control 0.1 ng imidacloprid 1.0 ng imidacloprid

Crall et al. (2018) *Science*

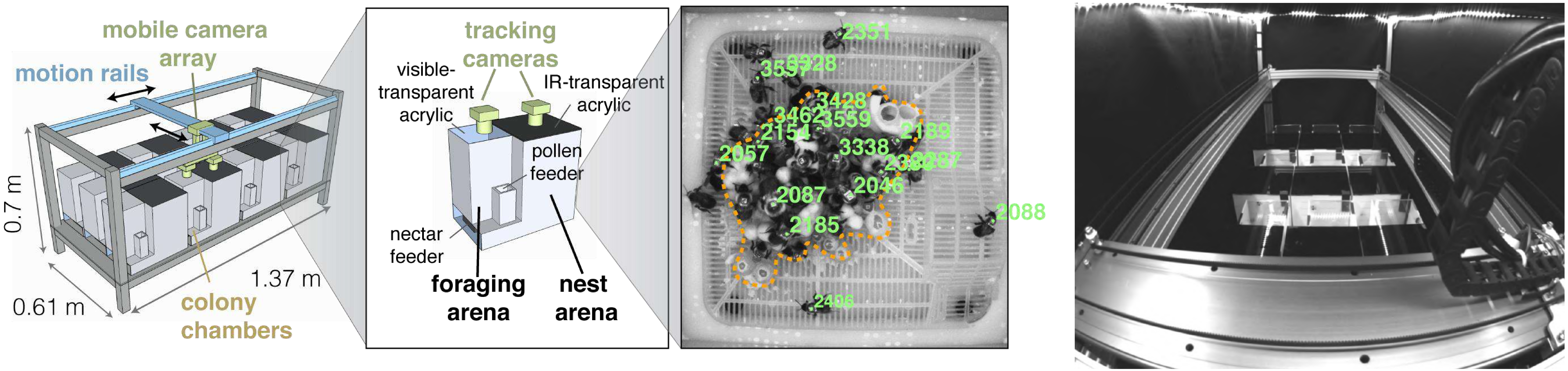
Acute neonicotinoid exposure within colonies

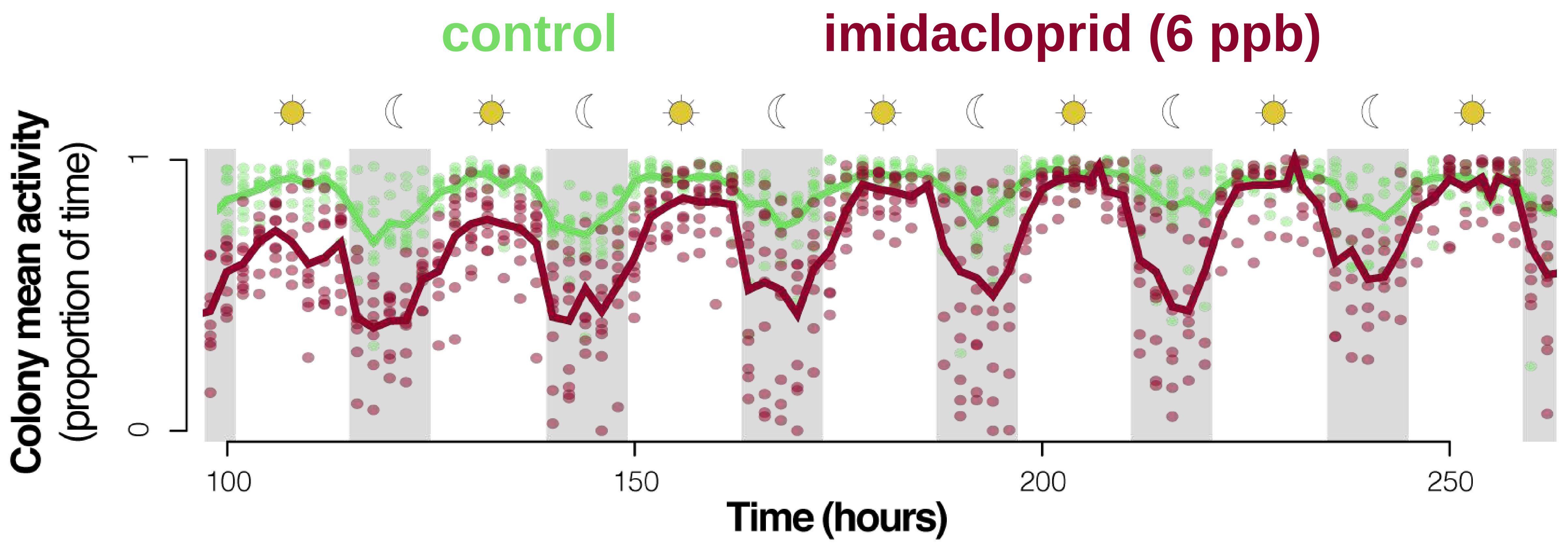


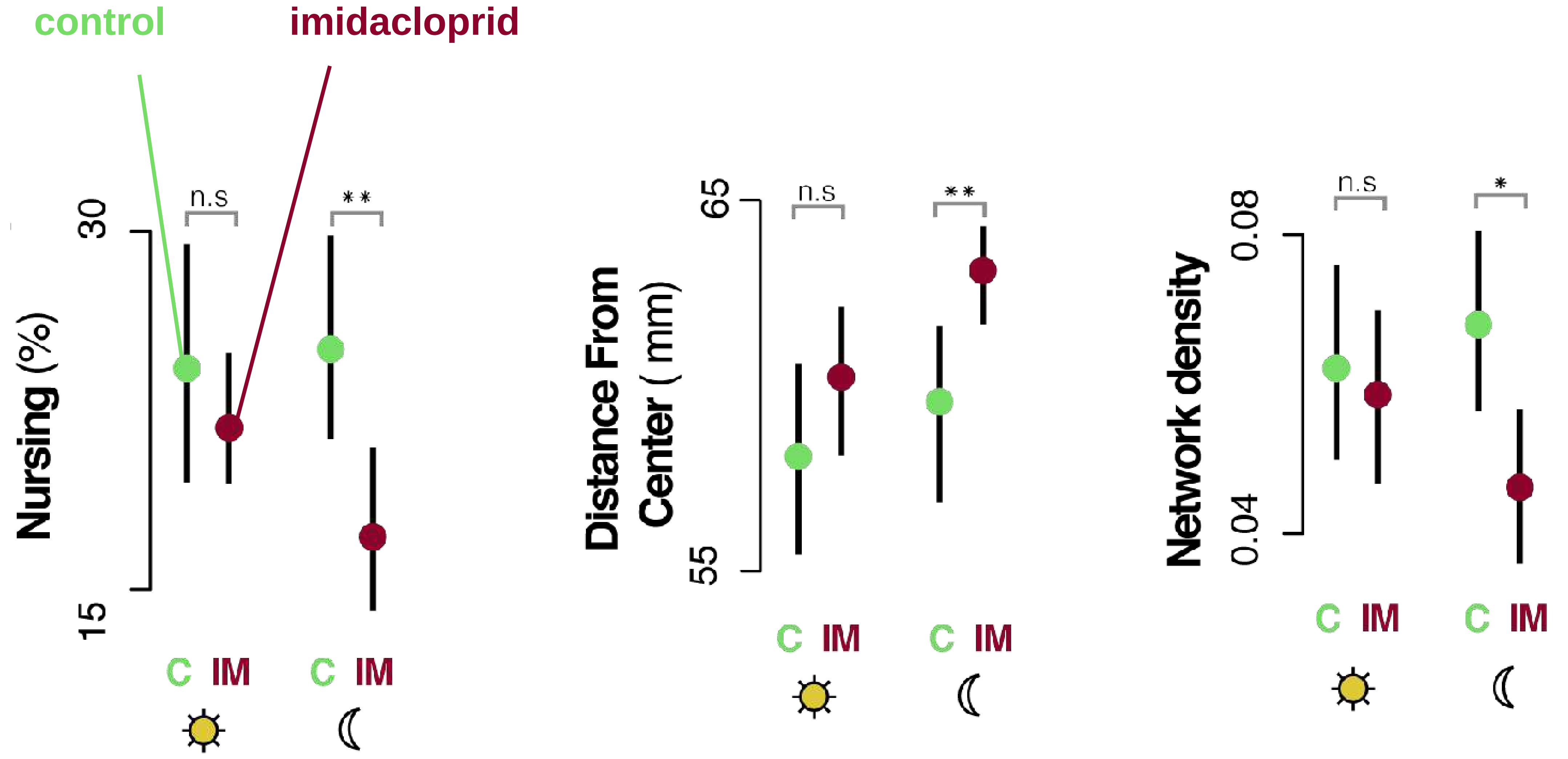
Acute imidacloprid exposure **reduces nursing, activity, and social interactions** in bumblebee (*Bombus impatiens*) colonies

