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Forum

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Honey Bees and Industrial Agriculture: What Researchers are Missing, and Why it's a Problem

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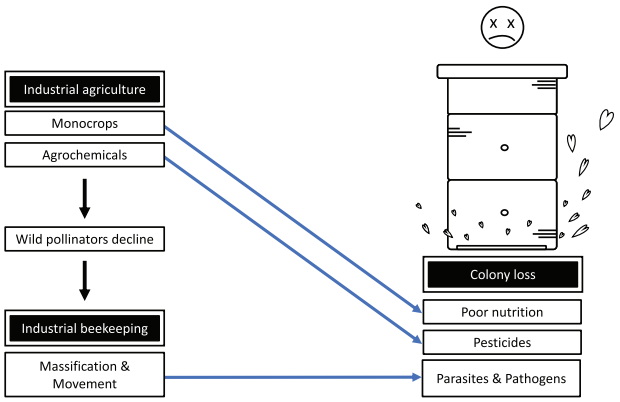
Abstract

Industrial agriculture is the root cause of many health problems that honey bees (*Apis mellifera* Linneaus, 1758) face, but honey bee researchers seldom call attention to this fact. We often discuss the stressors that contribute to colony loss (e.g., pathogens, pesticides, poor nutrition), but we rarely talk about where those stressors come from. This is a problem because we cannot resolve honey bee health issues unless we confront the systems that cause them harm. In this forum article, I unpack the relationship between honey bee health and industrial agriculture. I propose steps we can take to reframe our research to account for the impacts of this destructive system, and I discuss the uncomfortable questions that surface when we engage in this process. The goal of this article is to encourage conversation within the honey bee research community around the impacts of industrial agriculture, so that we can fully engage in the transformative change needed to support honey bee health.

Graphical Abstract



Key words: honey bee health, colony loss, industrial agriculture, food systems transformation, agroecology

In the United States, when honey bee researchers talk about honey bee health, we often start by describing the following problem: honey bee health is precarious, and colony losses occur at unsustainable rates (see 1 in "Notes" section). We then refer to a set of multiple interacting stressors to explain the causes of colony loss (Steinhauer et al. 2018). We point to the four P's: parasites, pathogens, poor nutrition, and pesticides ('Honey Bee Health' 2021). We note that these stressors are complex and mutually reinforcing (Spivak et al. 2011). We explain, for example that a malnourished colony is more susceptible to parasites and pathogens (Dolezal et al. 2019), and that a diseased colony is less likely to be able to collect the resources it needs for adequate nutrition (Wells et al. 2016, Dolezal and Toth 2018). Next, we reference some of the social, economic, and ecological implications of poor honey bee health and colony loss. We talk about the ways in which this problem negatively affects honey bee wellbeing and beekeeper livelihoods (Goodrich 2019). Sometimes we also mention that the spread of honey bee pathogens could spill over to native bees and other insects, which might negatively impact their health (Mallinger et al. 2017). Taking this one step further, we connect the importance of honey bee wellbeing and

Box 1: Honey bee health framing analysis

In an analysis of the top ten most cited honey bee health articles from the past decade (Web of Science: search terms 'honey bee' and 'health'; see Supp Tables S1 and S2 [online only] for selection criteria and analysis), seven articles discussed the problem of colony loss and the implications this has for agricultural production in the introduction section without acknowledging the ways in which intensive or industrial agriculture contribute to colony loss. One article did not discuss colony loss or agricultural production at all, and instead focused on pesticide toxicity. The two articles that did acknowledge the negative impacts of industrial agriculture in the introduction section were written by authors based at institutions outside of the United States at time of publication.

Articles that were narrowly framed (i.e., articles that did not connect the causes of honey bee colony loss to the expansion of intensive or industrial agriculture) most often concluded by highlighting the need for further research (6/7 articles). Two of these articles also mentioned the importance of taking action to support honey bee health, but the actions they proposed focused on responding to stressors (i.e., improving honey bee management strategies) rather than addressing their root cause (i.e., transforming agroecosystems).

beekeeper livelihoods to our agricultural system, the food supply, and global food security (vanEngelsdorp and Meixner 2010).

This narrative frames many of the grants we apply for, the articles we write, and the actions we take to support honey bee health. It is clear cut and widely agreed upon. It is also missing something big. The framing we use to discuss honey bee health highlights the stressors that drive colony loss, but it does not talk about where those stressors come from (see Box 1). In this forum article, I argue that in order to improve the health of honey bees, we, as honey bee researchers, must confront the systems that cause them harm. Here, I discuss the connection between honey bee health and industrial agriculture, a complex eco-social system whose biophysical components are characterized by large-scale monocultures, mechanization, and extensive off-farm inputs (e.g., seeds, chemicals, managed pollinators) (Kovács-Hostyánszki et al. 2017, Petersen-Rockney et al. 2021). I examine the ways that honey bee researchers discuss the causes of colony loss, and reflect on the consequences this messaging has. Finally, I propose options for reframing our research and explore the uncomfortable questions that emerge when we engage in this process. Ultimately, the goal of this paper is to encourage conversation within the honey bee research community around the impacts of industrial agriculture, so that we can fully engage in the transformative change needed to support honey bee health.

Industrial Agriculture Negatively Impacts Honey Bee Health

The problem of industrial agriculture – also known as intensive, conventional, or modern agriculture – is vast and unwieldy. For the purpose of this article, I will highlight the ways in which the biophysical expression of this system impacts honey bee health (see 2 in "Notes" section).

In non-industrial, low-input, diversified farming systems, complex communities of plants, animals, bacteria, and fungi contribute to ecosystem functions that support sustainable food production (Kremen and Miles 2012, Bommarco et al. 2013). These include vital processes such as pollination, pest control, soil formation, and water regulation (Bacon et al. 2012). To support their function, farmers must manage biodiversity at field, farm, and landscape scales (Petersen-Rockney et al. 2021).

