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Bitter Honey: A Political Ecology of Honey Bee Declines

Author
Durant, Jennie Lee

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Bitter Honey:
A Political Ecology of Honey Bee Declines in California

By

Jennie Durant

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Committee in charge:

Professor Nancy L. Peluso, Chair
Professor Nathan Sayre
Professor Kathryn De Master
Professor Jon (Jake) Kosek

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Abstract

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This dissertation examines the relationship between commercial beekeepers and the California almond industry to better understand the drivers behind honey bee declines and honey bee (*Apis mellifera*) vulnerability. Much of the current scholarship on honey bee declines addresses ecological drivers such as pesticides, parasites, and disease. Drawing on critical social theory and the tools of political ecology, this work contextualizes these drivers, and demonstrates that federal and state policies, beekeeper and almond industry management practices, and land use change have played important roles in shaping bee health.

Nearly all almond varieties are reliant on honey bee pollination and require approximately two colonies per acre each February. Since the mid-1980s, the almond industry has tripled its acreage from 400,000 acres to 1.2 million acres, and almonds have become one of the top agricultural exports in California. At the same time, beekeepers have struggled with annual colony losses each year as bees have become increasingly vulnerable to parasitic *Varroa* mites, pesticides, and land use changes that reduce floral resources. How have beekeepers been able to pollinate this ever-increasing acreage with a decreasing number of colonies nationwide? And how has honey bee health suffered as a consequence? These are the primary puzzles motivating this research.

I argue that beekeepers were able to pollinate for the almond industry with a diminishing number of colonies for two reasons. First, an increasing percentage of the nation's beekeepers migrated to pollinate almond bloom, and second, beekeepers industrialized bee production to provide larger colonies for almond pollination. In addition, I argue that producing bees industrially for the almond industry, rather than for honey production, has reconfigured the production of honey bees and contributed to honey bee vulnerability.

Bitter Honey is thus a double entendre, with both meanings applicable to the stories told in this dissertation. Materially, it refers to the acrid honey that bees produce during almond bloom, a varietal that beekeepers typically cannot sell. Symbolically, it alludes to the tenuous and at times fraught alliance between the two industries; one where beekeepers struggle to produce an ever-

increasing number of bees in the middle of winter, growers increasingly grumble about the high cost of pollination fees, and bees suffer the consequences of industrialized production for commercial agriculture.

But it is not only the industrial production of bees for almond pollination that contributes to honey bee vulnerability. Bees can also be exposed to acutely and sublethally toxic agrochemicals while in almond orchards. This is in part because EPA pesticide labeling requirements produce ignorance about bee-toxic agrochemicals. I introduce the terms 'regulatory disengagement' and 'ignorance loops' to describe how beekeepers disengage from regulatory processes that document bee kills.

I also build on theories of access and exclusion, to explain how honey bee vulnerability is perpetuated through lost access to forage, in part due to the neonicotinoid insecticides used on corn and soy in the Midwest. I use the term "toxic exclusion" to describe how pesticide use, in particular, excludes bees and beekeepers from the forage they need to produce honey.

Despite the challenges of pollinating for the almond industry, many beekeepers feel an economic imperative to do so as forage for honey production diminishes across the U.S. and cheap honey imports keep the price of honey low. By making honey production increasingly unviable, these trends incentivize beekeepers to shift their operations towards almond pollination, further cementing the U.S. beekeeping industry's dependence on the almond industry.

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Acknowledgements

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Introduction

Figure 0.1: A honey bee on an almond flower.

Overview

In 1982, Matt Thompson's[1] family beekeeping operation was completely different from today—and on the verge of going under. At the time, they ran two thousand hives in Idaho, and their operation was "sedentary" (as opposed to migratory) and entirely oriented around honey production. When November rolled around, they would start prepping their bees for a long Idaho winter. Matt, his dad, and his brothers packed about 30 colonies into a bee yard and placed them on bridge planks[2] so the wooden boxes did not rot on the ground. They tipped each colony just slightly to make sure it was heavy with enough honey to keep the bees alive over winter, and then fed the lighter colonies combs of honey that they had set aside in case the bees needed a bit more food to survive the winter. Matt and his brothers then covered the colonies with straw and then plastic, and then finally with chicken wire. Then they left the bees alone until March, when they unpacked them for their first spring flight.

These were the years before tracheal mites and *Varroa* mites arrived in the United States. They never fed their bees pollen or sugar syrup. They were also not in the business of pollinating almonds—at least, not yet. Beekeeping, they said, was fairly easy then, if not entirely profitable. Losing 10% of their bees each winter was a big loss; average winter losses were closer to 5%. Despite these low winter losses, however, Matt's family struggled to make ends meet. Honey production was declining as agricultural lands around them intensified, and Matt's grandfather and dad were taking out loans each year just to make ends meet.

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[1] All names in this dissertation are pseudonyms, unless an asterisk appears at the end of the name.
[2] Thick pieces of wood placed side by side in a bridge overlay

Matt describes the challenges his family faced as a reflection of the changing landscape, as farms industrialized into monocultures:

> We [experienced] insecticide use after World War II and we've never looked back. But that wasn't the only thing. We saw a lot of fertilizer and herbicides deployed, and we saw farming change from sustainable and diverse farms to very, very profit motivated row crop farming where there are no borders. If there is a low spot, it's [turned into a] field. If there's a high spot, it's leveled. If there's a wet spot it's drained. So, there's no wasteland; there's no opportunity for anything natural to grow that would provide the diversity that is needed for the honey bees' diet. The means of harvest and production are so efficient that they don't allow crops to bloom for long periods of time and insecticides are used to monitor or control pests on those crops. And so even if [bees] are foraging [on flowers], they're likely being affected. So as all of that happened, we saw diminished returns.

Matt's family saw honey production drop from 100 pounds of honey per colony to 30 pounds of honey within a decade or so. At first, it just seemed like a storm they had to weather, but eventually his father went to the farm home administration and took out an agricultural loan to manage cash flow. He did it again the next year and the following, until he was rolling them over each year instead of paying them back. When he was 21, back in the mid-nineties, Matt stepped into the business full time, and had to decide if he wanted to purchase his family's business that was in debt and not making a profit. He felt there were opportunities in the Midwest and California. So, he and his family changed the business model to focus on almonds in California and expand their honey production to a new location in North Dakota.

Nearly forty years later, Matt has taken over the operation of their family business. He now runs over 30,000 honey bee colonies between Idaho and North Dakota for honey production, and into California almonds for almond pollination each year. Matt is one of the largest commercial operators in the country; he employs 30 to 60 full-time and seasonal workers, depending on the season. His crew works hard to combat parasitic *Varroa* mites, by monitoring their colonies for *Varroa* every ten days. His bees overwinter in an insulated converted potato storage warehouse, where he can control humidity, temperature, and the level of CO_2, which helps keep mite populations down. The bees are given sugar syrup and pollen protein patties year-round, including right before winter to help stimulate and "fatten" them, so they are ready for February pollination services. Then they leave the colonies alone until January, when a semi-truck enters the warehouse and the bees are loaded—408 per truck—and shipped out to California for the almond bloom.

It is the almond bloom that now shapes Thompson's entire operation: how the crew manages bees year-round, how they approach colony health, what types of honey bee queens they buy and produce, and how often they are replaced. Beekeepers like Matt who pollinate almonds need bees that are ready to pollinate *en masse* by mid-February, and they have realigned their entire operations to do so. And yet, as Matt details, producing bees for almonds is extremely challenging. It requires a major shift from prioritizing producing bees for summer honey production to producing them for February pollination services. However, Matt admits that this realignment has been good for business in some ways, but it has been a hard road, with negative consequences for honey bee health.

Matt Thompson is part is of the majority of commercial beekeepers who have shifted their beekeeping operations to pollinate almond bloom each year. Out-of-state beekeepers did not always travel to California to pollinate for the almond industry or produce bees to be able to do so, pollination services were largely provided by California beekeepers until the 1970s . In fact, as I demonstrate, transitioning to almond pollination required a sea change in how migratory beekeepers produced their honey bees—a change most felt they had to make if they wanted to keep their operations afloat. It has required a shift from producing honey bees for honey to producing bees for their labor to pollinate almonds by mid-February. This transition is at the heart of this research.