Crall et al. (2018) *Science*

Impacts of colony-level, chronic imidacloprid exposure



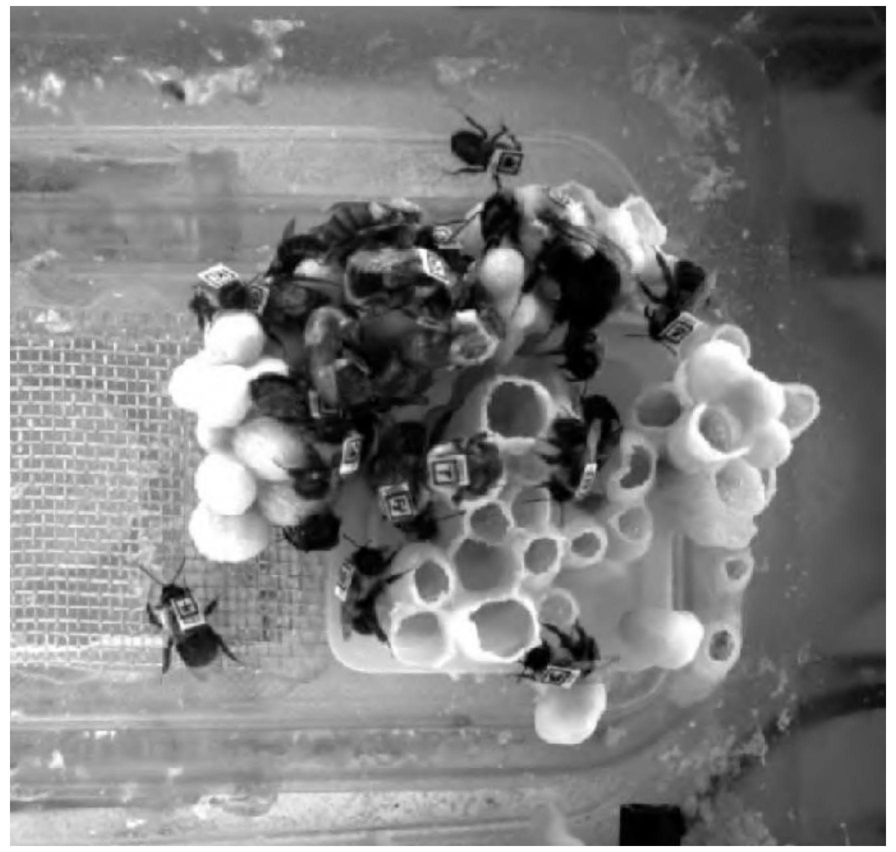


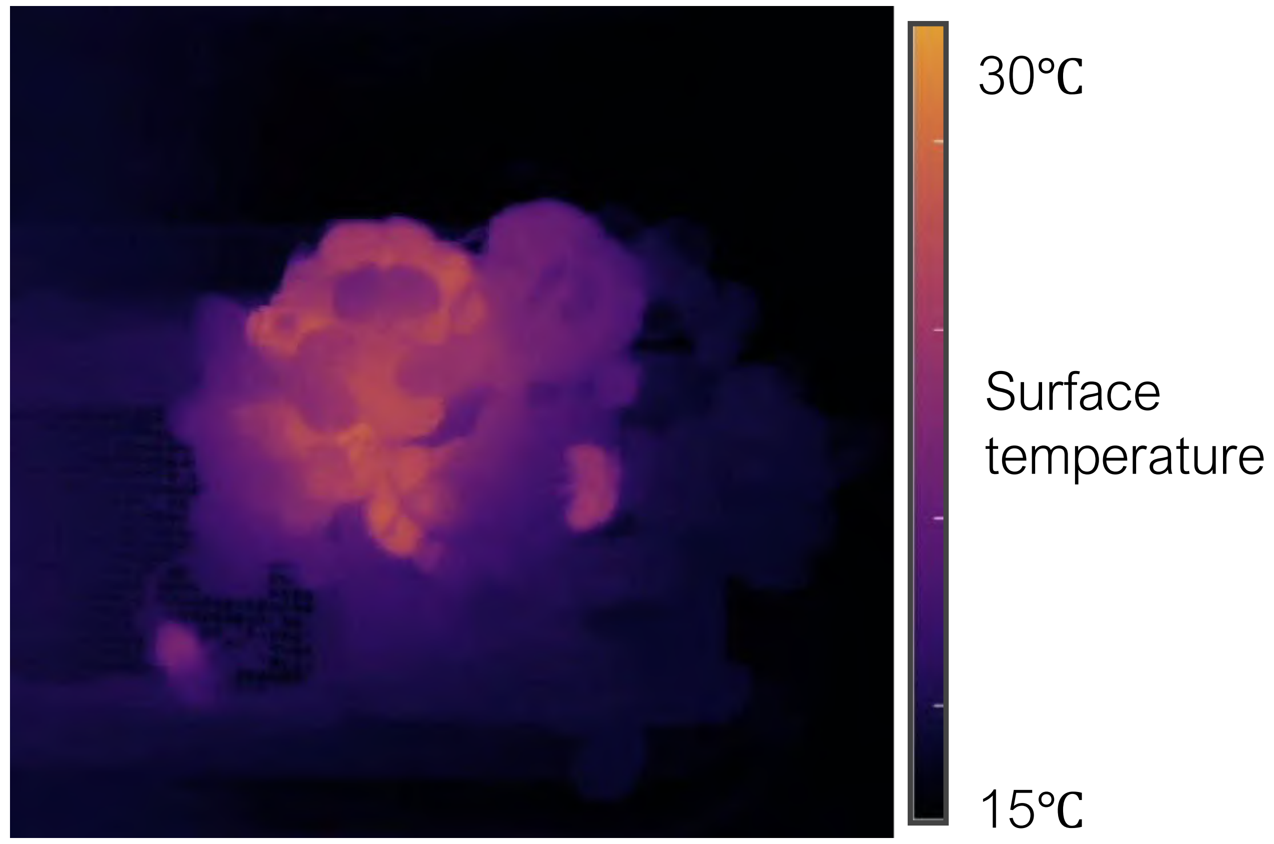


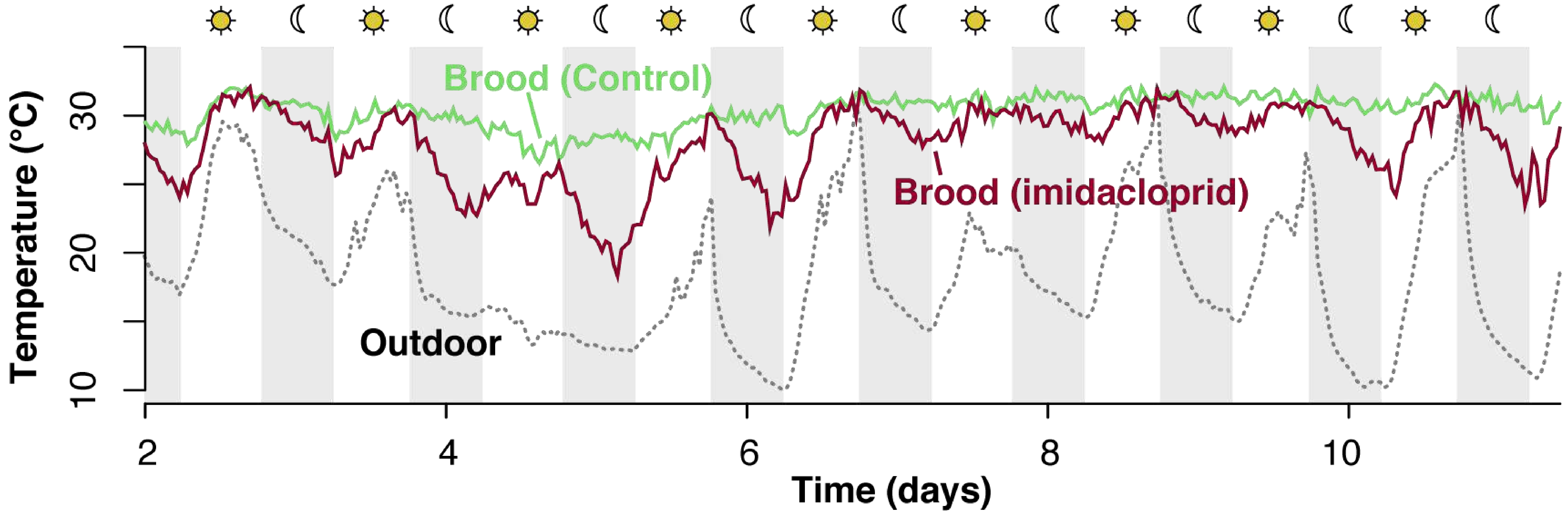