Industrial agriculture is designed around two main goals: 1) increased labor productivity (where the idea is to maximize output per worker) and 2) increased yield (where the idea is to maximize output per plant or animal) (Ellis et al. 2020). Proponents of industrial agriculture argue that farmers must simplify and standardize crop production in order to achieve these goals (Weis 2010, Ellis et al. 2020). This means establishing monocultures and replacing ecosystem services with synthetic fertilizers, pesticides, and other technological fixes (Altieri 1998, Socolar et al. 2021).

The simplification and standardization of agricultural landscapes can support increased yield, but these processes pose some major problems (Tscharntke et al. 2005). First, they undermine biodiversity and erode the ecosystem functions that diverse plants and animals provide, increasing farmer dependence on off-farm inputs (Tilman et al. 2002, Cardinale et al. 2012, Bretagnolle and Gaba 2015). Second, the industrialization of agriculture leads to consequences, or externalities, that extend far beyond crop fields. Some of these externalities include greenhouse gas emissions, viral spillover events, contaminated water supply, exploitation of workers, and, ironically, food insecurity (Tscharntke et al. 2005, Weis 2010, Kremen and Miles 2012, Montenegro de Wit 2020).

How does the industrialization of agriculture impact honey bee health? In diversified farming systems, farmers rely primarily on wild insects and other animals to pollinate their crops. These pollinators nest in and around agricultural landscapes, and their pollination services support abundant food production (Garibaldi et al. 2013). In industrial agriculture, monocrop landscapes provide limited nesting habitat and forage resources (Dolezal et al. 2016), and pollinators are exposed to an abundance of agrochemicals (Garibaldi et al. 2011, González-Varo et al. 2013). As a result, as agriculture intensifies, the overall abundance and richness of wild pollinators in agricultural landscapes decreases (Kremen et al. 2002, Klein et al. 2007, Garibaldi et al. 2014), and commercial beekeepers bring in honey bees to meet crop pollination needs (Spivak et al. 2011, Bond et al. 2021).

Because they pollinate a wide variety of plants, and because their colonies contain tens of thousands of individuals, honey bees are a relatively effective pollinator to mobilize and massify (vanEngelsdorp and Meixner 2010). When industrial agriculture manufactures a demand for pollination services, industrial beekeeping meets that demand (Cilia 2020). Every year, commercial beekeepers transport more than two million colonies around the United States to pollinate crops like almonds, apples, blueberries, and melons (Goodrich 2019, Bond et al. 2021). Pollination contracts – in which beekeepers rent colonies to growers on a temporary basis to support crop yields – provide a vital source of income for many commercial beekeepers (USDA National Agricultural Statistics Service 2021). These contracts lend some measure of economic stability to an increasingly precarious industry (Goodrich 2019). But, while renting out colonies can be a lifeline for beekeepers, engaging with industrial agriculture is not good for bees (Decourtye et al. 2010, Maderson and Wynne-Jones 2016).

Industrial agriculture – and industrial beekeeping – expose honey bees to the multiple interacting stressors that lead to colony loss (Fig. 1) (Colwell et al. 2017, Alger et al. 2018). Monocrop landscapes can provide honey bees with a lot of forage all at once, but the resources they offer are often short-lived and lacking in diversity and

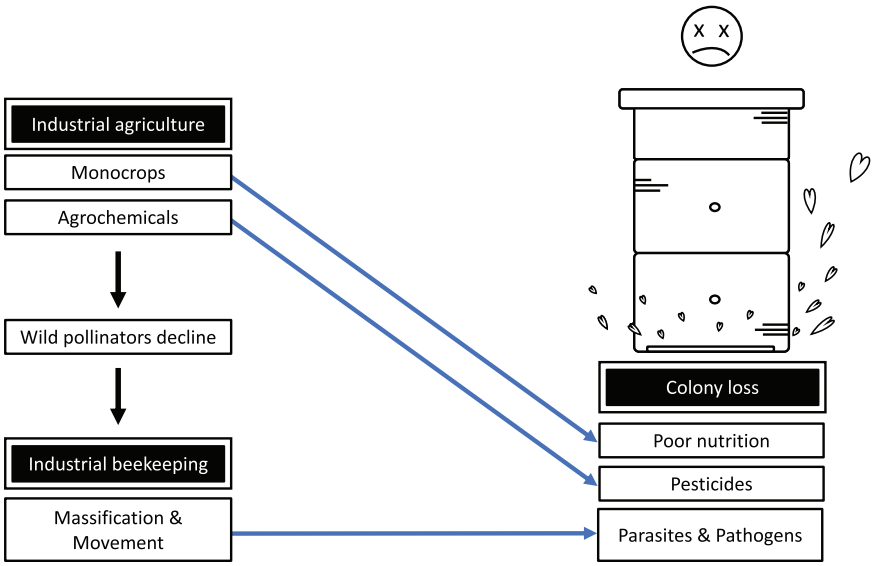


Fig. 1. The multiple interacting stressors that negatively impact honey bee health are rooted in and exacerbated by industrial agriculture.

nutritional quality (Di Pasquale et al. 2016). As a result, the proliferation of monocrop landscapes contributes to poor nutrition in honey bees (Decourtye et al. 2010, Durant and Otto 2019). Agrochemicals do further damage. Herbicides kill the so-called weeds that would otherwise provide important forage resources, and can have both lethal and sublethal effects on the bees themselves (Bretagnolle and Gaba 2015, Requier et al. 2015, Abraham et al. 2018, Motta et al. 2018). Fungicides disrupt in-hive microbial communities and affect honey bee metabolism, immune response, and other physiological processes critical to colony function (Cizelj et al. 2016, Kakumanu et al. 2016, Mao et al. 2017, Steffan et al. 2017). Insecticides negatively impact the bees' ability to learn, communicate, and locate their homes, and adversely affect egg-laying and colony development (Goulson 2013, Wu-Smart and Spivak 2016, Mengoni Goñalons and Farina 2018).