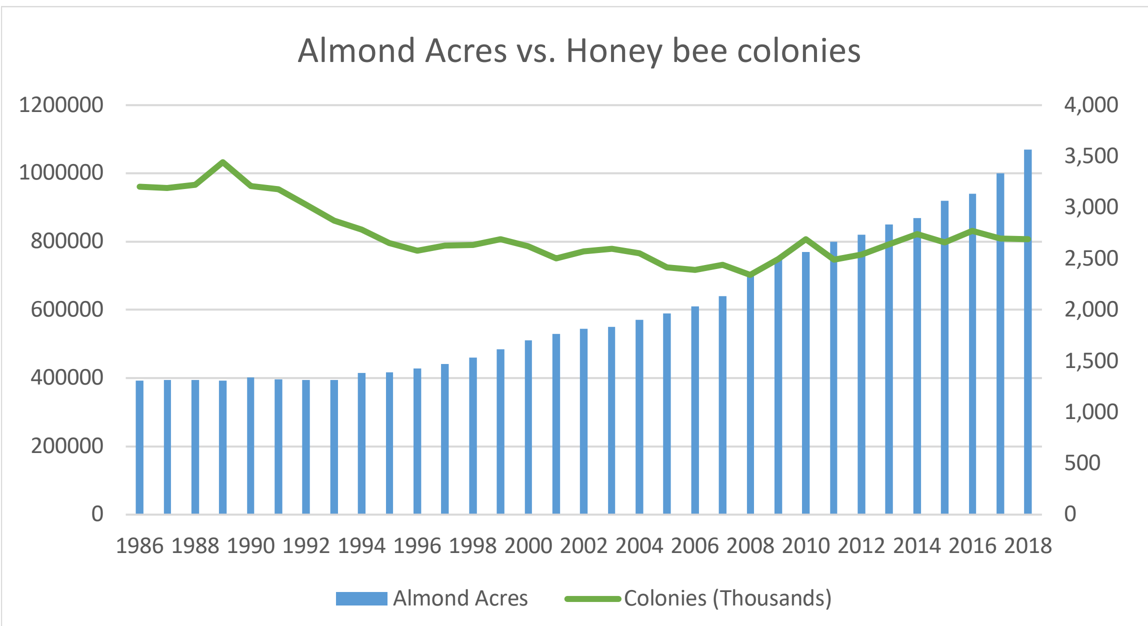

Figure 0.2: Almond acres vs. bee colonies 1986-2018. Data compiled from USDA 2018 Almond Forecast and USDA ERS Honey Production and Trade Data, Table 46

Figure 0.2 illustrates the uneven dynamic between the two industries and underscores one of the primary puzzles at the heart of this research. From 1986 to 2018, U.S. bee colonies declined by over a million, from 3.5 million colonies to 2.5 million by 2018. Meanwhile, bearing almond acreage more than doubled during from around 400,000 acres of bearing almond trees to over one million acres in California. The graph begs the question: how have U.S. commercial beekeepers pollinated an increasing number of almond acres with a decreasing amount of bee colonies? And how has pollinating for the almond industry reconfigured the honey bee and beekeepers' management practices in turn?

In this dissertation, I argue that beekeepers were able to pollinate for the almond industry with a diminishing number of colonies for two reasons. First, an increasing percentage of the nation's beekeepers migrated to pollinate almond bloom, and second, beekeepers industrialized bee production to produce robust colonies in time for almond pollination. In addition, I argue that producing bees industrially for the almond industry, rather than for honey production, has reconfigured the production of honey bees and contributed to honey bee vulnerability.

Bitter Honey is thus a double entendre, and both meanings define the stories told in this dissertation. Materially, it refers to the acrid honey that bees produce during almond bloom, a varietal that beekeepers typically cannot sell, which consequently drives up the pollination fee. Symbolically, it alludes to the tenuous and at times fraught alliances between the two industries, where beekeepers struggle to produce an ever-increasing number of bees in the middle of winter, growers increasingly grumble about the high cost of pollination fees, and bees suffer the consequences of industrialized production for commercial agriculture. This relationship has become deeply entwined as U.S. honey bees and almonds have become co-constitutive over the past several decades, to the point where a majority of U.S. commercial beekeepers migrate to California for almond bloom each year and describe the almond industry as essential to their economic survival.

This dissertation attends, in part, to how production practices have changed in both industries and what has driven beekeepers to pollinate almonds, and growers to convert land into almond production. To understand how the commercial beekeeping and almond industry relationship formed and functioned over the past decades, I conducted participant observation and in-depth, semi-formal interviews with 87 participants: 41 U.S. commercial beekeepers, 23 almond growers and representatives in the California almond industry, 12 state and federal regulators, and 11 researchers and extension specialists who support the beekeeping and almond industries primarily from 2015-2018. I also attended five beekeeping conferences, two almond conferences, and multiple bee club meetings, and had countless informal conversations and follow-up interviews with key informants to understand and frame my findings as they emerged.

This research also traces the political economic processes (such as policies, regulations, and marketing), and ecological factors (such as water availability, land use change, and honey bee and almond reproduction) that played central roles in facilitating the expansion of almond acreage and creating the conditions that incentivized beekeepers to pollinate almond bloom. As such, I also conducted an extensive review of policies that shaped both industries, such as federal marketing orders and pesticide regulations, as well as county pesticide and beekeeper regulations. I conducted a literature review of current and historical research on both industries and their commodities, extending back to the mid-1800s. Finally, I conducted a trend analysis of pesticide and agrochemical use in the almond industry from 1990 to 2016, to understand how pesticide regulations shaped grower pesticide practices. This data helped triangulate interview data and provided a deeper context for the political economic and ecological factors that wove the two industries together over the past several decades. I detail these methods in my Appendix.

Background on the Almond Bloom and Honey bee Vulnerability

Each year, right around Valentine's Day, almond trees (*Prunus dulcis*) begin to blush white and pink throughout California's Central Valley, a giant wave of flowers blossoming south to north as winter fades. This bloom launches the largest managed pollination event in the world (Jabr 2013). Beekeepers from around the nation haul thousands of colonies into orchards on flatbed trucks and semis, an estimated two million colonies in 2018 (NASS 2017)[3]. At the height of bloom at the end of February, when the different varieties' blooms all briefly overlap, one can stand in the middle of an orchard and smell the blossoms' fragrance and hear the hum of bees zipping through the splayed almond branches, gathering nectar and pollen as they cross-pollinate the trees. By the end of bloom, it looks like winter once again; the petals fall, and the ground is blanketed with what looks like snow. The tree branches will typically be barren for at least another week or so until their leaves slowly emerge and tiny nutlets form on the branches where the flowers once grew.

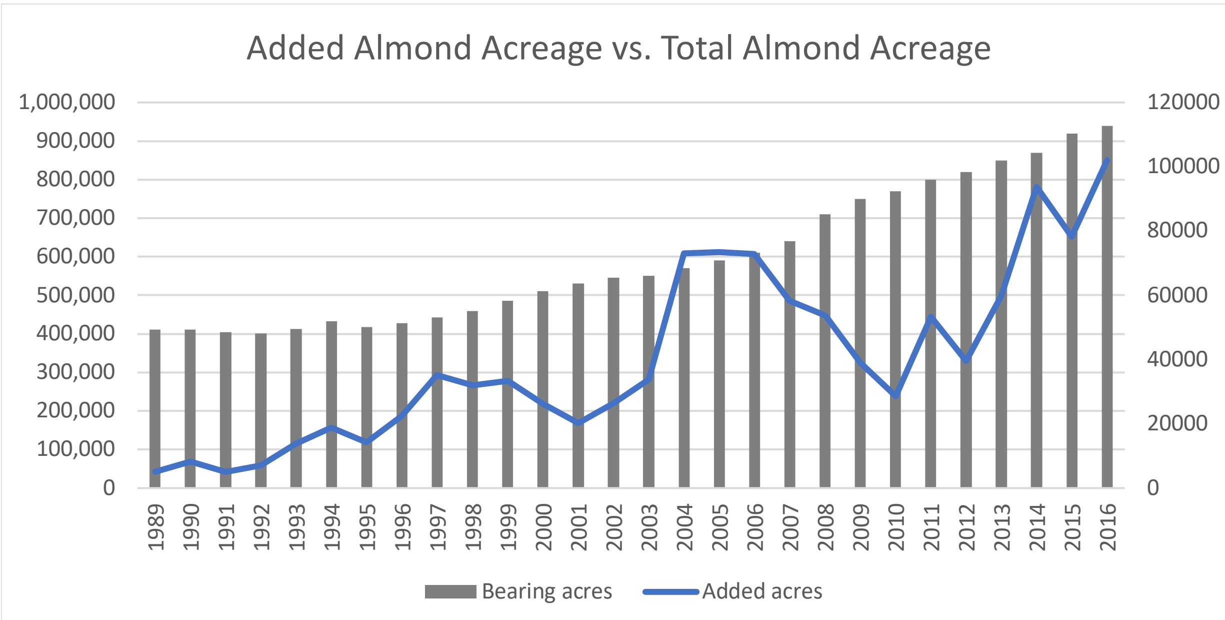

Figure 0.3: Added acres of almonds (line) vs. bearing acres of almond (Data compiled from USDA NASS California Almond Forecast and the 2018 USDA NASS Almond Acreage Report).

The California almond[4] industry grows over 80% of the world's almonds and 99% of the almonds consumed in the United States (Almond Board 2016). The majority of these almond trees are planted in California's Central Valley (USDA-NASS 2018a), with the greatest percentage in San Joaquin Valley, the site of this research. The industry has accomplished this production through continual expansion since the mid-1980s, expanding from around 400,000 planted acres of trees to 1.3 million acres as of 2018 (ibid.). Yet this booming industry has an ecological Achilles heel: almonds are entirely reliant on insect pollination and most varieties require approximately two colonies of managed honey bees per acre (W. Micke 1996).

As almond acreage has expanded, so has the industry's need for honey bees (*Apis melliffera*). As a result, U.S. beekeepers bring over 76% of the nation's approximately 2.8 million honey-producing colonies to the Valley to pollinate almonds February through March (Goodrich and Goodhue 2016; USDA NASS 2018). Commercial beekeepers primarily earn their income

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[3] This assumes two colonies per just over one million colonies of bearing almonds in 2017.
[4] From here forward, I use the term almond industry and almond grower without specifying California because all commercially produced almonds are grown in California.