Chronic exposure shows **similar qualitative effects to acute exposure,** but effects **vary with time of day**

Crall et al. (2018) *Science*

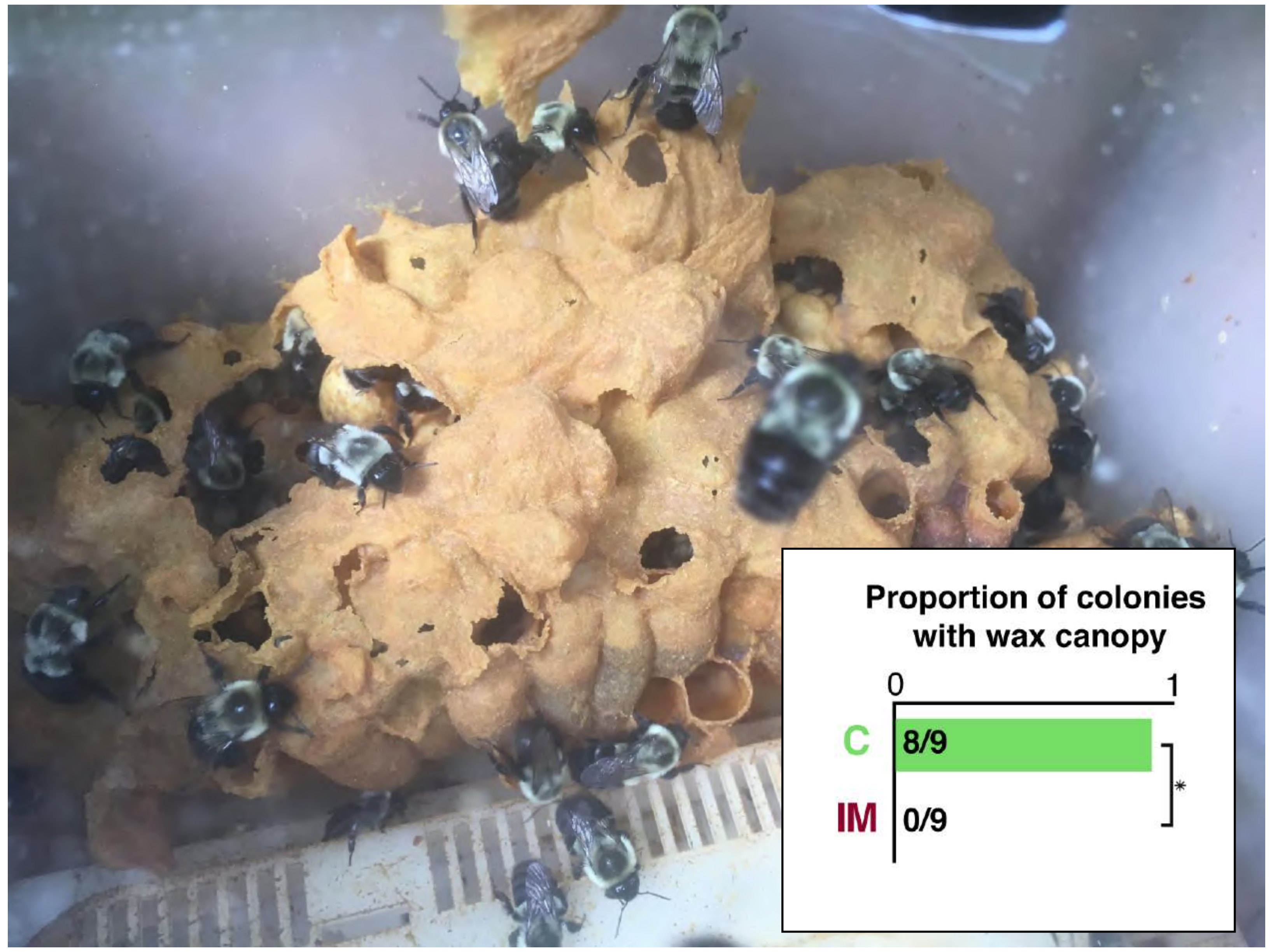
Imidacloprid and social thermoregulation