Even parasites and pathogens – stressors that seem separate from industrial agriculture – are exacerbated by this system (Welch et al. 2009, Alger et al. 2018). High stocking density leads to heightened pathogen transmission, increased virulence, and depressed immune response in a variety of industrialized livestock systems (Mennerat et al. 2010, Houshmand et al. 2012, Yarahmadi et al. 2016). Indeed, when honey bees are housed in crowded bee yards, high stocking density contributes to increased pathogen transmission potential, and creates conditions that favor increased virulence (Brosi et al. 2017, Dynes Id et al. 2019). Moreover, migratory practices, the cross-country sale of honey bee 'packages' and nucleus colonies, and the growing popularity of hobby beekeeping bring honey bees – and the pathogens they carry – to all corners of the country. Since pathogen transmission across long distances also contributes to increased virulence, these practices further compound pathogen problems (Brosi et al. 2017). Commercial beekeepers take great care to keep pathogen loads in check, but the conditions of industrial agriculture constantly up the ante. As a result, the spread of parasites and pathogens, on top of poor nutrition, on top of pesticides, makes keeping colonies alive a complicated endeavor.

To review, when honey bee researchers frame honey bee health issues, we often focus on the fact that deteriorating colony health has negative consequences for our agricultural system. But, when we consider the problem of industrial agriculture, we see that colony loss is actually the logical result of the way that we farm, and the way we push honey bees to produce in conditions that are not designed to support their survival (Spivak 2013). When we broaden our framing, we find that industrial agriculture is not the victim of unsustainable colony loss; it is the cause.

This is not actually new information. Sociologists, ecologists, geographers, agroecologists, journalists, and many beekeepers and farmers have provided critical analyses that describe this 'manifestly unsustainable system' (Nimmo 2015a, 2015b, Goulson and Nicholls 2016, Maderson and Wynne-Jones 2016, Suryanarayanan et al. 2018; Cilia 2019, 2020, Durant 2019a, Ellis et al. 2020, McGivney 2020). Many of these analyses explicitly connect honey bee health issues to industrial agriculture (e.g., the 'apis-industrial complex') and to the political, social, and economic structures that underlie this system. These resources are relevant to honey bee research because they help to describe the context in which honey bee health issues are situated. However, we honey bee researchers rarely cite our colleagues across disciplines. We focus on specific aspects of honey bee health, and we skip the broader context.

Why does this matter? The way we frame a problem shapes the solutions that we implement (see Box 1). When we frame this problem as an issue with honey bee health, rather than an issue with the industrial agriculture system, we undercut our research efforts and lend further support to an unsustainable status quo.

Failing to Name Industrial Agriculture Undercuts Our Research Efforts

Through years of focused research, honey bee scientists have developed a detailed understanding of many aspects of honey bee biology and colony health. This work often describes or addresses the negative impacts of industrial agriculture, but it seldom names this system explicitly (Supp Tables S1 and S2 [online only]). This is a problem because when we attempt to address honey bee health issues without acknowledging industrial agriculture as the underlying driver of colony loss, we run the risk of focusing our energy on partial fixes that make it only marginally more possible for honey bees to survive an inhospitable system (Maderson and Wynne-Jones 2016).

Here is another way to put that. The 'canary in the coalmine' metaphor is commonly employed to warn of the catastrophic consequences

of pollinator demise (Goulson and Nicholls 2016, Hall and Martins 2020, Paffhausen et al. 2021), where honey bees are often (mis-)used as a stand-in for all pollinators (Geldmann and González-Varo 2018). Essentially, the story goes that if honey bees collapse, our food systems will follow. We can extend this metaphor to illustrate the consequences of a framing that focuses on the stressors that cause honey bee disease, without questioning the system that creates those stressors. In this case, if the honey bee is the canary, a narrow framing leads us to focus on the health of the bird instead of its surroundings. We see the canary, we know it is unwell, but instead of evacuating the coalmine and bringing the bird up to the surface for the fresh air that it needs, we scientists are setting up a more permanent camp inside the mine, hooking the canary up to oxygen, running diagnostic tests, supplementing the canary's diet to elevate its hemoglobin levels, and initiating a program to develop a canary that can survive on CO_2. Our efforts may allow the canary to live a little longer, but focusing solely on individual aspects of canary health actually keeps us from asking more fundamental questions: Why are we keeping canaries in coalmines in the first place? Why are we still building coal mines at all?

Attempting to support honey bee health without addressing the root causes of colony loss will not create the change we need. In order to address the larger issue, we must reframe our research. We must name industrial agriculture.

Reframing Our Research

As scientists, we reframe our research all of the time. We do this to reach different audiences, tap into different funding sources, and contextualize our work to fit different publications. So, broadening our framing of honey bee health issues to name industrial agriculture as a root cause of colony loss should not be much of a stretch.

Here is one example of what that might look like (Fig. 2). When we introduce our research, we start by providing context, we then state the problem, and we talk about how our research will address that problem. Currently, when honey bee researchers talk about honey bee health, we start by stating that honey bees are essential pollinators in agricultural systems; their contribution to crop production is valued at so many billions of dollars. We then describe this problem: colony loss is occurring at unsustainable rates. These losses result from multiple interacting stressors, such as pathogens, pesticides, and poor nutrition. Finally, we talk about how our research will help honey bees or beekeepers manage or overcome one or several of the multiple interacting stressors.