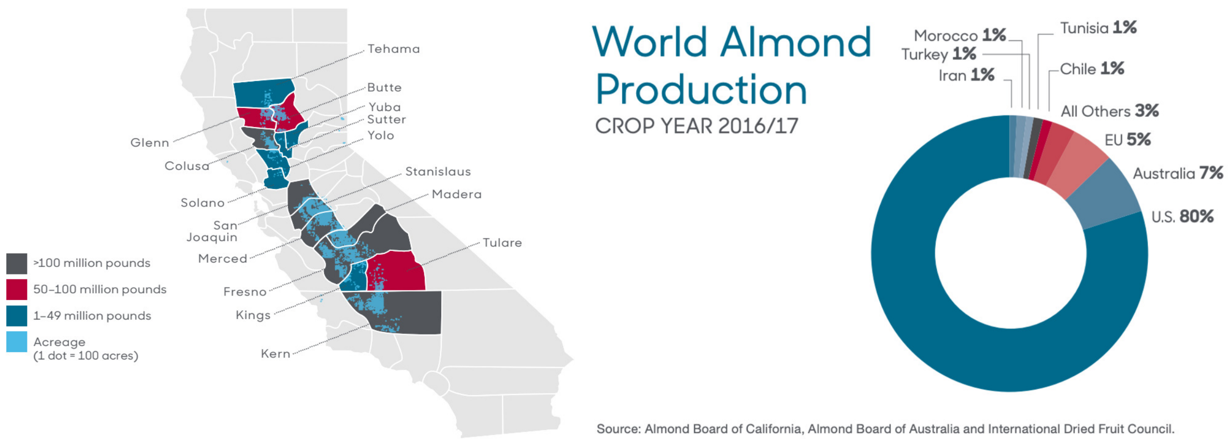


Figure 0.4: Geography of almond acreage in California (left) and global almond production (right). (Source: The Almond Almanac, 2017, p. 7)

through two forms of production, honey production and by providing commercial pollination services for agriculture (H. Lee et al. 2017). Almond pollination now accounts for over 80% of the annual pollination income for beekeepers nationwide (ibid., 2). This has meant that beekeepers are not only relying more on almond pollination than any other pollination income, but also that many beekeepers are relying on almond pollination as much or more than income from honey production as well (Ferrier et al. 2018; H. Lee et al. 2017).

Between 2005 and 2007, pollination fees tripled from an average of $80 a colony in 2005 to approximately $145 per colony in 2007 (H. Lee et al. 2017), an 80% increase over two years. Because growers require at least two colonies per acre, in three years almond growers' pollination expenses went from approximately $160 per acre to $290 an acre—nearly double the cost of an essential input. This spike in pollination fees (see Figure 0.5) has stayed constant enough to warrant the transformation of most U.S. beekeepers' annual operations to have colonies ready for the February bloom—a transformation, I argue, that shifted beekeeper management practices and reconfigured the honey bee in turn.

What drove this enormous spike in pollination fees? And what have the implications been for growers, beekeepers, and honey bees? Agricultural economists have attributed the fee spike to economic supply and demand, with increased almond acreage booming and colony availability low enough to allow beekeepers to demand double the price to come out to California from states as far as the East Coast (Sumner and Boriss 2006). As noted earlier, the overall supply of colonies had declined over fifteen years from 3.4 million colonies in the United States in 1989, to 2.5 million colonies in 2004 (ibid., 10)—so there were simply fewer bees available and supply was lower than it had been in over a decade. The spike then partly reflects the cost to incentivize an East Coast or Midwestern beekeeper to ship their bees out to California, an expensive and logistically complicated process.

It is important to understand, however, why colony numbers were low in the first place, and what drivers incentivized beekeepers from around the country to fulfill the industry's colony demands. In Chapter Three, I detail the factors driving annual colony losses and overall colony decline,

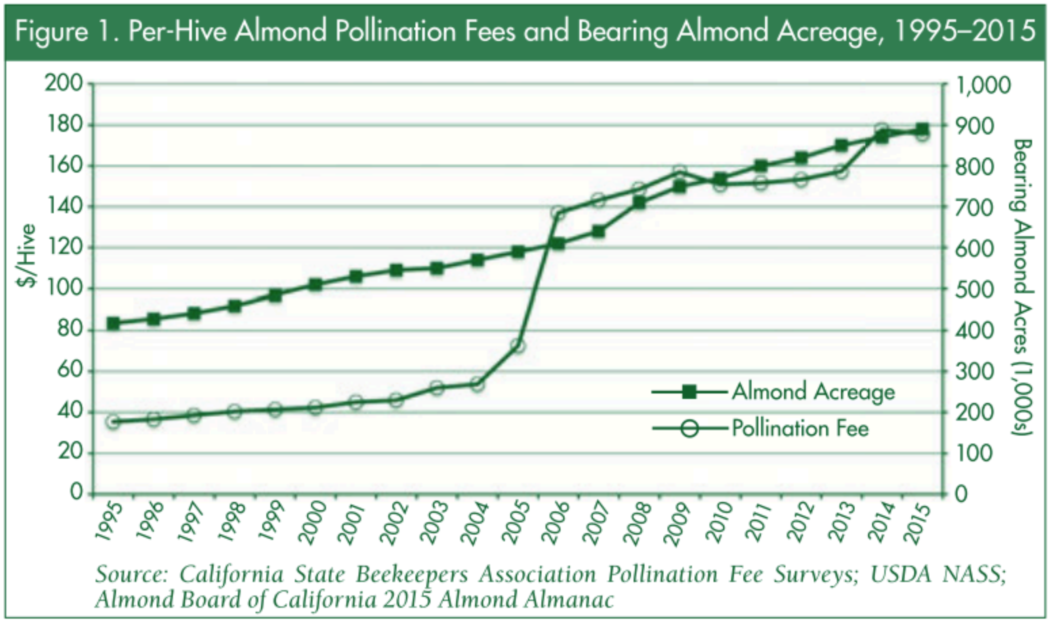


Figure 0.5: Almond pollination fees 1995-2015 (Source: Goodrich and Goodhue, 2016)

and how this provided an economic incentive for beekeepers to head west for the almond industry's early pollination. One of these incentives was a sharp decrease in the honey price from $1.38 in 2003 to $0.90 cents in 2005 (USDA NASS 2006, 2005). This likely lowered the number of bee colonies that beekeepers produced (Sumner and Boriss 2006, 10) and also incentivized beekeepers to pollinate almonds for additional income.

Another factor limiting colony populations was the increasing virulence of the *Varroa destructor* mite, which first appeared in the U.S. in 1987 (R. M. Johnson et al. 2010). A beekeeping survey estimated that winter mortality rates doubled from 15% in 2003/2004 to 29.6% in 2004/2005 due to mite-related losses (Sumner and Boriss 2006, 10). This meant that when many beekeepers opened their colonies in January and early February 2005, they found that nearly 50% of their colonies were dead. As a result, numerous beekeepers were unable to fulfill their pollination contracts to growers in February.

In interviews, beekeepers and bee brokers shared how after they discovered these losses, they made desperate phone calls to beekeepers in the Dakotas, Texas, Florida, and other Southern and Eastern states to get them to ship their colonies to California to meet their contract requirements. One Florida beekeeper described a conversation with a broker who asked him to "name the price" he would need to ship his bees to California almonds (interview, Mar. 22, 2017). The high prices that beekeepers across the country required to ship bees all the way to California in the middle of winter guided the industry's pricing that year—and, as growers often grumbled in interviews, the prices have only increased since. This is largely because high winter losses, *Varroa* mites, inputs, and the cost of shipping have all stayed steady and kept the cost of producing bees for almonds high.

Another factor driving East Coast beekeepers to pollinate almonds in 2006 was citrus growers spraying bee-toxic pyrethroids to ward off citrus greening disease. Florida citrus attracts numerous commercial beekeepers around the same time as almonds, since the bloom also occurs around mid-February through mid-March and (unlike almonds) is a vital honey crop. Citrus greening disease, or HLB[5], is a bacterial disease transmitted by the Asian and African citrus psyllid that requires pyrethroids to address it (UC IPM 2018). On top of the sprays, the citrus industry had also been hit in 2004-2005 by two record-breaking years for hurricane damage, which included the infamous hurricane Katrina in 2005 (Pielke et al. 2008; Albrigo et al. 2005). Beekeepers reliant on citrus honey income were faced with lost profits unless they found another income source; as a result, the almond industry suddenly became a viable option.

In 2007, yet another factor limited bee colony supply and drove almond pollination fees up further. At the end of 2006 and beginning of 2007, colonies started to suffer from what would become known as Colony Collapse Disorder (CCD). The genesis narrative of CCD's arrival in the U.S. goes something like this: in November 2006, beekeeper Dave Hackenberg*, a beekeepers with 40 years of experience, walked into his yard in Florida to inspect his beehives (Benjamin and McCallum 2009, 103). Like many migratory beekeepers, he and his hives spent the summer on the road providing pollination services, and he had just returned from Pennsylvania three weeks earlier with 400 hives in tow (ibid., 104). That afternoon, Hackenberg lit his smoker—a device that uses smoke to calm the bees—and lifted the lid of his hive to puff the cool smoke onto the frames to conduct a bee inspection (ibid., 103). After a few moments he noticed that bees were leaving the hive. When he pulled the lids off to inspect, he saw something highly unusual: nearly the entire colony had vanished (ibid.). The hive was completely empty, save the queen, the brood (bee larvae), and some nurse bees. In fact, he quickly discovered that 360 out of 400 of his previously healthy bee colonies had totally disappeared (ibid.).

CCD was the official name later given to a particular condition that resulted in the rapid loss of a hive's entire adult population: hives and apiaries had few if any bees remaining, and the population usually only consisted of a queen and a few worker bees (VanEngelsdorp et al. 2007). Further, if the bees left honey stores, the honey was often left untouched for weeks by robber bees or other common hive predators such as wax moths and small hive beetles—an otherwise unheard-of occurrence (Stokstad 2007; VanEngelsdorp et al. 2007).