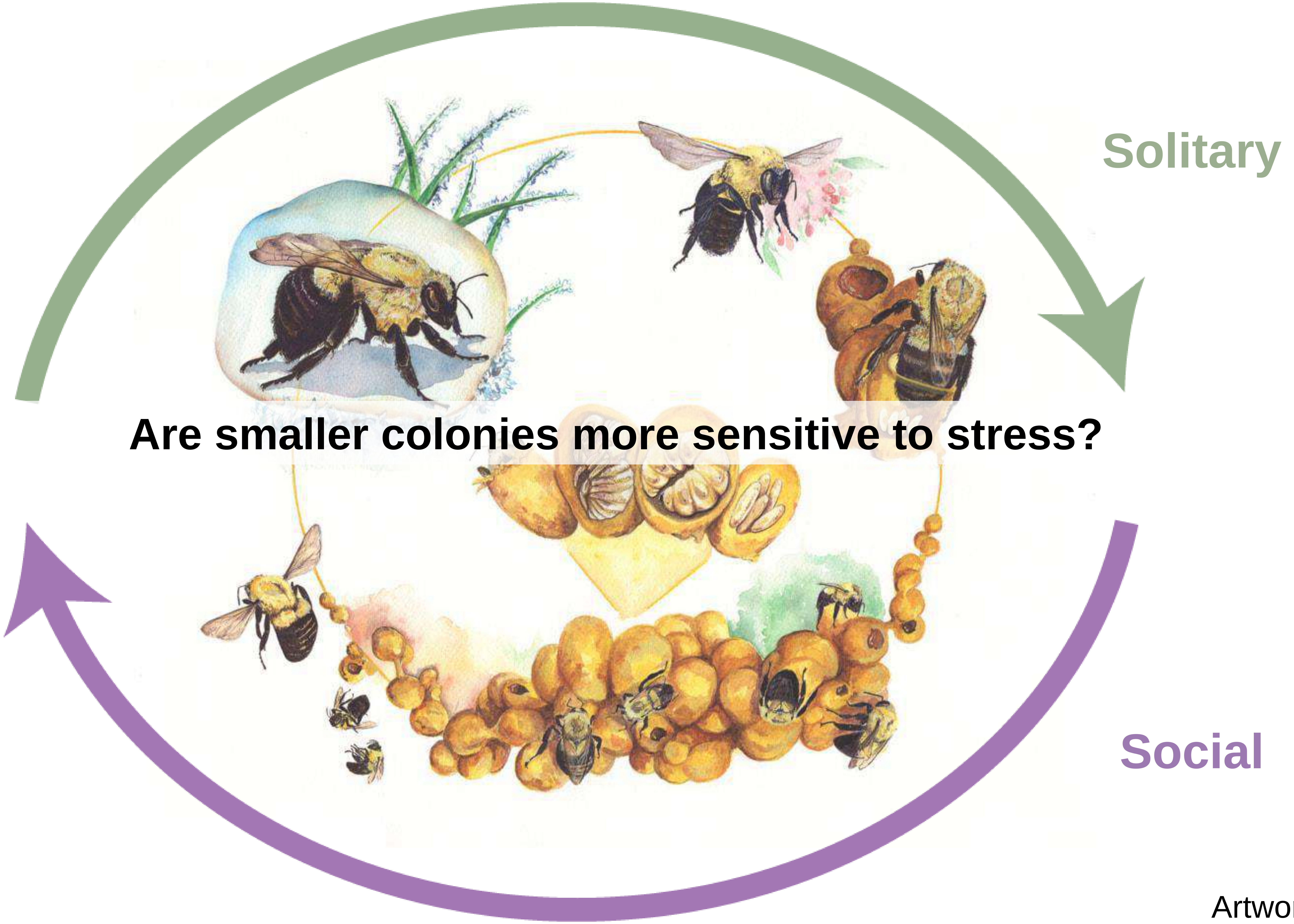


Imidacloprid **impairs active social thermoregulation** and **adaptive changes to nest architecture**



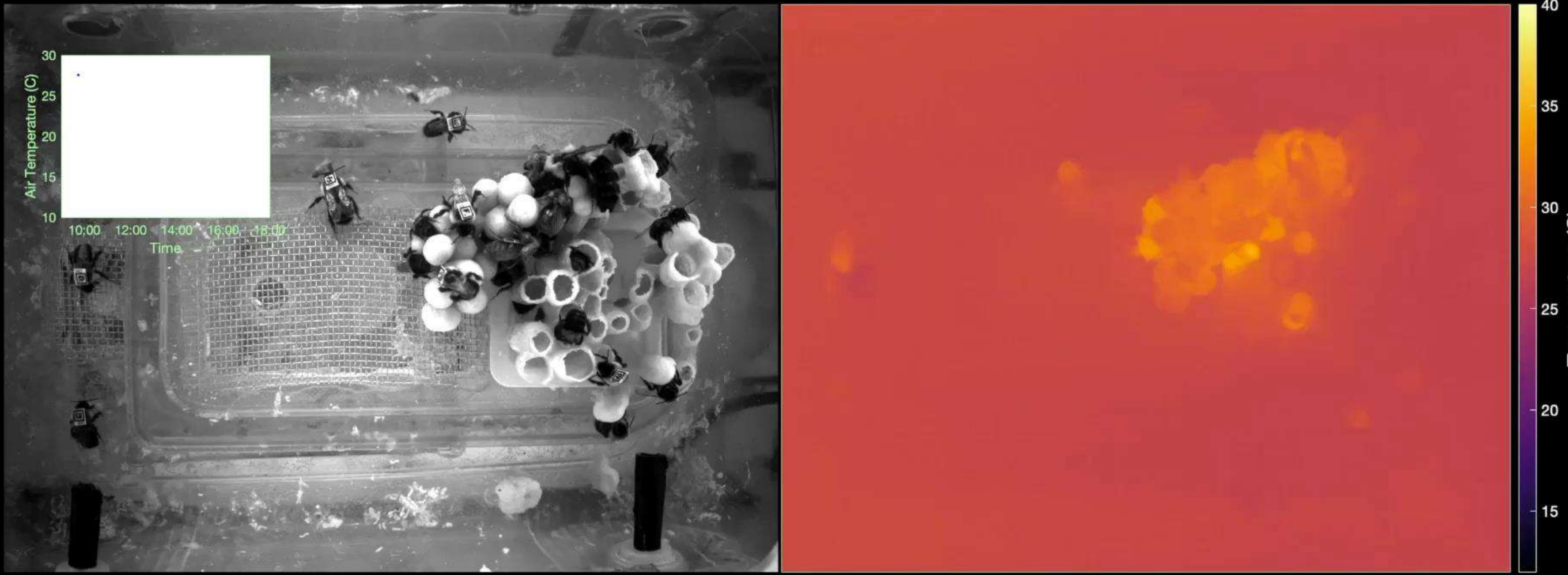
Crall et al. (2018) *Science*

Does sociality drive sensitivity to novel stressors?



Artwork: Trenton Jung

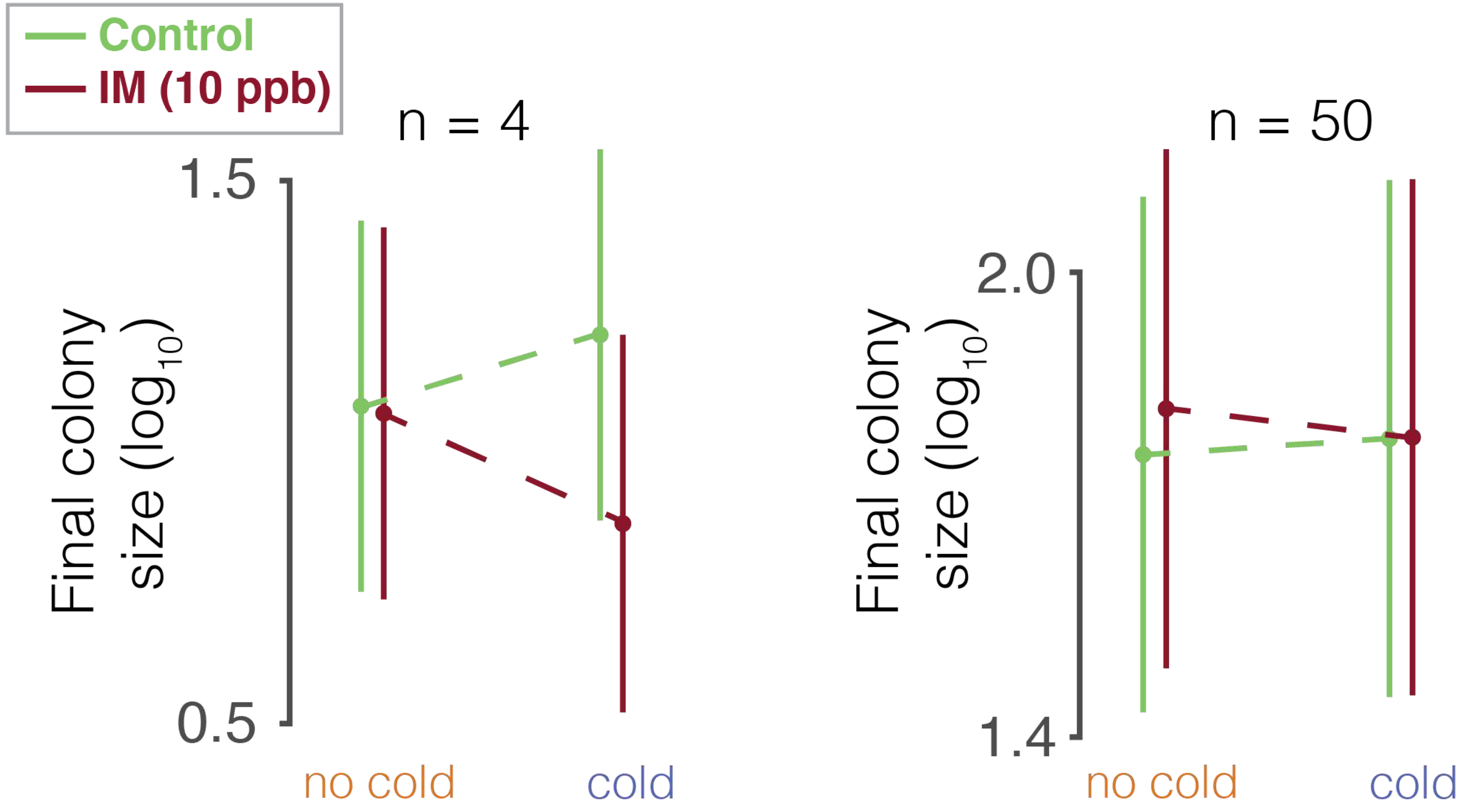
Temperature stress in bumble bee colonies