A hypothetical reframe could look like this: we start by stating that the proliferation of industrial agriculture results in decreased abundance of wild pollinators, so growers across the country rent honey bee hives to meet pollination needs in large monocultures. We then describe this problem: although this arrangement may improve yields in the short-term, it ultimately exacerbates a series of multiple interacting stressors which negatively impact honey bee health. This is where I stop and notice that shifting my framing *does* change the way I think about the research I am doing. Now that I have named industrial agriculture as a primary driver of colony loss, I must also acknowledge that my specific research focus (resin use and immune function) is unlikely to make much of a difference in honey bee health outcomes, absent structural change. That does not mean my research is useless, but I will have to think more deeply about how my actions fit into a broader strategy to promote honey bee health, and how I can use my research to forward that strategy in a meaningful way.

Changing our framing is simple – I only added a few sentences there – but it is not easy. Why? Engaging with the root causes of colony loss exposes the need for bigger change (Ellis et al. 2020), and big change can be hard to face. This brings us to The Dangerous Questions.

The Dangerous Questions

The Dangerous Questions invite us to reassess the role of beekeeping and honey bee research in agricultural systems. For example, if we acknowledge that industrial agriculture and industrial beekeeping are bad for honey bee health, and we know that our goal is to move towards a food system that supports bee health, then: what *is* the role of beekeeping in agriculture? If we transform agricultural landscapes in the United States so that they support wild pollinators, and those wild pollinators support crop production, then will beekeeping have a significant role? What if the answer is no, not really? Or, not in a way that could support the livelihoods of the approximately 25,000 apiary workers currently employed in the United States (USDA 2020)?

The dangerous questions do not just impact beekeepers; they affect honey bee researchers as well. In the long-term, if 'saving the

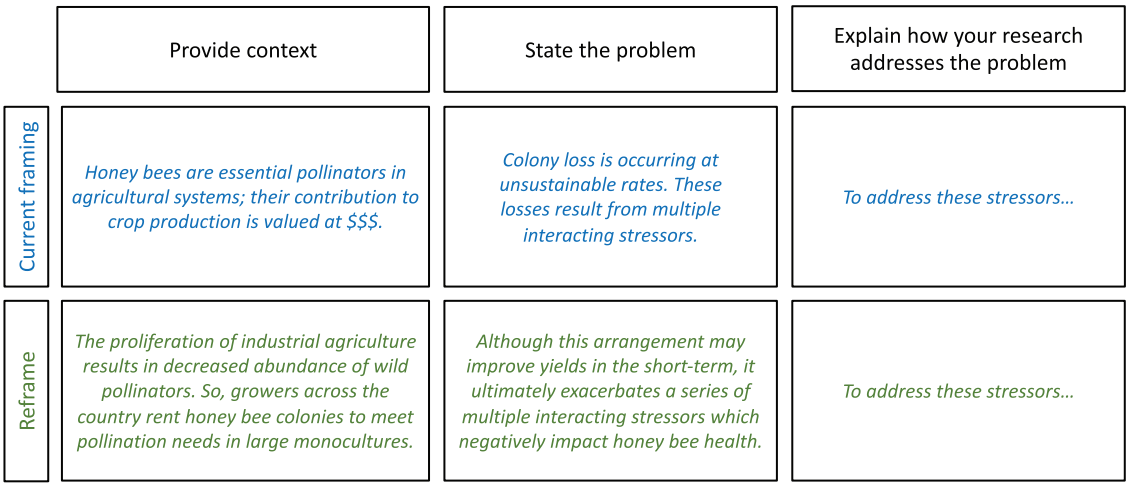


Fig. 2. Reframing honey bee health issues to name industrial agriculture as a root cause of colony loss creates an opportunity for researchers to consider how the actions we take fit into a broader strategy of food systems transformation, and how we can use our research to forward that strategy in a meaningful way.

honey bee' is less about drilling down on honey bee biology and behavior, and more about food system transformation, then what *is* the role of honey bee research? Does it have a significant role? What if the answer is no, not really? Or, not in its current form? And, in the short term, if honey bee researchers present a critique of the predominant agricultural system in the United States – the system that currently supports so much of our research – then what happens to our funding?

These questions are dangerous because they represent an existential threat to all those that work within the existing system to support honey bee health. For many honey bee researchers, speaking openly about industrial agriculture may further seem off-limits because engaging with the dangerous questions poses a problem not just for beekeepers, not just for researchers, but for researcher–beekeeper relationships. Researchers may worry that reframing this problem – implicating industrial agriculture and industrial beekeeping in colony loss – will hurt commercial beekeepers. These are people who we work with and care about. Our research is often oriented towards supporting them, and in many ways their work gives our work meaning. If we speak openly about the negative impacts of industrial agriculture, will we alienate the people that work within that system?

To answer this question, I think we have to remember that industrial agriculture is a complex system, one in which all of us – researchers, beekeepers, and farmers alike – are embedded. Beekeepers are acutely aware of the myriad problems that this system poses, and work in their own ways to address them (Maderson and Wynne-Jones 2016, Durant 2019b, Cilia 2020). Describing the impacts of industrial agriculture is not about blame; it is about getting clear about how this system works, so that we can transform it, together. It makes sense to be thoughtful about the way we discuss these issues. It makes sense to acknowledge that, for many, beekeeping is a labor of love, and current conditions make it difficult for bees, beekeepers, and beekeeping businesses to thrive. I think we can do this, while also speaking openly about the root of the problems we collectively face. I believe that beekeepers, researchers, and beekeeper–researcher relationships are capable of holding that complexity. And, that researchers' concern for commercial beekeepers' experience, while valid, should not distract us from also doing the work of understanding the ways in which our own actions – the actions of the honey bee research community – uphold industrial agriculture.