This was not an isolated event (Benjamin and McCallum 2009, 104). As the year progressed, story after story emerged of huge colony disappearances (ibid.). By spring of 2007, almost a quarter of all beekeepers found that their bees had vanished over winter, and in July the USDA officially confirmed that CCD had claimed over a third of the honey bee colonies in the U.S. (Underwood and VanEngelsdorp 2007). It was also not limited to the U.S.; beekeepers in Europe began to report record losses as well (Ratnieks and Carreck 2010).

As the news about CCD spread around the world, reasons for the disease ran the gamut, some more likely, some quite a bit more speculative. Several newspaper articles spurred fears that cell phone radiation confused the bee's navigational abilities, a possibility scientists quickly debunked (Ratnieks and Carreck 2010; Stokstad 2007). As research continued over the following decade, scientists were never able to pinpoint a single cause to CCD's symptoms, and gradually beekeepers stopped experienced the symptoms of CCD losses. They still, however, continued to suffer crippling annual colony losses, typically over winter, but with different symptoms than

[5] Short for *huánglóngbìng*; literally: 'yellow dragon disease'.

those attributed to CCD. However, the majority of beekeepers I interviewed no longer used CCD to describe annual mortalities and instead framed bee health issues in terms of summer and winter colony losses. Following their lead, I draw on the terms 'colony loss' and 'honey bee vulnerability' (Kosek, 2016), to talk about colony loss and declining bee health.

Research has since revealed a complex nexus of factors that shape beekeepers' continued annual losses and increase honey bee vulnerability: agrichemicals and pesticides (R. M. Johnson et al. 2010; C. A. Mullin et al. 2010; Zhu et al. 2014), the parasitic *Varroa destructor* mite and other pests and diseases (DeGrandi-Hoffman et al. 2014), and the decline of diverse, high quality pollen (Di Pasquale et al. 2016, 2013). Beekeepers refer to these as the four P's: Pests and Pathogens, Pesticides, and Poor nutrition. Many commercial beekeepers involved for decades in the industry told me that 20 to 30 years ago, winter losses of 5-10% were considered normal. Now, commercial beekeepers often experience colony losses of nearly 40% of their colonies every year, while stating that losses would need to be under 16.5% to be sustainable (Kulhanek et al. 2017, 334). With these kinds of losses, beekeepers have needed the income from almond pollination to help keep their operations afloat.

Two things become clear from this brief overview. First, a tangle of political economic and socionatural processes created the conditions for both honey bee vulnerability and the interdependency now woven between the two industries. Second, given this interdependency, analyzing the almond and beekeeping industry's relationship is essential to contextualizing some of the drivers of honey bee declines. In this dissertation, I unravel this complex tangle to better understand the linkages between them; particularly the effect that the interdependency between beekeepers and almond growers has had on honey bee health. Guided by the methods and commitments of political ecology, I start by casting my analysis far back into the early history of the two industries, starting from the mid-1800s, when both bees and almonds were first cultivated in California.

Through the chapters that follow, I trace the development of both industries over the following 160 years, as agriculture in the U.S. and California industrialized. Commercial pollination became a necessary input for farmers around the U.S., and almond growers in particular, with the industrialization of monoculture agriculture. Additionally, almond pollination provided an important source of income for beekeepers struggling economically from diminished honey prices and forage for honey production. At the same time, however, beekeepers have exposed their bees to toxic agrochemicals inside and outside the hive and managed their bees industrially to produce bees for almond pollination each year. What becomes clear from this analysis is that while producing bees for almond pollination has become an ecological necessity for growers and an economic lifeline for many beekeepers, it has also contributed to honey bee vulnerability in turn.

Toward a Theory of Honey bee Vulnerability

This dissertation is a political ecology of honey bee declines. Political ecology is cross-disciplinary and as such is not one thing or theory, but rather a shared research agenda among scholars from varied disciplines that share certain basic assumptions, theoretical orientations, and modes of explanation (Watts and Peet 2004; Peet, Robbins, and Watts 2011; Robbins 2012).

Political ecologists formulate accounts of environmental crises that look beyond simplistic, single-cause assessments of environmental conflict and degradation. Instead, political ecologists analyze how history and social and socionatural relations play a role in environmental change.

Political ecology is defined, in part, by a set of common commitments (Bridge, McCarthy, and Perreault 2015). The first is a theoretical commitment to *critical social theory*, specifically 'a post-positivist understanding of nature and production of knowledge about it, which views these as inseparable from social relations of power' (ibid., 7). The second commitment is *methodological*, particularly through in-depth, direct observation or qualitative research (interviews, direct observation, etc.), often in combination with document analysis and quantitative research as well (ibid., 7-8). The third commitment is *political*, a normative commitment to social justice and structural political change: "Political ecologists thus seek not just to explain social and environmental processes, but to construct an alternative understanding of them, with an orientation toward social justice and radical politics" (ibid., 8)—in other words, the point of political ecology is not simply to understand the world it observes, but to play a role in changing it as well (ibid.).

Guided by this set of commitments, this dissertation explores the commodification and industrialized production of two socionatures: one a tree and one a highly mobile insect. Throughout the dissertation I show how the shifting social relations that develop from their commodification and industrialization have shaped the trajectories of the almond and beekeeping industries and led to ecological contradictions and changes.

The following bodies of theory represent debates engaged by political ecologists that help frame and contextualize this dynamic. The first debate focuses on the commodification and production of nature, and capital crises that ensue from this process. The second engages the 'agrarian question' and discusses how nature can act as a barrier and opportunity to capital, and how capital develops unevenly in part as a result of this dynamic. The third focuses on the production of socionatures as nature is subsumed under a capital logic. The fourth draws from literature on new materialisms and explores the role that the materiality of nature plays in shaping environmental change such as honey bee declines and the expansion of the almond industry. The fifth focuses on the production of knowledge, and the role expertise plays in determining what we know about environmental crises and changes—and alternatively, what we remain ignorant about. At the end of each section, I briefly discuss how my dissertation engages with these theories and/or contributes to them in turn.

The Commodification of Nature and Crises of Capital

My research, and this dissertation, start from Polanyi's assertion that nature is a fictitious commodity, and that commodifying nature invariably leads to economic and ecological contradictions and crises (1944). Allowing these fictitious commodities to be subjected to unregulated market forces, Polanyi argued, could destroy the commodity or society as a result (Polanyi 1944, 76–77). As a result of this fictitiousness, the development of modern capitalist economies is thus inherently "fraught with tensions" that arise from two different organizing principles in society with vastly different institutional objectives (ibid., 138). Polanyi termed this a double or dual movement between efforts to govern nature in an unregulated, laissez-faire market, and a secondary movement to protect or conserve it (ibid., 138-139).

In order for capital to impose its economic rationality on the world, nature must be treated by capital as nothing more than a store of potential use values that "can be used directly or indirectly (through technologies) in the production and realization of commodity values." (Harvey 2014, 250). As a result, nature can also be "disrupted and destroyed" to the point where it becomes unusable for capital and crises of capital ensue (ibid., 262).

Marx's first crisis of capital is one of labor overexploitation and subsequent capital *overproduction* that leads to a falling rate of profit. If capital overexploits labor through low wages designed to increase profits, producers cannot sell their products because laborers cannot afford to purchase the commodities they produce (Marx 1981, chap. 13, Vol. III). This leads to a crisis of overproduction and subsequent falling rate of profit, where too many commodities exist on the market and prices must be lowered substantially to sell them. Firms must stave off crises of overproduction through aggressive marketing, constant product innovation, and by supplying credit to consumers (O'Connor 1991, chap. 107; Marx Vol. III).

The "second contradiction" of capital, however, is one of *underproduction* (O'Connor 1998). Because of capitalism's "self-destructive" appropriation and use of labor power, urban infrastructure, space, and the environment (O'Connor 1991, 108), capital tends to underproduce the very materials it needs for its own reproduction. This occurs as capitalist firms "pass on the environmental costs of production to society and the biophysical world" even as they paradoxically rely on the "conditions of production" offered by the biophysical world (Castree 2008, 144). Thus, if left unregulated, capitalist firms will pollute or exhaust their own conditions of production. This leads to a crisis of capital for these firms, but also to ecological crises for capitalist societies as well (ibid.). These crises do not emerge objectively from the "biophysical problems caused by capital accumulation," but instead are dependent on the "type and scale" of the problems in order for them to generate any "real or perceived" crises among the firm itself, the state apparatus, or society more broadly (ibid., pp. 144-145).

Agricultural crises often emerge as a direct or indirect result of the metabolic rift that occurred during the development and expansion of capitalism (Foster 1999). Metabolic rift, the separation of agriculture from its biological base arise when "agronomic methods abandon agriculture's natural biological base, interrupting the recycling of nutrients in and through the soil and water" (McMichael 2008, 15). Before the development of capitalism, agriculture functioned as a closed-loop system where human 'metabolic activity linked society and nature' (Wittman 2009). As land and food became commodities, and the division between town and country and agriculture and industry expanded, and human labor became increasingly disembedded from the ecologies with which they were inextricably linked (Wittman 2009; Foster 1999). This rift violated the basic conditions of sustainability, a fact that became increasingly obvious with the advent of soil fertility depletion, as human and food waste was no longer returned to the soil and farmers required bones and guano to replenish soil fertility (Foster 1999, 383).