Easton-Calabria et al (2023) Proc B

Long-term impacts on **colony size**

***Bombus* colonies** exposed to 2-day stress combinations at random times during colony development



small colonies
(n = 4)

large colonies
(n = 50)

Smaller, younger colonies are **more sensitive to interacting stressors** (e.g., cold and pesticides), partially because of improved thermoregulation

Generalized linear mixed effects model, Poisson distribution, three-way interaction [imidacloprid]*[cold]*[colony size]: df = 47, z=3.16, **p = 0.0016**

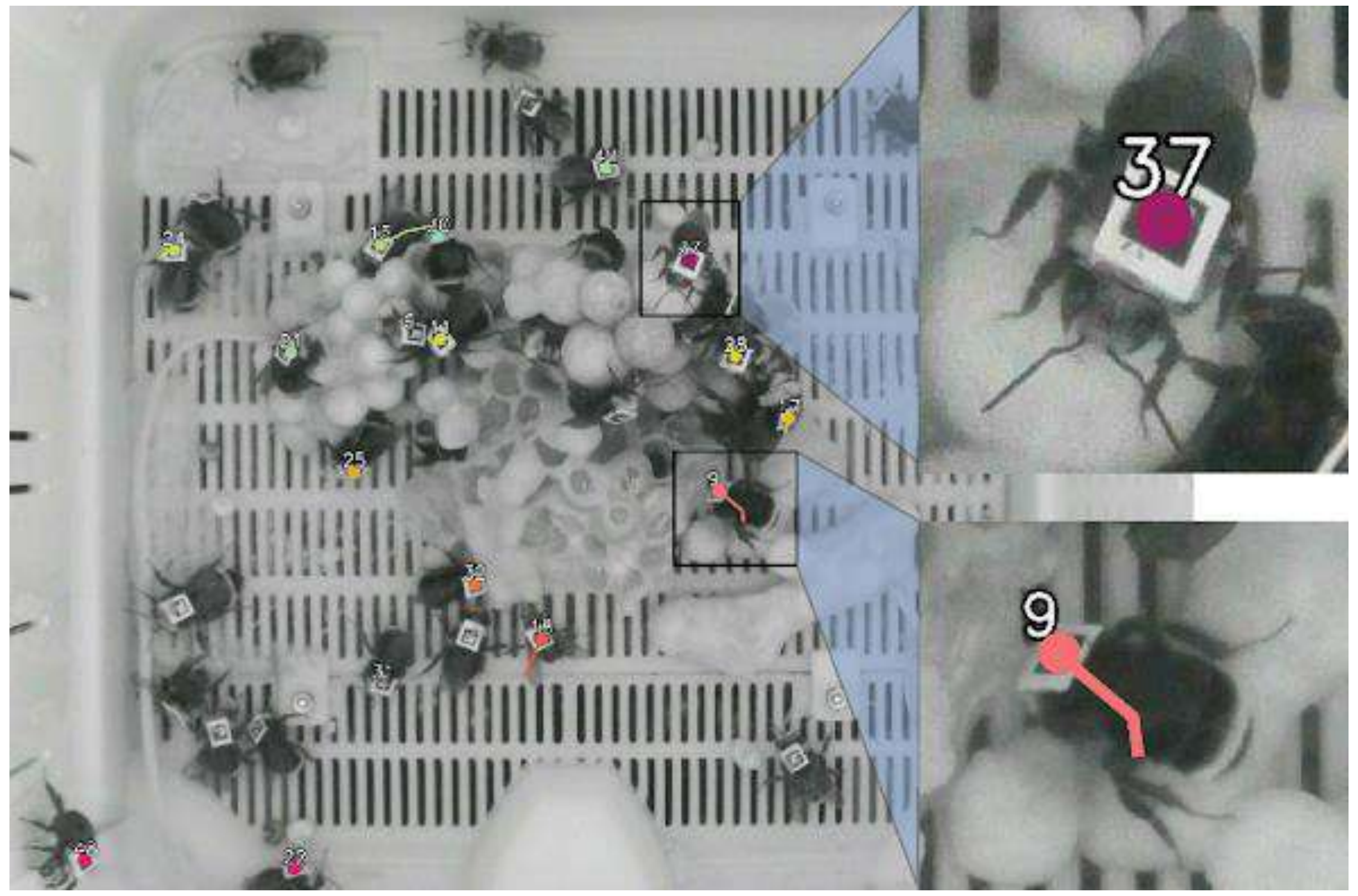
Easton-Calabria et al (2023). Proc B

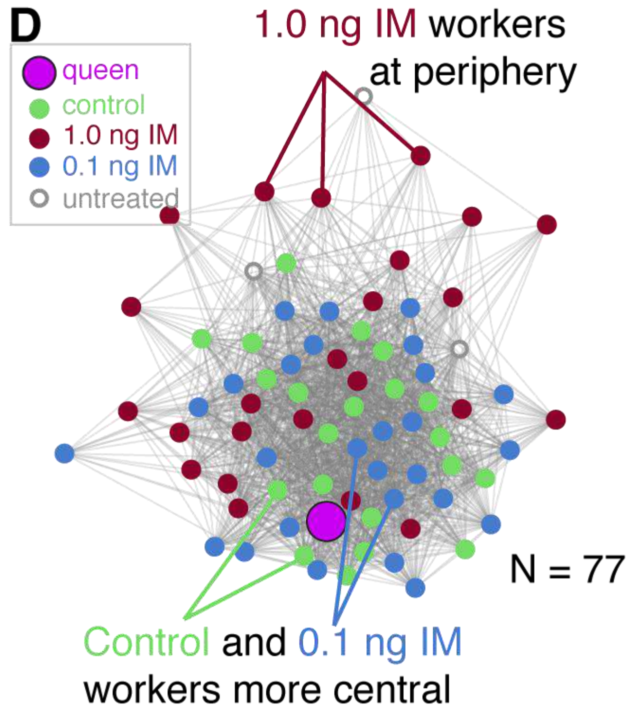
Conclusions

Neonicotinoid exposure can **alter critical behaviors within bumblebee nests** and reduce colony growth, even at **‘sublethal’ concentrations**