Holding Complexity

It is difficult for me to confront the broader systems that lead to such massive colony loss, in part because of the implications that a reframe might have for my life and work. The scope of my research is limited. Like so many scientists, I have specialized. I have focused on one tractable problem, hoping to make a small amount of positive change. I am not an expert in agricultural systems. What can a scientist studying honey bee immune health contribute in the face of such a massive and tangled problem? Three important things: First, I can do my best to direct my research to support honey bee health within our current system. Second, I can engage with interdisciplinary scholarship and diverse knowledge systems to better understand the context in which my work is situated. Third, I can directly describe the origin of the problems that my research attempts to address. The benefits of the first action will not have much impact unless we connect with the second, and actualize the third (Mortensen and Smith 2020). So, here is the call to action. Honey bee researchers: name industrial agriculture in the grants you apply for, in the articles you write, and in the actions you take to support honey bee health. When you talk about colony loss, when you list the multiple interacting stressors, explain where those stressors come from. Take a closer look at industrial agriculture, and name the problems it presents, so that, collectively, we can move towards transforming this system.

This may not seem like much, or it may seem like too much. But, when we consider the massive harms that industrial agriculture imposes on individuals, communities, and living systems, we find that telling the truth in honey bee research is both necessary and the barest of minimums. And, if turning towards The Dangerous Questions is uncomfortable, turning away from them represents its own existential threat. When we normalize industrial agriculture, we are not just pushing honey bees to survive a system that does not support their survival. It is much more than that. When honey bee researchers describe the conditions of industrial agriculture without calling into question the system that creates them, we lend legitimacy to the erroneous idea that industrial agriculture is an immutable system, when it is actually only one of many forms of food production (Kloppenburg 1991, Rosset and Altieri 2018, Carlisle et al. 2019). When we fail to acknowledge the broader context contributing to colony loss, we protect that toxic system from actual transformation (Montenegro de Wit and Iles 2016). We are stuck making things work when we should be making them change, and the consequences of these actions extend far beyond honey bee health, to native bees, greenhouse gas emissions, viral spillover events, exploitation of workers, food insecurity, and beyond.

Fortunately, there are ways forward. Beekeepers, farmers, individuals, communities, and organizations in the United States and all over the world are working to envision, enact, and defend alternatives to industrial agriculture (Maderson and Wynne-Jones 2016, Mier y Terán Giménez Cacho et al. 2018), and to realize the social, political, and economic changes that must accompany their widespread implementation (e.g., 'Agrarian Trust' 2021, Calo et al. 2021). These efforts are supported by ample research which demonstrates that so-called 'alternative' farming systems (e.g., diversified farming systems, regenerative agriculture, agroecological systems, and Indigenous and traditional farming systems) support abundant food production (Tscharntke et al. 2012, Kremen and Merenlender 2018) and can help to repair many of the harms imposed by industrial agriculture (Petersen-Rockney et al. 2021). Efforts to enact these alternatives are inherently interdisciplinary. They connect food systems transformation to broader social and political movements for justice (e.g., see Indigenous land and seed sovereignty initiatives ('Indigenous Seed Keepers Network' 2020, 'Reparations' 2021) and efforts to eradicate racism from the food system (e.g., 'Soul Fire Farm' 2021)). When honey bee researchers recognize industrial agriculture as the root cause of honey bee health issues, we open ourselves to the opportunity to collaborate meaningfully in these movements, and contribute to the future that must be built. We add our voices to the growing chorus that knows, and insists, that industrial agriculture is not the only way. It is one way. It is a way that we made. It is a thing we can change. The question is whether we open up and allow that change to happen *through* us, or dig in our heels until that change happens *to* us.

Notes

1. I use the word 'we' because I am a honey bee researcher and I am part of this learning process, too. After several years as an extension educator and beekeeper, I chose to pursue a Ph.D. because I saw and experienced unsustainable colony loss, and I hoped that research could provide better solutions for beekeepers at all scales. The analysis I share here is centered in the United

States, where much of my beekeeping and bee research experience has taken place, though I believe it to be relevant wherever honey bees interact with industrial agriculture.

2. There are, of course, other problems with industrial agriculture. Many of these problems are rooted in the ways in which this system perpetuates destructive capitalist and colonial projects. The biophysical focus of this paper is not meant to elide these related issues, but to highlight the dynamics that impact honey bee health most directly. For broader analyses on the social, political, and economic components of this sprawling problem, see work by honey bee researchers from the social sciences and humanities (e.g., see Nimmo 2015a; Cilia 2019, 2020).

Supplementary Data

Supplementary data are available at *Journal of Insect Science* online.

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Author Contributions

MS: conceptualization, investigation, and writing (original draft, review, and editing).

References Cited

Abraham, J., G. S. Benhotons, I. Krampah, J. Tagba, C. Amissah, and J. D. Abraham. 2018. Commercially formulated glyphosate can kill non-target pollinator bees under laboratory conditions. Entomol. Exp. Appl. 166: 695–702.

(Agrarian Trust) Agrarian Land Trust. 2021. Agrarian Trust. (agrariantrust.org).

Alger, S. A., P. Alexander Burnham, Z. S. Lamas, A. K. Brody, and L. L. Richardson. 2018. Home sick: impacts of migratory beekeeping on honey bee (Apis mellifera) pests, pathogens, and colony size. PeerJ. 2018: 1–22.

Altieri, M. A. 1998. Ecological impacts of industrial agriculture and the possibilities for truly sustainable farming. Mon. Rev. An Indep. Social. Mag. 50: 60.

Bacon, C., A. Iles, and C. Kremen. 2012. Diversified farming systems: an agroecological, systems-based. Ecol. Soc. 17: 44.

Bommarco, R., D. Kleijn, and S. G. Potts. 2013. Ecological intensification: harnessing ecosystem services for food security. Trends Ecol. Evol. 28: 230–238.