The concept of metabolic rift brought attention to the fact that soil fertility was not so much a natural quality of the soil but bound up in social relations between humans and the ecologies in which they were embedded (ibid., 375). Advances in biology, agronomy, and soil science eventually helped 'solve' soil depletion with synthetic fertilizers, a technological fix that supported the second agricultural revolution from the 1830s-1880s (F. M. L. Thompson 1968; Foster 1999, 373). These advances then laid the foundation for a third agricultural revolution in the 20th century with the introduction of machine traction, concentration of animals in massive feedlots, genetic alteration plants and subsequent monocultures, and intensive use of chemical inputs such as more fertilizers and pesticides (Foster 1999, 373–74)—and, I argue, the rise of commercial pollination services as well.

In this dissertation, I argue that the industrialized commodification of almonds and bee labor has led to a series of ecological contradictions resulting in ecological contradictions and crises. I demonstrate that pollination services—like soil fertility—are also bound up in social relations between humans and the ecologies they are embedded within. The 'crisis' of declining honey bees and insect populations thus brings attention to the changing social relations between humans and the landscapes honey bees are reliant on. In Chapter One, I trace the early development of the beekeeping and almond industries and show how the beekeeping industry's current reliance on commercial pollination as a source of income emerged out of the metabolic rift that drove the second and third agricultural revolutions. As agriculture became increasingly monoculture due to inputs such as fertilizers and pesticides, farmers lost access to the natural insect populations that once pollinated their crops. This process happened even earlier in California, an agricultural production system that has been capitalist and largely monoculture from its inception (Walker 2005). Diversified, closed-loop farming systems became dependent on outside inputs for production, particularly the pollination services that managed colonies provided—thus laying the foundation for an economic need for commercial pollinators to fill this gap.

In Chapter Two, I trace the development of the almond industry from the 1950s-2016, and the ecological contradictions that have ensued as it expanded its scale of production, particularly the depletion of ground water the industry requires for its reproduction. In Chapters Three and Four, I attend to two additional contradictions related to honey bees and the almond industry. The first contradiction arises largely because of the almond trees' early bloom period in February. This early bloom, and almond growers' stringent colony strength demands, requires beekeepers to push their bees throughout winter to have large colony numbers ready in time for bloom, which makes bees—whose pollination services the industry requires—more vulnerable. The second contradiction results as growers spray agrochemicals that are toxic to bee larvae during almond bloom; in their attempt to combat fungal issues, growers potentially endanger the large investments they have made in pollination services. This process aligns with O'Connor's second contradiction of capital, as the almond industry pollutes the inputs (honey bee pollination) that it needs for reproduction.

Chapter Five focuses on yet another ecological contradiction and potential crisis of capital that has ensued as a result of land use change in the U.S. from capitalist agriculture. Beekeepers have been driven to pollinate for the almond industry in large part because they can no longer support their operations with honey production because of lost access to forage and cheap honey prices on the market. Drawing on a case in the Midwestern Prairie Pothole Region, where over 40% of all managed U.S. bee colonies travel for honey production in the summer, I show how beekeepers have lost access to land due to the expansion of GMO corn and soy and the federal policies that support its production. Without this vital source of floral diversity, many beekeepers have found it increasingly challenging to maintain their colonies for commercial pollination services, thus endangering future production for bee-dependent agricultural industries—including the almond industry as well.

Nature as Barrier and Opportunity for Capitalist Development

Production processes and crises play a central role in the uneven development of capital in varied sectors. As capital develops unevenly through space and time, some firms, sectors of production, and entire regions remain underdeveloped while capital concentrates in certain regions or sectors (Smith 1982; Harvey 1982). This occurs as capitalism encounters 'barriers within its own nature' that produce new forms of geographical and economic differentiation (Harvey 1982, 416).

Part of the "problem" of nature is not only its fictitiousness and exploitability, but also its ability to act as an impediment to capital circulation, thus contributing to the uneven development of capital. A key point about Marx's conception of capital is that it is "value in motion" (Harvey 2010, 90). Given this, barriers or impediments to this circulation and capital development writ large are ultimately barriers capital will seek to exploit, bypass, or ultimately capitalize.

The question of the barriers that agrarian production poses to capitalism in particular has been explored by Marx, Lenin, Kautsky, and a host of contemporary scholars through the 'agrarian question'. In the late 1800s, Lenin and Kautsky sought to understand the persistence of the peasantry and smallholder farms, despite Marx and Lenin's prediction of the dissolution of the peasantry and the rise of wage labor production in agriculture as the peasantry was largely forced into the proletariat class. Decades later, S. Mann and J. Dickinson extended this analysis further, aiming to identify the barriers that smallholder farms pose to capital penetration, or in other words, why capital 'appears to stop at the farm gate' (Mann and Dickinson 1978, 467). The Mann-Dickinson thesis brought attention to the materiality of certain agricultural commodities over others, by arguing that capitalism is slow to penetrate agricultural systems that have a big gap between production time and when value can be realized, i.e. when the commodity is sold on the market.

Since labor time is where value is created (and since this happens during production), it is in capital's interest to have value-adding labor time maximized, and the "natural processing time" (where no value-adding labor is applied) as short as possible. Some examples of crops with long processing times and short labor times are crops with single harvests such as wheat, soybeans, nuts, and stone fruits (Mann and Dickinson 1978, 473). Capitalism tends to penetrate more quickly in spheres where this turnover time can be reduced, or where production can be highly increased to make up for the high turnover time. When there are commodities where this is not possible, the state will often subsidize that industry (ibid.). Mann and Dickinson also note some of the other key challenges that agriculture poses to capital circulation and penetration, such as the storage of perishable goods, spoilage, and problems of seasonal labor (ibid.).

And yet, while nature may pose barriers to capital, it offers new opportunities for capital penetration as well. The case of California agriculture provides numerous opportunities to see this dynamic at work. Henderson (1999) demonstrates how industrial agriculture developed in California by *exploiting* (rather than circumventing) the obstacles nature posed to industrial production:

> Whereas the centering of agricultural production in nature may impose constraints on capitalist development, the same nature-centered production poses *opportunitie*s for capital precisely because it must circulate and precisely because the disunities of production and working time (necessitated by natural processes) and capital's time in circulation (in part, nature as distance or as space) exist…*Nature is both invitation and barrier to capital.* (Ibid., 32, emphasis added)

Walker also pushes back against debates arguing for supposed barriers to capital penetration in agriculture, by showing how those barriers were bypassed or overcome in California's agriculture by through the mobilization of labor, capital, and technologies, in ways that created new sites and modes of capital accumulation (Walker 2005).

California's massive scale of production has facilitated both its ability and need to overcome these natural barriers. Large-scale monoculture production requires inputs such as pesticides to address the pest pressures that result (Romero 2016). By "chasing economies of scale and scope, we simplify, standardize, and intensify, fabricating novel agroecosystems structured around the production for and realization of value in the market" (ibid., 5). Scale then becomes a powerful determinant of capital's need and ability to mobilize technology, labor, and capital to address the barriers nature poses to industrial production. Guthman's research on organic farming highlights how even under the supposedly more socially and environmentally just auspices of the organic label, scaling up production results in nearly-identical labor and environmental practices as their non-organic counterparts (Guthman 2004).

The scale of agricultural production plays a central role in determining labor relations as well. California agribusiness' need for "an abundance of cheap, skilled, mobile, and temporary labor" drove growers' exploitation of migrant agricultural laborers (McWilliams 1939, 65). Wells' *Strawberry Fields* (1996) and Mitchell's *Lie of the Land* (1996) (1996) illustrate how California's specialty crops have required a particular blend of high capital investment, a large passage of time before production, and subsequent intensive labor at harvest time. This mix has tended to result in exploitative social relationships between growers and their laborers. Mitchell (1996) in particular examines the spatial consequences of these labor relations, and the role they played in shaping California's landscape, as well as how migratory labor has repeatedly been made invisible in the production of California's landscape, a process that elides and allows the exploitation of these laborers.

This dissertation demonstrates how different natures have served as both a barrier and opportunity for capital accumulation in California, particularly as the almond industry expanded in the 1960s and 70s to the point where it needed out of state beekeepers to pollinate its orchards. Chapter Two attends to the numerous ways the almond industry overcame natural barriers to its expansion, by breeding new root stocks that could tolerate California's diversity of soils, and through drilling wells during drought to access the water needed for production, particularly in western Kern County. And yet, we see how overcoming these barriers creates new barriers in turn. For example, Chapter Two shows how drilling wells during drought periods has lowered the water table and is draining the aquafer unsustainably, leading to land subsidence as well. Chapter Four shows how applying pesticides to deal with barriers posed by monoculture production and pests has exacerbated honey bee vulnerability.

Chapter Two, however, traces how certain natural barriers have led to new opportunities for the almond industry's capital accumulation. The rising cost and uncertainty of bee colonies led to the development of self-fertile almond varieties such as the Independence almond, now the third most-planted almond variety since its introduction. Additionally, almond processing inevitably results in chipped and substandard almonds, as well as a mass of bi-products such as almond hulls. I show how the industry overcame these barriers to accumulation by creating new markets for substandard almonds and almond biproducts—and how this supported almond expansion as a result.