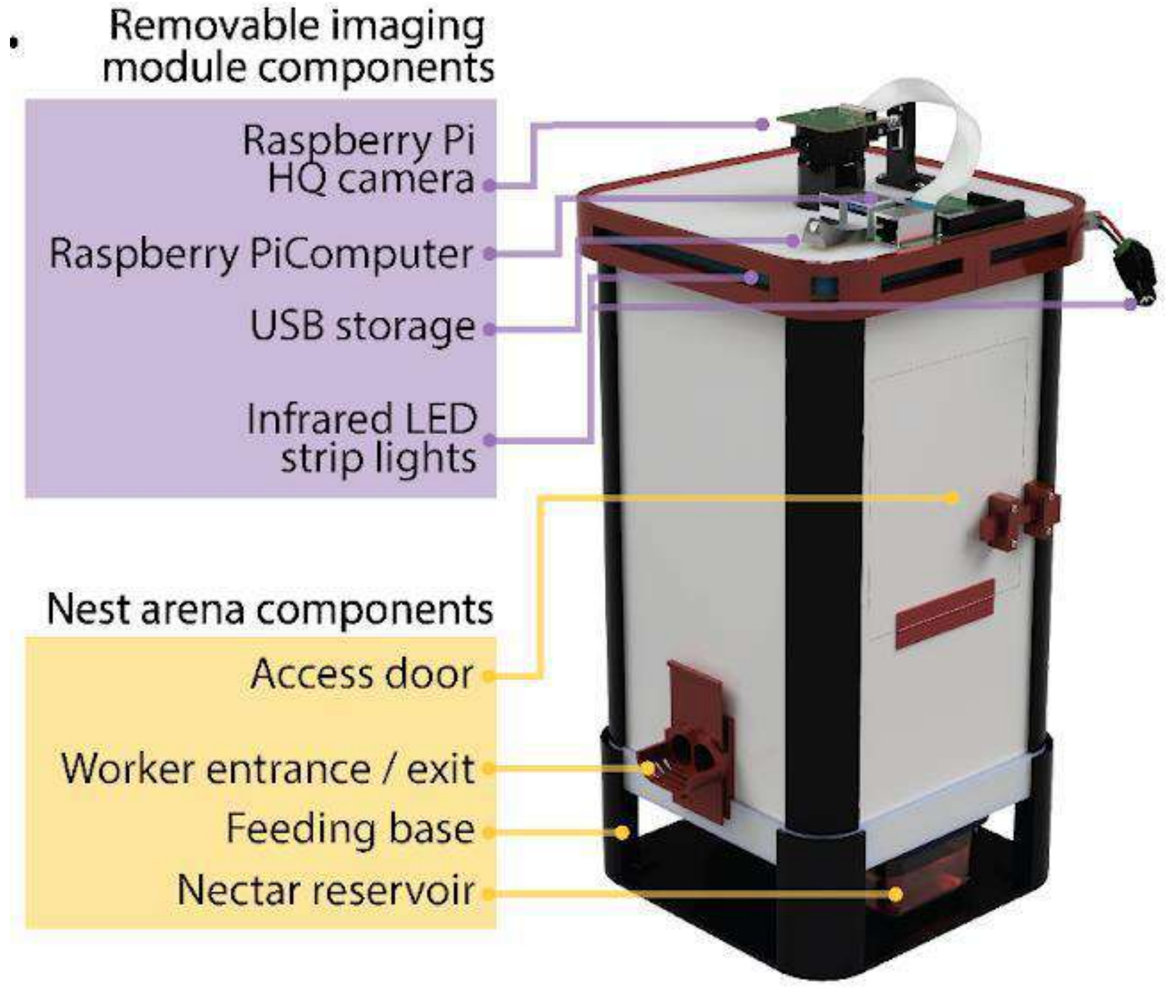
Focusing on well-fed, mature colonies under lab conditions might **underestimate effects in the field**

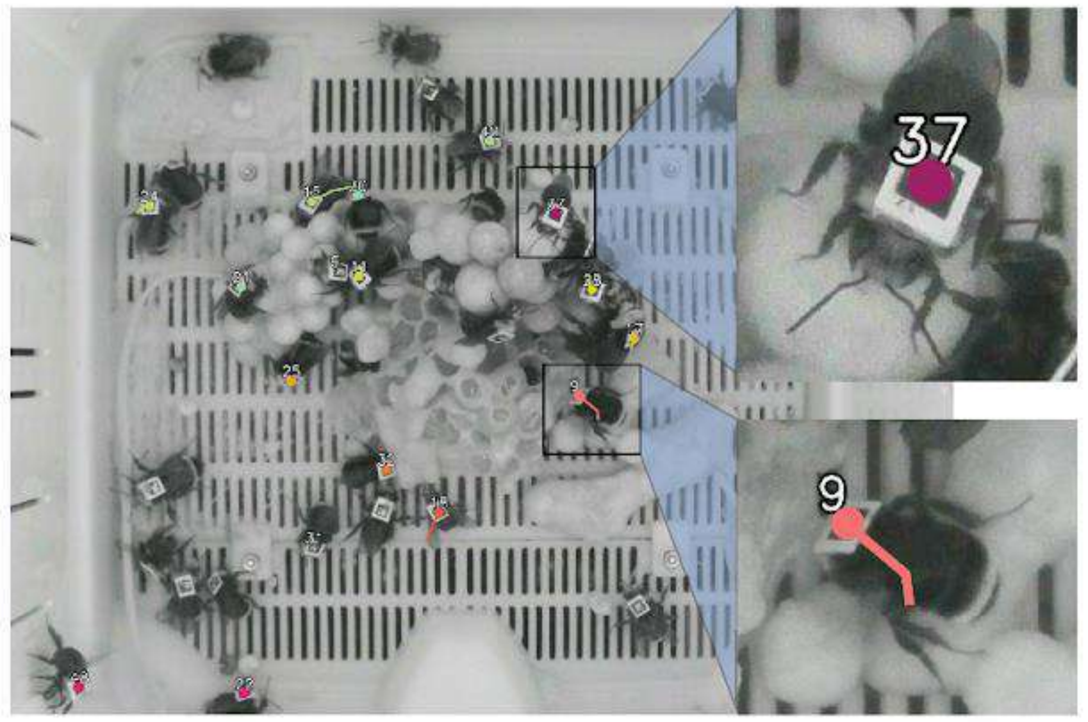
Emerging technologies and monitoring programs can help us better understand the effects of neonicotinoids in natural environments