Bond, J. K., C. Hitaj, D. Smith, A. Perez, G. Ferreira, K. Jennifer, C. Hitaj, D. Smith, K. Hunt, A. Perez, and G. Ferreira. 2021. Honey bees on the move: from pollination to honey production and back, U.S. Dep. Agric. Econ. Res. Serv. Report number: 290.

Bretagnolle, V., and S. Gaba. 2015. Weeds for bees? a review. Agron. Sustain. Dev. 35: 891–909.

Brosi, B. J., K. S. Delaplane, M. Boots, and J. C. de Roode. 2017. Ecological and evolutionary approaches to managing honeybee disease. Nat. Ecol. Evol. 1: 1250–1262.

Calo, A., A. McKee, C. Perrin, P. Gasselin, S. McGreevy, S. R. Sippel, A. A. Desmarais, K. Shields, A. Baysse-Lainé, A. Magnan, N. Beingessner, and M. Kobayashi. 2021. Achieving food system resilience requires challenging dominant land property regimes. Front. Sustain. Food Syst. 5: 683544.

Cardinale, B. J., J. E. Duffy, A. Gonzalez, D. U. Hooper, C. Perrings, P. Venail, A. Narwani, G. M. MacE, D. Tilman, D. A. Wardle, A. P. Kinzig, G. C. Daily, M. Loreau, J. B. Grace, A. Larigauderie, D. S. Srivastava, and S. Naeem. 2012. Biodiversity loss and its impact on humanity. Nature. 486: 59–67.

Carlisle, L., M. Montenegro de Wit, M. S. DeLonge, A. Calo, C. Getz, J. Ory, K. Munden-Dixon, R. Galt, B. Melone, R. Knox, A. Iles, and D. Press. 2019. Securing the future of US agriculture: the case for investing in new entry sustainable farmers. Elementa. 7: 17.

Cilia, L. 2019. The plight of the honeybee: a socioecological analysis of large-scale beekeeping in the United States. Sociol. Ruralis. 59: 831–849.

Cilia, L. 2020. 'We don't know much about bees!' techno-optimism, techno-scepticism, and denial in the American large-scale beekeeping industry. Sociol. Ruralis. 60: 83–103.

Cizelj, I., G. Glavan, J. Božič, I. Oven, V. Mrak, and M. Narat. 2016. Prochloraz and coumaphos induce different gene expression patterns in three developmental stages of the Carniolan honey bee (Apis mellifera carnica Pollmann). Pestic. Biochem. Physiol. 128: 68–75.

Colwell, M. J., G. R. Williams, R. C. Evans, and D. Shutler. 2017. Honey bee-collected pollen in agro-ecosystems reveals diet diversity, diet quality, and pesticide exposure. Ecol. Evol. 7: 7243–7253.

Decourtye, A., E. Mader, and N. Desneux. 2010. Landscape enhancement of floral resources for honey bees in agro-ecosystems. Apidologie. 41: 264–277.

Di Pasquale, G., C. Alaux, Y. Le Conte, J. F. Odoux, M. Pioz, B. E. Vaissière, L. P. Belzunces, and A. Decourtye. 2016. Variations in the availability of pollen resources affect honey bee health. PLoS One. 11: 1–15.

Dolezal, A. G., and A. L. Toth. 2018. Feedbacks between nutrition and disease in honey bee health. Curr. Opin. Insect Sci. 26: 114–119.

Dolezal, A. G., J. Carrillo-Tripp, W. A. Miller, B. C. Bonning, and A. L. Toth. 2016. Intensively cultivated landscape and varroa mite infestation are associated with reduced honey bee nutritional state. PLoS One. 11: e0153531.

Dolezal, A. G., J. Carrillo-Tripp, T. M. Judd, W. Allen Miller, B. C. Bonning, and A. L. Toth. 2019. Interacting stressors matter: Diet quality and virus infection in honeybee health. R. Soc. Open Sci. 6: 181803.

Durant, J. L. 2019a. Where have all the flowers gone? Honey bee declines and exclusions from floral resources. J. Rural Stud. 65: 161–171.

Durant, J. L. 2019b. Bitter honey: a political ecology of honey bee declines in California. University of California, Berkeley in Berekeley, California. It is archived at https://escholarship.org/uc/item/20f1f816#main

Durant, J. L., and C. R. V. Otto. 2019. Feeling the sting? addressing land-use changes can mitigate bee declines. Land Use Policy. 87: 104005.

Dynes, T. L., J. A. Berry, K. S. Delaplane, B. J. Brosi, and J. C. de Roode. 2019. Reduced density and visually complex apiaries reduce parasite load and promote honey production and overwintering survival in honey bees. PLoS One 14: e0216286. doi:10.1371/journal. pone.0216286.

Ellis, R. A., T. Weis, S. Suryanarayanan, and K. Beilin. 2020. From a free gift of nature to a precarious commodity: bees, pollination services, and industrial agriculture. J. Agrar. Chang. 20: 437–459.

Garibaldi, L. A., I. Steffan-Dewenter, C. Kremen, J. M. Morales, R. Bommarco, S. A. Cunningham, L. G. Carvalheiro, N. P. Chacoff, J. H. Dudenhöffer, S. S. Greenleaf, A. Holzschuh, R. Isaacs, K. Krewenka, Y. Mandelik, M. M. Mayfield, L. A. Morandin, S. G. Potts, T. H. Ricketts, H. Szentgyörgyi, B. F. Viana, C. Westphal, R. Winfree, and A. M. Klein. 2011. Stability of pollination services decreases with isolation from natural areas despite honey bee visits. Ecol. Lett. 14: 1062–1072.

Garibaldi, L. A., I. Steffan-dewenter, R. Winfree, M. A. Aizen, R. Bommarco, S. A. Cunningham, C. Kremen, and L. G. Carvalheiro. 2013. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science (80-.). 339: 1608–1611.