In Chapter Three, I demonstrate how beekeepers have had a harder time overcoming the barriers managed bees pose to industrial production. Because almond pollination occurs in February and growers require robust bee colonies for full payment, beekeepers must push their colonies with inputs, manage them intensely for *Varroa* mites, deal with pesticide exposure during almond bloom, and rely on honey bee queens that produce bees prolifically but are more susceptible to the *Varroa* mites that plague the industry. In addition, bees are mobile and require constant new sources of diverse floral resources. Chapter Five demonstrates how this requires beekeepers to be mobile producers and rely on other land owners to provide access to the floral resources they require for honey production. As mobile producers, beekeepers have less political economic leverage and are often at the losing end of regulations that largely support land owners and commodity producers, such as pesticide regulations and farm insurance programs that (largely unintentionally) result in land use practices that exclude bees from the healthy and diverse forage they need for reproduction.

The Production of Socionatures

Because capital is an evolving and working ecological system in which nature is internalized within the circulation and accumulation of capital, nature and capital are constantly being produced and reproduced (Harvey 2014, 246–47). Previously uncommodified resources are continually subsumed into capitalist social relations through the process of "accumulation by dispossession," a process by which wealth and power become centralized in the hands of a few, through the dispossession of public resources such as wealth, land, human labor, and knowledge (Harvey 2003). Accumulation by dispossession highlights capitalism's need to "expand continuously if it is to survive" (Smith 1984, 383):

> To this end, capitalism stalks the earth in search of material resources; nature becomes a universal means of production in the sense that it not only provides the subjects, objects, and instruments of production, but is also in its totality an appendage to the production process. (ibid.)

Smith described the process of nature being produced through capital as the vertical production of nature, where capitalism commodifies nature "all the way down" (Smith 2007). Material resources are a type of "first nature," but once they have been subjected to the labor process and produced or improved for exchange on the market (such as honey bee labor used in pollination, or almonds grown and sold to Blue Diamond), they are transformed into "second natures" (Smith 1984, 381). Although these new natures—bees and almonds, in this example—are still "natural" in that they are subject to non-human forces and processes, these second natures are now also subject to a new set of forces and processes that are social in origin. Examples of this abound, of course, but some include GM seeds (Kloppenburg 1988), Haraway's Oncomouse (Haraway 1997), or, from my own case, the "Independence" almond, a self-fertilizing variety whose name celebrates its autonomy from honey bee pollination. These "improvements" happen in part because nature represents an inherent obstacle to capital circulation and accumulation—seeds reproduce themselves, mice are not cancer-prone enough for oncological research, and almonds require prolific honey bee populations months earlier than a colony has usually developed to that scale. In order for capital to continue circulation, these obstacles must be removed (Smith 2007, 30).

Nature not only acts as an obstacle or opportunity, but also as a surprise, providing "unexpected events, challenges of industrialization, and profit-making opportunities that emerge from their interactions with the biophysical world" (Boyd, Prudham, and Schurman 2001, 556). Capitalist firms typically seek to subordinate all three of these qualities for industrial production (ibid.). Building on Marx's formal and real subsumption of labor, the "formal and real subsumption of nature" highlights the ways that biophysical systems can operate as productive forces (ibid.). The formal subsumption of nature under a capitalist logic occurs *without* the manipulation of nature in such a way that it increases or intensifies biological productivity (i.e. yield, turnover time, metabolism, etc.) (ibid., 564). Mining, oil extraction, commercial fishing, and old growth logging are examples of industries that *extract* natural materials—either biological or nonbiological—and face natural obstacles such as seasonal fluctuations in resource availability and slow growth cycles. However, they are unable to control, intensify, manipulate, or otherwise "improve" upon nature to suit their purposes or increase productivity—which results in nature only being *formally* subsumed by capital (ibid.).

The *real* subsumption of nature occurs often within nature-based industries focused on cultivation, such as beekeepers and almond growers. With the real subsumption of nature:

> The primary vehicle driving [it] is the manipulation of the genetic program, both through traditional breeding programs and, more recently, through the application of new biotechnologies, such as recombinant DNA techniques. The desired result, of course, is higher yields, shorter turnover times, improved disease resistance, etc. *Nature, in short, is (re)made to work harder faster and better.* (Ibid., 564, emphasis added)

The point of drawing a parallel between the subsumption of nature and labor is to highlight the way that competition leads firms to intensify biological growth to increase productivity (ibid., 565), thus making *nature* act as a force of production—such as honey bees transforming into pollinating laborers, or almond trees transforming into self-pollinators such as the fairly recently bred variety, the Independence. It is a way of considering nature not as an obstacle, but instead as a set of living organisms that can "solve problems or make useful products" (Boyd et al. citing Caswell, Fugile, and Klotz 1994, 1). In industries that are able to harness biological growth as a source of increased productivity, capital circulates *through* nature instead of meeting an obstacle (Boyd, Prudham, and Schurman 2001, 566).

As natures are subjected to real subsumption, their bodies are reconstructed and restructured to fit the needs of the industries that produce them and the desires of those that consume their commodities. Livestock production offers a helpful example of this process:

> Increased technological intervention into genetics, feed, and confinement has meant that the animals themselves are being homogenized and altered to fit the needs of consumers wanting cheap meat *and* of producers needing standardized animals to control the feed and keep the slaughter process efficient. (Urbanik 2012, 114)

However, while the real subsumption of nature may allow capital to bypass natural obstacles, this real subsumption can also lead to problematic vulnerabilities that can pose new barriers and opportunities for capital accumulation. For example, while feeding broiler chickens Vitamin D and antibiotics helped breeders raise chickens indoors year-round (Boyd 2001; Watts 2000), indoor production has also made chickens more susceptible to pathogens and raised mortality rates (Boyd and Watts 1997, 207).

The subsumption and production of nature thus highlights how nature is social artefact, a socionature mediated by humans, with different meanings, values, and characteristics depending on the context (Swyngedouw 1999). These elements of nature can only be defined relative to "specific sets of economic, cultural, and technical relations and capacities" (Castree 2001, 13). Put another way, the same "chunk" of nature—such as bees—will have "different physical attributes and implications for societies, depending on how those societies use it"—meaning that social practices determine the physical characteristics and values of nature.

These qualities are not "fixed" (ibid.), but are rather in "constant motion, with many shifting social, environmental, and ideational relationships being constructed and broken apart" (Peluso 2012, 81). Peluso describes socionatures as "Latourian hybrid[s] between cultural conceptions and representations of nature and the actual 'natural objects' and social relationships that they describe" (ibid.). Once commodified, socionatures take on new life, and new practices and social relations develop in response to this transformation (ibid., 83). These socionatures produce new landscapes in turn, consequently creating new spaces and types of environmental degradation, as well as access conflicts, property regimes, and new social relations. As a result, some of these natures require new regimes of access and resource management (Ribot and Peluso 2003).

This dissertation looks at how the commodification of honey bees for pollination labor services has transformed honey bee bodies and led to new production practices and social relations in turn. As I argue in Chapter One and Five, commercial beekeepers have relied on property they do not own for honey bee production since the late 1800s in California, and the early 20th century in the U.S. more broadly. Thus, beekeepers have always had power asymmetries with land owners as they sought to maintain access to the land required to produce honey and healthy bees. However, I argue that producing bees for commercial pollination fundamentally changed beekeepers' social relationships with landowners, as beekeepers transformed from producers who secured access through a gift economy (typically honey), to contracted migratory laborers providing a service for growers through pollination. This supports Peluso's argument that commodified socionatures "take on new life, and new practices and social relations develop in response to" the production of socionatures (Peluso 2012, 83).

To produce bees for almonds, honey bee bodies have become new sites of capital accumulation, and have been made more vulnerable in turn. This happens in part due to the 'real subsumption' of queen bees who are selected and bred to be prolific, 'hygienic' pollinators. In Chapter Three, I show how this shift occurred as beekeepers shifted from valuing bees for honey production to their pollination labor. As a result of this shifting value and subsequent transformation in production, bees are now brought into a context where they are poisoned by agrochemicals (sometimes lethally, sometimes sublethally), fed artificial nectar and pollen, and pushed year-round to produce as many bees as possible. This supports arguments (e.g. Boyd and Watts 1997) that while animals (and insects, I argue) can be produced at an industrial scale, this form of production leads to new vulnerabilities in turn.

The concept and analytic of socionatures also helps explain how the almond's multivalence has supported the creation of new markets around the world. The almond industry sells almonds as products of an aestheticized California, a narrative that elides the labor of beekeepers and exploitation of honey bees. Through varied marketing strategies that each promote a different facet of the almond (i.e. its nutritious qualities or that it is a product of California), the almond industry has been able to secure new markets around the world and help keep almond production lucrative enough that growers continue converting land into almond production. The almond's socionaturality is also clear through the breeding strategies discussed in Chapter Two, where almonds are grafted onto the root stocks of different *Prunus* subspecies to expand its soil compatibility and allow the spread of the almond across the Central Valley.

New Materialism and Unruly (Socio)natures

The social production of nature and socionatures thesis helps explain how capital subsumes and transforms nature through labor processes, positioning resources and environments as political-economic projects (Bakker and Bridge 2006). However, it falls short in its ability to allow for a 'productive or generative role for ecological or biophysical processes' (ibid., 9) in explaining environmental change such as honey bee declines, the expansion of the almond industry, and the way bee honey bee mobility challenges beekeepers' attempts to industrially reproduce bees. In other words, socionatures are construed as the products of a human labor process on nature, not necessarily seen as agents of change in and of themselves.