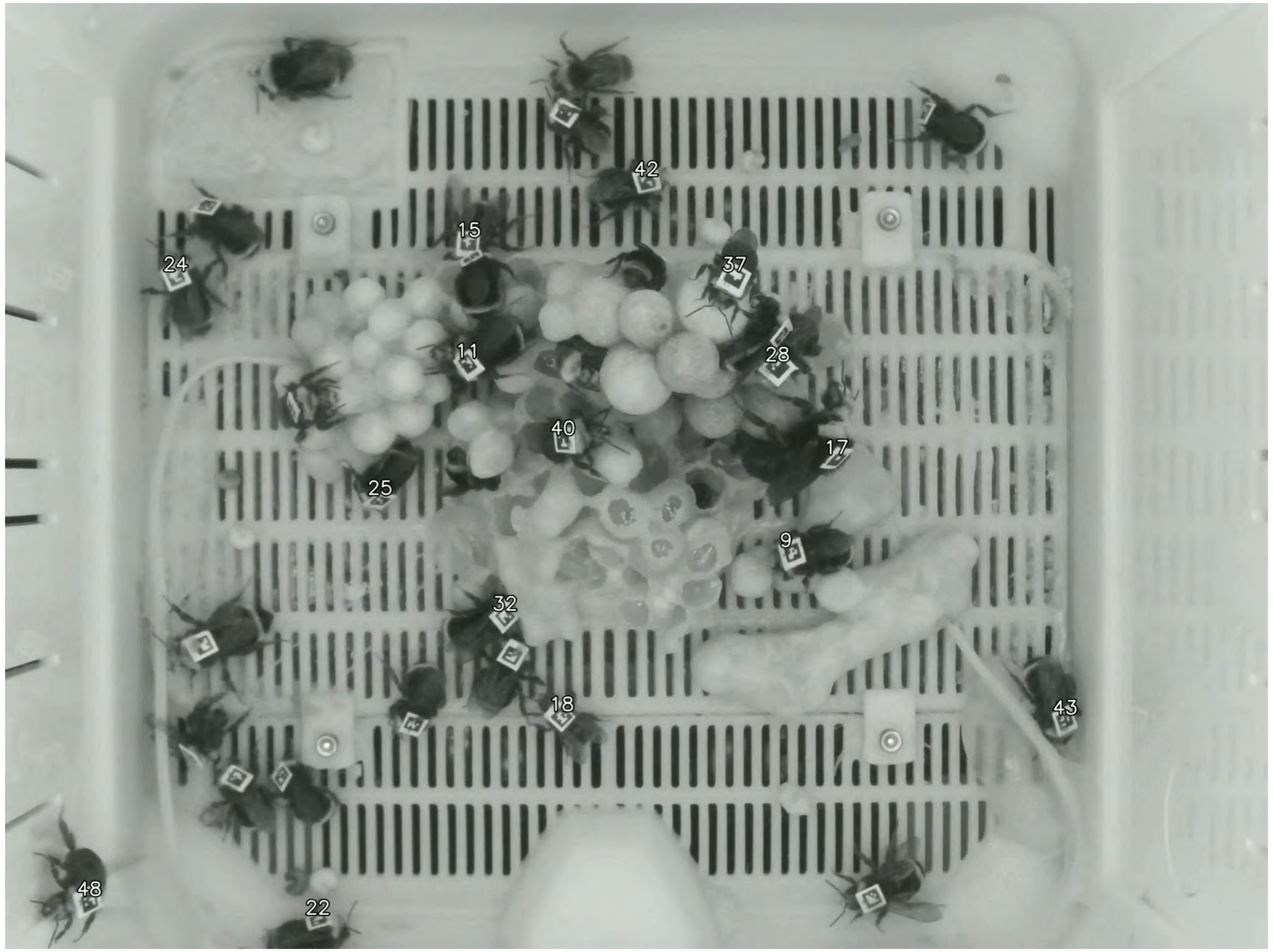




The **BumbleBox**: A low-cost, open-source platform for bumblebee nest tracking

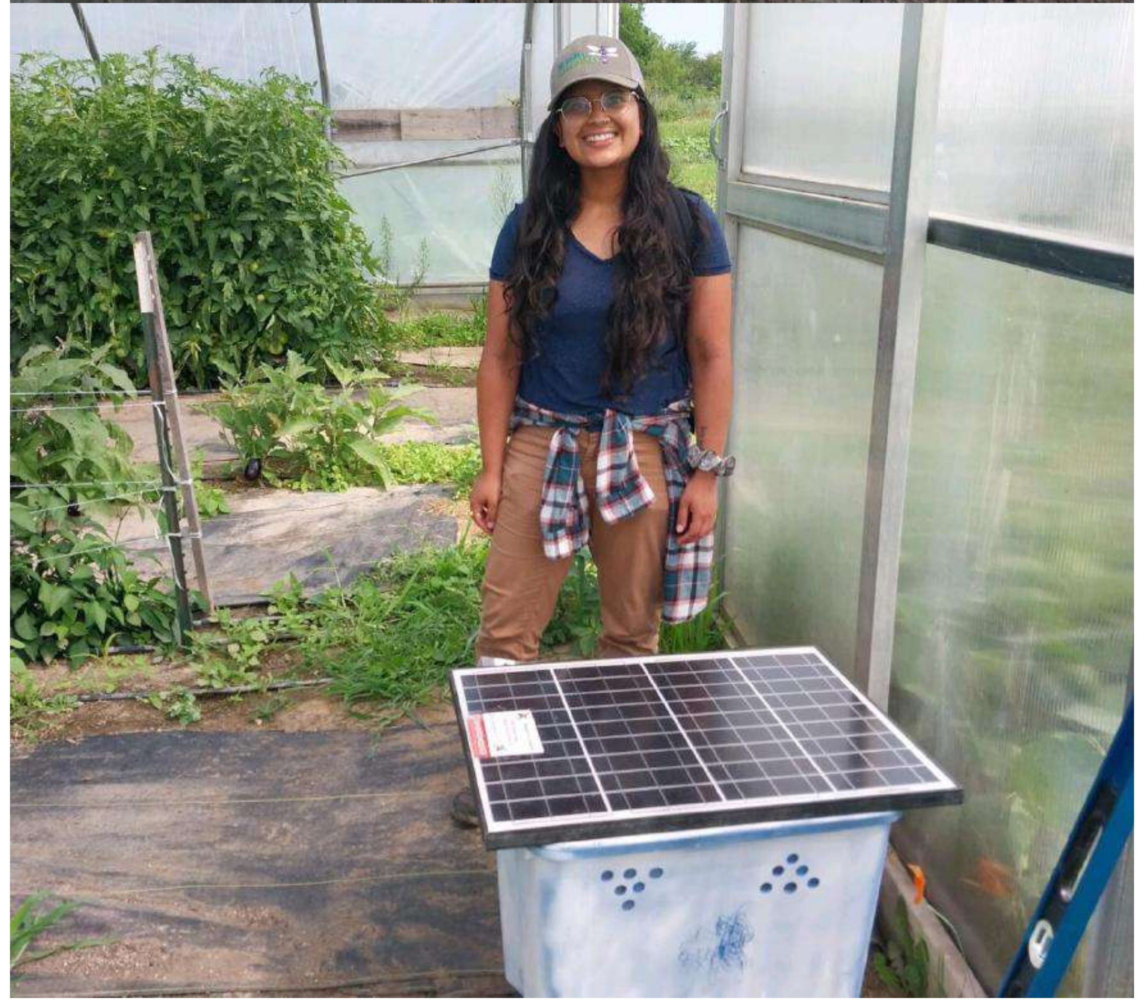




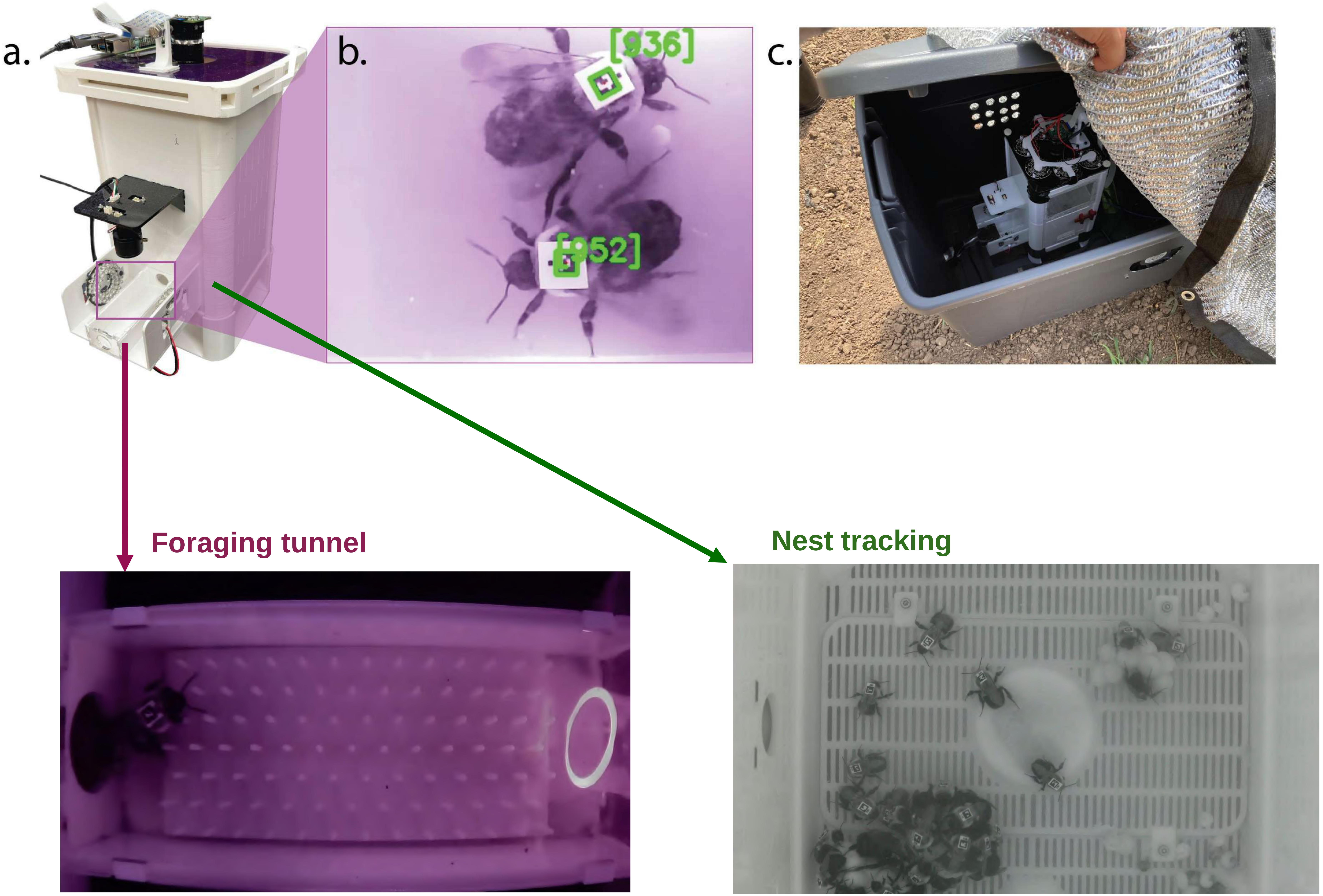


August Easton-Calabria

Understanding behavior and colony health in the field



Anupreksha Jain



Global patterns of neonicotinoid exposure

Article

Pesticide use negatively affects bumble bees across European landscapes

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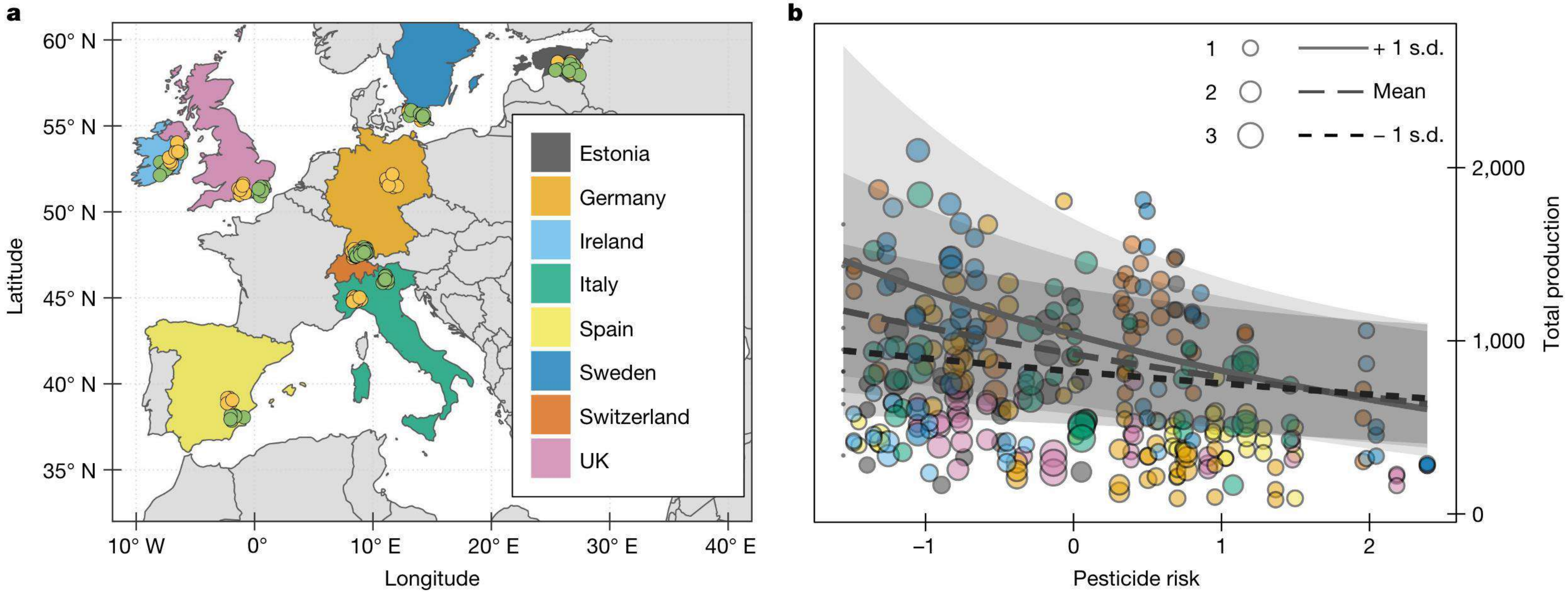
Table 2 | Ten compounds found in the colony pollen stores posing most risk to bumble bees in European agricultural landscapes

Pesticide (type)	Chemical group	LD_{50} mean	LOQ	Concentration mean	Concentration median	Concentration 90th percentile	Frequency	Compound risk
Indoxacarb (I)	Oxadiazine	0.1560	5.0	1,310	57	3,380	17 (16%)	1,430
Spinosad (I)	Spinosyn	0.0303	5.0	658	658	1,170	2 (2%)	434
Chlorpyrifos-Ethyl (I)	Organophosphate	0.1090	5.0	282	13.9	561	9 (8%)	233
Deltamethrin (I)	Pyrethroid	0.0358	5.0	68.80	68.8	117	2 (2%)	38.50
Dimethoate (I)	Organophosphate	0.1000	1.0	31	15.4	77.3	11 (10%)	34.10
Imidacloprid (I)	Neonicotinoid	0.0424	1.0	9.490	8.1	17.5	9 (8%)	20.20
Cyfluthrin (I)	Pyrethroid	0.0255	1.0	41.50	41.5	41.5	1 (1%)	16.30
Dithianon (F)	Quinone	62.700[a]	50.0	3,300	244	12,900	25 (24%)	12.60
Etofenprox (I)	Pyrethroid	0.2020	5.0	61.90	47.5	91.9	3 (3%)	9.19
Chlorpyrifos-Methyl (I)	Organophosphate	0.1620	5.0	36.90	16.6	80.9	4 (4%)	9.08

Neonicotinoids are **one important component** of the overall ‘risk landscape’ bees and other biodiversity are facing



Thank you! Questions?

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