Garibaldi, L. A., L. G. Carvalheiro, S. D. Leonhardt, M. A. Aizen, B. R. Blaauw, R. Isaacs, M. Kuhlmann, D. Kleijn, A. M. Klein, C. Kremen, L. Morandin,

J. Scheper, and R. Winfree. 2014. From research to action: enhancing crop yield through wild pollinators. Front. Ecol. Environ. 12: 439–447.

Geldmann, J., and J. P. González-Varo. 2018. Conserving honey bees does not help wildlife. Science (80-.). 359: 392–393.

González-Varo, J. P., J. C. Biesmeijer, R. Bommarco, S. G. Potts, O. Schweiger, H. G. Smith, I. Steffan-Dewenter, H. Szentgyörgyi, M. Woyciechowski, and M. Vilà. 2013. Combined effects of global change pressures on animal-mediated pollination. Trends Ecol. Evol. 28: 524–530.

Goodrich, B. 2019. Contracting for pollination services: overview and emerging issues. Choices. 34: 1–13.

Goulson, D. 2013. An overview of the environmental risks posed by neonicotinoid insecticides. J. Appl. Ecol. 50: 977–987.

Goulson, D., and E. Nicholls. 2016. The canary in the coalmine; bee declines as an indicator of environmental health. Sci. Prog. 99: 312–326.

Hall, D. M., and D. J. Martins. 2020. Human dimensions of insect pollinator conservation. Curr. Opin. Insect Sci. 38: 107–114.

(Honey Bee Health) Bee Health Collective. 2021. Honey Bee Health. (https://beehealthcollective.org/honey-bee-health).

Houshmand, M., K. Azhar, I. Zulkifli, M. H. Bejo, and A. Kamyab. 2012. Effects of prebiotic, protein level, and stocking density on performance, immunity, and stress indicators of broilers. Poult. Sci. 91: 393–401.

(Indigenous Seed Keepers Network) Native American Food Sovereignty Alliance. 2020. Indigenous Seed Keepers Network. (https://nativefoodalliance.org/our-programs-2/indigenous-seedkeepers-network/).

Kakumanu, M. L., A. M. Reeves, T. D. Anderson, R. R. Rodrigues, and M. A. Williams. 2016. Honey bee gut microbiome is altered by in-hive pesticide exposures. Front. Microbiol. 7: 1–11.

Klein, A. M., B. E. Vaissière, J. H. Cane, I. Steffan-Dewenter, S. A. Cunningham, C. Kremen, and T. Tscharntke. 2007. Importance of pollinators in changing landscapes for world crops. Proc. R. Soc. B Biol. Sci. 274: 303–313.

Kloppenburg, J. 1991. Social theory and the de/reconstruction of agricultural science: local knowledge for an alternative agriculture. Rural Sociol. 56: 519–548.

Kovács-Hostyánszki, A., A. Espíndola, A. J. Vanbergen, J. Settele, C. Kremen, and L. V. Dicks. 2017. Ecological intensification to mitigate impacts of conventional intensive land use on pollinators and pollination. Ecol. Lett. 20: 673–689.

Kremen, C., and A. M. Merenlender. 2018. Landscapes that work for biodiversity and people. Science (80-.). 362; eaau6020.

Kremen, C., and A. Miles. 2012. Ecosystem services in biologically diversified versus conventional farming systems. Ecol. Soc. 17: 40.

Kremen, C., N. M. Williams, and R. W. Thorp. 2002. Crop pollination from native bees at risk from agricultural intensification. Proc. Natl. Acad. Sci. U. S. A. 99: 16812–16816.

Maderson, S., and S. Wynne-Jones. 2016. Beekeepers' knowledges and participation in pollinator conservation policy. J. Rural Stud. 45: 88–98.

Mallinger, R. E., H. R. Gaines-Day, and C. Gratton. 2017. Do managed bees have negative effects on wild bees?: a systematic review of the literature. PLoS One. 12: e0189268.

Mao, W., M. A. Schuler, and M. R. Berenbaum. 2017. Disruption of quercetin metabolism by fungicide affects energy production in honey bees (Apis mellifera). Proc. Natl. Acad. Sci. U. S. A. 114: 2538–2543.

McGivney, A. 2020. 'Like sending bees to war': the deadly truth behind your almond milk obsession. Guard. 1–14. https://www.theguardian.com/environment/2020/jan/07/honeybees-deaths-almonds-hives-aoe

Mennerat, A., F. Nilsen, D. Ebert, and A. Skorping. 2010. Intensive farming: evolutionary implications for parasites and pathogens. Evol. Biol. 37: 59–67.

Mengoni Goñalons, C. M., and W. M. Farina. 2018. Impaired associative learning after chronic exposure to pesticides in young adult honey bees. J. Exp. Biol. 221: jeb176644.

Mier y Terán Giménez Cacho, M., O. F. Giraldo, M. Aldasoro, H. Morales, B. G. Ferguson, P. Rosset, A. Khadse, and C. Campos. 2018. Bringing agroecology to scale: key drivers and emblematic cases. Agroecol. Sustain. Food Syst. 42: 637–665.

Montenegro de Wit, M. 2020. What grows from a pandemic? toward an abolitionist agroecology. J. Peasant Stud. 48: 99–136.

Montenegro de Wit, M. M., and A. Iles. 2016. Toward thick legitimacy: creating a web of legitimacy for agroecology. Elementa. **2016**: 1–24.

Mortensen, D. A., and R. G. Smith. 2020. Confronting barriers to cropping system diversification. Front. Sustain. Food Syst. 4: 1–10.

Motta, E. V. S., K. Raymann, and N. A. Moran. 2018. Glyphosate perturbs the gut microbiota of honey bees. Proc. Natl. Acad. Sci. U. S. A. 115: 10305–10310.