Political ecologists have drawn from various analytics and modes of analysis to try to address this gap in Marxian analysis, to explain the agency or role of non-human things and beings in accounts of environmental change. Latour's Actor-Network Theory (ANT)— actually not a theory (Law 2009, 142)—was put forth as a descriptive analytical tool to remedy this shortfall, one that seeks to include non-human actors in its explanation of technoscientific narratives and processes (Sismondo 2009, 81). ANT does this by eroding ontological distinctions and undoing dualisms such as human and non-human, social and technical, nature and culture (Law 2009, 147–48). As a result, notions of power are turned on their head. Rather than attributing all power to humans, power is seen as a "shared capacity involving myriad natural actants as much as social ones" (Castree and MacMillan 2001, 214). Power is dispersed, rather than concentrated, a "relational achievement, not a monopolizable capacity radiating from a single center or social system" (ibid.). Instead of being categorized and objectified as a "thing not as an agent," nature and things are imbued with power (Haraway 1988, 592).

ANT has numerous conflicts with the commitments of political ecology and its mode of analysis. ANT tends to flatten or deny society and structural power, leaving out the political economic processes central to political ecology analyses (Lave 2015, 218). ANT underemphasizes the explanation of networks (Castree and MacMillan 2001, 222) by focusing on the descriptive rather than the explanatory, the *how* rather than the *why* (Law 2009, 148), leaving out the vital role that processes of capital accumulation play in shaping society-nature relations (Castree 2003, 123). ANT is also problematic because it assumes that each actor-network is "unique and qualitatively distinct" (Castree and MacMillan 2001, 221). In other words, ANT ignores the cultures and practices particular to the human actors in its accounts, and as a result, the "world of ANT is culturally flat" (Sismondo 2009, 89). ANT also lacks the normative political commitment inherent in political ecology. By insisting on the 'ontological equivalence of nonhuman identities,' ANT does not support the 'emancipatory struggles for human beings suffering oppression' (Lave 2015, 218). As such, Lave argues that ANT and political ecology are ultimately incompatible and grafting one onto the other ultimately weakens each mode of analysis.

Numerus scholars offer analytic alternatives to and/or hybrids of ANT in technoscience analyses and its ability to incorporate hybridity and material agency. Some examples are Haraway's "cyborgs" (1991) and "material-semiotic actors" (1988) and Barad's "agential realism" (Barad 2007). Castree and MacMillan (2001) argue for a 'weak' ANT, which "would remain critical of binarist thinking, of asymmetry, of limited conceptions of agency and of centered conceptions of power" (p. 222).

The field of 'new materialisms' and 'other than human' geographies have emerged as a way to include the role that that materiality plays in constituting social worlds, while still paying attention to the political economic processes that shape environmental change. Bennett argues for a vital materialism in which the agentic capabilities of nonhuman actants transform the field of analysis from a world of "subjects and objects" (e.g. beekeepers laboring on bee colonies, or almond growers harvesting almond trees) to one where "various materialities [are] constantly engaged in a network of relations' (Bennett 2004, 354).

New materialists' engagement and alignment with Marx's historical materialism varies considerably (Cole 2018). Some new materialists see their work as building on Marx's work, particularly his grounding of metaphysical materialism and demonstrated 'entwinement of culture and materiality' (ibid., 170). In these cases, arguing for "thing power" is not the same as "adding spirit to matter," but rather tracing the effect of materiality (Ferguson 2014, 403). Bennett, however, places her 'vital materialism' parallel to historical materialism, where matter is an 'active principle' that also acts as an 'outside or alien power', rather than historical materialism's more exclusive focus on 'structures of human power' (Bennett 2010, 47).

Nature's agency and resistance to commodification and domestication has also been described through the concept of unruliness. "Unruly" environments can be resource frontiers not yet fully governed under the authority of the state because they pose a particular challenge to capital, and even inspire alternative management regimes (Karlsson 2011, 6). Unruly environments are "places difficult to control and categorize," spaces and natures that "remind us of the limits of environmental control in an era of technological and institutional hubris [that serve as a] useful corrosive for the more encrusted categories of nature, society, and agency" (Krishnan, Pastore, and Temple 2015, 5). Nature's unruliness poses a challenge to the domestication and domination inherent in capital development, and constitutes the "edges and seams of imperial space" that challenge capital's purview and traditional property regimes (Tsing 2012). The term encapsulates the challenge nature can pose to certain types of commodification, domination, and management, while allowing nature to be analyzed within a Marxian analysis.

This dissertation investigates the production of two natures, the honey bee and the almond, and argues that their materiality has played a role in determining the expansion of the almond industry, the vulnerability of the honey bee, and social relations between beekeepers and land owners. As a political ecology analysis, social relations between growers and beekeepers, beekeepers and their bees, and the political economic processes that shape their production practices are at the heart of this research, as well as how these dynamics have evolved over time and space. To this extent, I agree with Castree (2003) that analyzing "society-nature relations in abstraction from processes of capital accumulation is to miss a vital aspect of their logic and consequences" (p. 123). At the same time, I also attend to the role that the materiality of bees and almonds play in the development of each industry. These power relations are in no way flattened, but instead I adopt new materialisms analytical approach similar to that articulated by Ferguson (2014), to explain how various actants (bees, water, almonds, pesticides, etc.) have shaped the development of each industry and honey bee vulnerability as well.

In Chapter One and Two, for example, I demonstrate how the almond industry was able to expand in part because of the durability, flavor profile, and nutritional composition of the almond. In addition, I show how the almond trees' materiality as a *Prunus* subspecies allowed for the development of a diversity of new scions (the top part of the tree) and new root stocks (the bottom part of the tree) that could be mixed and matched to support the industry's growth and make the almond compatible with nearly any soil type in the Central Valley.

In Chapter Three, I position honey bees as "unruly natures," and argue that their mobility has made them particularly challenging to industrially produce without subsequently making them more vulnerable. I continue this in Chapter Four where I discuss how the materiality of the pesticide, combined with the mobility and reproduction of the bee, contribute to the production of ignorance about bee-toxic agrochemicals. Finally, in Chapter Five, I add to theories of access and exclusion by exploring how bee mobility is both an opportunity and a barrier to capital. On the one hand, bee mobility is how flowers are pollinated, and why honey bees are commodified in the first place. And yet their mobility can also result in beekeepers losing access to land for production (e.g. if bees are a nuisance) or losing entire bee colonies if bees are exposed to toxic pesticides on neighboring properties, or if they bring sublethally toxic pesticides back to the colony and poison honey bee larvae. The unruly, semi-feral quality of honey bees highlights why beekeepers' access to floral resources is so tenuous, and why beekeepers are particularly vulnerable to enclosures and exclusions from floral resources.

The Social Production of Knowledge

Why is it so challenging to determine what is killing honey bees? This is in large part because, as Haraway notes, "science is about knowledge and power" (Haraway 1991, 43). Scientific research does not present a 'mirror of reality' but is instead embedded in social contexts that produce the practices, norms, conventions, instruments, and discourses that produce what we understand as scientific knowledge (Jasanoff 2004, 3). Discourses are not only important because of their meaning and consequences, but also because understanding how particular discourses came into being helps pinpoint the power dynamics that produced the discourse. In other words, what we know about a thing or a phenomenon is produced, in part, by our understanding of the world, and these understandings of the world are often shaped by institutions and communities in positions of power.

The analytic of co-production helps explain this process, an idiom that uses Foucauldian concepts of power to explain the way that society and technology produce *each other* (Jasanoff 2004). Foucault conceived of power as a "disciplining force dispersed throughout society and implemented by many kinds of institutions" (Jasanoff 2004, 14). Building on Foucault, Jasanoff argues that "science and technology are indispensable to the expression and exercise of power, [and]…operate, in short, as *political* agents" (ibid). Co-production allows us to analyze the ways that knowledge and technology are produced by humans with innate biases, cultures, political agendas, and imperfect understandings of the world. At the same time, science and technological institutions use these productions of knowledge to legitimate and moderate their power over social order. In this way, the analytic of co-production helps trace how power and knowledge are co-constituted rather than seeing either as a unidirectional process.

What types of knowledges and technologies are produced is determined in part by the civic epistemologies of a given context (Jasanoff 2007). Different societies mobilize culturally particular modes of reasoning when making decisions around science and technology, and these modes are constructed by and embedded in different cultural contexts, or civic epistemologies (ibid.). In order to establish public trust, public institutions enroll science "experts" whose role is to "satisfy society's twin needs for knowledge and reassurance under conditions of uncertainty" (ibid. 267). In other words, "experts" are the people whom society deems knowledgeable and credible (though things like Ph.D.'s, publications, affiliations, etc.) to address the many issues and questions that arise in a modern era rife with "shifting facts, untested technologies…and unforeseen environmental externalities" (ibid.).

Yet there is an important difference between "experts" and "expertise." Where expertise is situated and valued is highly contested, and assuming that designated "experts" are in sole possession of this knowledge has political and social consequences (Wynne 1996). Scientific managers can "dismiss local environmental knowledge as politically interested, not objective, and poorly informed" (Robbins 2012, 133). For example, in Yellowstone, ecologists dismiss hunters' ecological models as "barstool biology" and in Ohio, women calling attention to water and air pollution are referred to as "hysterical housewives" (ibid.).

This points to the need to investigate and understand the historical drivers that led to the establishment and institutionalization of particular epistemic forms in those communities (Suryanarayanan and Kleinman 2013, 219). Who gets designated the expert, whose knowledge and accounts are heard, whose accounts are considered "true," and who gets included and excluded from the production of knowledge around dying bees are all questions that help us understand why beekeepers and almond growers have varied experiences of the bee "crisis," and ultimately circle back to questions of power and expertise.