Nimmo, R. 2015a. Apiculture in the anthropocene: between posthumanism and critical animal studies, pp. 177–199. *In* Anim. Anthr. Crit. Perspect. Non-Human Futur. Sydney University Press, Sydney, New South Wales, Australia.

Nimmo, R. 2015b. The bio-politics of bees: industrial farming and colony collapse disorder. Humananimalia. 6: 20.

Paffhausen, B. H., J. Petrasch, U. Greggers, A. Duer, Z. Wang, S. Menzel, P. Stieber, K. Haink, M. Geldenhuys, J. C. Cavojská, T. A. Stein, S. Wutke, A. Voigt, J. Coburn, and R. Menzel. 2021. The electronic bee spy: eavesdropping on honeybee communication via electrostatic field recordings. Front. Behav. Neurosci. 15: 647224.

Petersen-Rockney, M., P. Baur, A. Guzman, S. F. Bender, A. Calo, F. Castillo, K. De Master, A. Dumont, K. Esquivel, C. Kremen, J. LaChance, M. Mooshammer, J. Ory, M. J. Price, Y. Socolar, P. Stanley, A. Iles, and T. Bowles. 2021. Narrow and brittle or broad and nimble? comparing adaptive capacity in simplifying and diversifying farming systems. Front. Sustain. Food Syst. 5: 1–30.

(Reparations) Northeast Farmers of Color Land Trust. 2021. Reparations. (https://nefoclandtrust.org/reparations).

Requier, F., J. F. Odoux, T. Tamic, N. Moreau, M. Henry, A. Decourtye, and V. Bretagnolle. 2015. Honey bee diet in intensive farmland habitats reveals an unexpectedly high flower richness and a major role of weeds. Ecol. Appl. 25: 881–890.

Rosset, P., and M. Altieri. 2018. Agroecología ciencia y política. Icaria editiorial, s.a., Barcelona, Spain.

Socolar, Y., B. R. Goldstein, P. De Valpine, and T. M. Bowles. 2021. Biophysical and policy factors predict simplified crop rotations in the US Midwest. Environ. Res. Lett. 16: 054045.

(Soul Fire Farm Strategic Goals) Soul Fire Farm. 2021. Soul fire farm strategic goals. (https://www.soulfirefarm.org/about/goals/).

Spivak, M. 2013. Why bees are disappearing [video]. TED Conferences. (https://www.ted.com/talks/marla_spivak_why_bees_are_disappearing?language=en).

Spivak, M., E. Mader, M. Vaughan, and N. H. Euliss Jr. 2011. The plight of the bees. Environ. Sci. Technol. 45: 34–38.

Steffan, S. A., P. S. Dharampal, L. Diaz-Garcia, C. R. Currie, J. Zalapa, and C. T. Hittinger. 2017. Empirical, metagenomic, and computational techniques illuminate the mechanisms by which fungicides compromise bee health. J. Vis. Exp. 128: e54631.

Steinhauer, N., K. Kulhanek, K. Antúnez, H. Human, P. Chantawannakul, M. P. Chauzat, and D. vanEngelsdorp. 2018. Drivers of colony losses. Curr. Opin. Insect Sci. 26: 142–148.

Suryanarayanan, S., D. L. Kleinman, C. Gratton, A. Toth, C. Guedot, R. Groves, J. Piechowski, B. Moore, D. Hagedorn, D. Kauth, H. Swan, and M. Celley. 2018. Collaboration matters: Honey bee health as a transdisciplinary model for understanding real-world complexity. Bioscience. 68: 990–995.

Tilman, D., K. G. Cassman, P. A. Matson, R. Naylor, and S. Polasky. 2002. Agricultural sustainability and intensive production practices. Nature. 418: 671–677.

Tscharntke, T., A. M. Klein, A. Kruess, I. Steffan-Dewenter, and C. Thies. 2005. Landscape perspectives on agricultural intensification and biodiversity - ecosystem service management. Ecol. Lett. 8: 857–874.

Tscharntke, T., Y. Clough, T. C. Wanger, L. Jackson, I. Motzke, I. Perfecto, J. Vandermeer, and A. Whitbread. 2012. Global food security, biodiversity conservation and the future of agricultural intensification. Biol. Conserv. 151: 53–59.

USDA National Agricultural Statistics Service. 2020. Honey report. USDA National Statistics Service, Beltsville, Maryland.

USDA National Agricultural Statistics Service. 2021. Honey report. USDA National Statistics Service, Beltsville, Maryland.

vanEngelsdorp, D., and M. D. Meixner. 2010. A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. J. Invertebr. Pathol. 103 Suppl: S80-95.

Weis, T. 2010. The accelerating biophysical contradictions of industrial capitalist agriculture. J. Agrar. Chang. 10: 315–341.

Welch, A., F. Drummond, S. Tewari, A. Averill, and J. P. Burand. 2009. Presence and prevalence of viruses in local and migratory honeybees (Apis mellifera) in Massachusetts. Appl. Environ. Microbiol. 75: 7862–7865.

Wells, T., S. Wolf, E. Nicholls, H. Groll, K. S. Lim, S. J. Clark, J. Swain, J. L. Osborne, and A. J. Haughton. 2016. Flight performance of actively foraging honey bees is reduced by a common pathogen. Environ. Microbiol. Rep. 8: 728–737.

Wu-Smart, J., and M. Spivak. 2016. Sub-lethal effects of dietary neonicotinoid insecticide exposure on honey bee queen fecundity and colony development. Sci. Rep. 6: 1–11.

Yarahmadi, P., H. K. Miandare, S. Fayaz, and C. M. A. Caipang. 2016. Increased stocking density causes changes in expression of selected stress- and immune-related genes, humoral innate immune parameters and stress responses of rainbow trout (*Oncorhynchus mykiss*). Fish Shellfish Immunol. 48: 43–53.