This dissertation is ultimately about environmental change, and how we come to know what we know about nature and the environment and its degradation. In Chapter Two, I discuss how growers expressed little concern about the future availability of managed bee colonies. This stood in stark contrast to many beekeepers describing their challenges in keeping their bees alive and the constant state of crisis they feel their industry is in, highlighting the problematic of expertise in understanding honey bee vulnerability.

In Chapter Four, I highlight conflicts between beekeepers and regulatory agencies over agrochemical bee losses that occur in almond orchards during almond bloom. This kind of "othering" and overall dismissal of beekeepers not only deepens the schism between the expert-lay divide, it also contributes to a "production of ignorance" that (perhaps strategically) makes it more difficult to track and understand how pesticides contribute to honey bee vulnerability. This chapter extends the literature on productions of knowledge by engaging theories on agnotology, and the co-production of ignorance. It explores what happens when stakeholders feel regulations that are supposed to protect them are highly flawed, obtuse and unwieldy, and potentially compromised by corporate interests. I describe how beekeepers stop participating in regulatory processes designed to determine which chemicals are bee-toxic, thus contributing to the production of ignorance about which chemicals are toxic to bee kills. I introduce the concept of an "ignorance loop" to describe the circulation of ignorance produced between stakeholders and the state as stakeholders disengage from epistemological regulatory processes.

Dissertation Overview

This dissertation takes a relational approach to the recent history of beekeeping and almond production, by studying two industries that have become mutually co-constitutive. Both industries are, at present, intertwined with each other and dependent on the other's existence. At the same time, both industries are feeling the growing pains of a rapidly expanding almond industry whose expansion, form of production, and pollinator demand both support the beekeeping industry and threaten the pollinators on which almonds depend.

In this dissertation, I break apart and reassemble the trajectories of each of these industries, investigating their changes in production separately and in relation to one another. I argue for their interdependence and joint responsibility for the recent crisis of honey bee reproduction reflected in honey bee colonies' high annual mortalities. While this is in part an ecological process, I argue that the demands of the almond industry and the historically weak position of beekeepers in protecting their colonies have to be understood in order to deal effectively with honey bee vulnerability and improve the health of honey bees in the long term. This is clearly in the interest of both the beekeeping industry and the almond industry as well.

My intent is not to place blame, but rather to identify how and in what moments the production practices in the two industries have changed, some to deleterious effect, and how there is a need to take a full accounting of the implications of these practices. Despite current efforts to breed self-pollinating trees, the majority of the current almond stock is still pollination dependent. To make my case I use a political ecology approach, looking at the situated histories and relational dynamics of the two industries.

Chapter One: A History of the Almond and Bee Industries from 1800s to 1950

This chapter covers the early history of almond and beekeeping industries in the U.S. and California from the mid 1800s through the 1940s, highlighting key moments in their separate histories that laid the ground for their eventual interdependency. I argue that the almond industry has been dependent on managed pollination since at least the early 1920s, demonstrating that beekeepers have played a central role in almond expansion and increased production for over a century. Second, the two industries have always had distinctly different organizational structures and roles in industrial agriculture, which has shaped their political economic relationship. Almond growers consolidated geographically in California in the late 1800s and have had a strong cooperative guiding grower organization and marketing since the early 1900s. Meanwhile, migratory beekeepers are (and have always been) geographically dispersed and mobile since the 1920s and largely operated as independent producers. This meant that growers were able to affect and benefit from political processes as a consolidated force.

Third, policies and beekeeper preferences at the turn of the 20th century limited the importation of diverse bee subspecies, which helped limit honey bees' genetic diversity and played a role in their current vulnerability. Finally, the chapter traces how beekeeping transitioned from a backyard, smallholder hobby to a commercial honey-producing enterprise. As sugar regained popularity after WWII and agriculture industrialized into monoculture production, bees became valued more for their pollination services than honey production. This set the stage for beekeepers to transition their operations to prioritize commercial pollination as an equal or primary source of income as well.

Chapter Two: Going Nuts—The Expansion of the Almond Industry in California from 1950s to 2017

In this chapter, I analyze the drivers of the almond industry's expansion and increased production. I argue that the industry's marketing efforts and innovations in plant breeding helped the industry rapidly expand during the period but has also led to ecological contradictions that threaten the industry's future growth. In the 1950s, the Almond Board worked in tandem with Blue Diamond Growers Cooperative to establish and maintain domestic and global markets for almonds. By keeping the demand for almonds high, new land conversions and increased almond acreage did not lead to falling profits that could have caused a capital crisis for the industry.

This chapter also discusses other factors that contributed to the expansion of almond acreage across the state. For example, the material qualities of almonds facilitated expanded production and trade; growers were able to mechanize nearly every aspect of harvesting and processing, store almonds long term, and ship them overseas without spoilage. In addition, the California State Water Project supported irrigation for expanded agricultural production in the San Joaquin Valley—the current site of the highest acreage of California almonds. Yet as the industry overcame one natural obstacle after the other to industrialization, they have also created a set of ecological contradictions: increasing pollination fees and limited bee colonies have inspired the production of self-fertile almonds, and the industry's water use has contributed to aquifer depletion and land subsidence that may limit future growth.

Chapter Three: Feedlot Bees/Unruly Bees—The Industrialization of Honey Bee Production

In this chapter, I focus on the industrialization of honey bee production from the 1990s to 2016, and argue that shifting from producing bees for honey, to producing bees for almond pollination has contributed to honey bee vulnerability. While the introduction highlighted several factors that drove out-of-state beekeepers into almond pollination in early 2000s, this chapter details how low honey prices due to cheap honey imports and mite infestations from tracheal and *Varroa* mites both played a role in driving beekeepers to almond pollination.

The chapter then traces changes beekeepers made to their operations to pollinate the almond bloom, such as increasing feed inputs, shipping bees cross-country, treating *Varroa* mites with miticides, and increasing the use of antibiotics in hive. Beekeepers' demands for a prolific honey bee queen for almond pollination, one that breeds a large population of worker bees for February almond pollination, has incentivized queen breeders to produce honey bees more vulnerable to the pest that most plagues the industry. Beekeepers argue that only one honey bee subspecies properly produces enough bees in time for almond pollination, the Italian honey bee, *Apis mellifera ligustica*. Unfortunately, the Italian honey bee is also most susceptible to *Varroa* mites, the industry's prime pest pressure, demonstrating a contradiction of capital where beekeepers have prioritized the species of honey bee that allows them to produce the greatest number of bees, which also makes their honey bees and the beekeeping industry more vulnerable. Drawing from theories of the commodification and production of nature and socionatures, I use the term "unruly nature" to describe how bees are particularly resistant to industrialized production.

Chapter Four: Productions of Ignorance about Bee-toxic Agrochemicals

This chapter examines pesticide labeling and regulation and the role they play in exacerbating honey bee vulnerability. I argue that improper pesticide labeling and limited county investigation processes have produced ignorance about which agrochemicals are bee toxic, and enabled the application of bee-toxic agrochemicals during almond bloom. Though a number of factors influence bee health, beekeepers, researchers, and policymakers cite pesticides as a primary contributor. In the U.S., pesticide registration is overseen by the U.S. Environmental Protection Agency (EPA), with the required tests conducted by chemical companies applying for registration. To date, EPA only requires tests that measure acute toxicity for non-target species (those not targeted by the pesticide), which means that pesticides with sub-lethal or chronic toxicities are not labeled bee-toxic, and farmers can apply them without penalty while bees are on their farms or orchards. In addition, California state and county regulators will typically only investigate a bee kill caused by a *labeled* bee toxic pesticide, so emergent data on non-labeled, sub-lethal pesticides goes uncollected.

These gaps in data collection disincentivize beekeepers from reporting colony losses to regulatory agencies—thus reinforcing ignorance about which chemicals are toxic to bees. I term the cycle of ignorance co-constituted by regulatory shortfalls and beekeepers' regulatory disengagement an 'ignorance loop' and conclude with a discussion of what this dynamic can tell us about the politics of knowledge production about pesticides and the consequences of 'ignorance loops' for stakeholders and the environment.

Chapter Five: Honey Bee Declines and Exclusions from Floral Resources

This chapter considers the social factors that shape beekeepers' lost access to floral resources, and how this drives beekeepers into almond pollination and contributes to honey bee vulnerability and beekeeper precarity. Most large-scale beekeepers in the United States are migratory and depend on access to private land to produce honey and healthy bees—a surprisingly tenuous arrangement for producers who add over $17 billion to U.S. agriculture.

Drawing from three cases in the Midwest—an area central to honey production in the U.S.—I argue that this dynamic places beekeepers in asymmetrical power relationships with both landowners and state entities that tend to favor property owners and farmers over migrant beekeepers. Consequently, land use policies often do not favor beekeepers or honey bees. As beekeepers lose access to forage for honey production and face greater precarity, they increasingly turn to commercial pollination and manufactured pollen inputs—both of which can have negative impacts on honey bee health. I close with a discussion of efforts beekeepers and stakeholders in the almond industry have made to increase access to healthy forage both in almonds and in the Midwest as well.

Together, these five chapters offer an important contribution to both the field of political ecology, debates on honey bee declines; as well as our understanding of the contemporary, vulnerable honey bee. It becomes clear that honey bee vulnerability, beekeeper precarity, and the expansion of the almond industry cannot be understood separately from this highly intertwined relationship. Understanding the contradictions that result from their synergy sheds light on the vulnerability that results when nature is transformed into a productive agent in an industrial system, and highlights the way that socionatures operate as obstacles, opportunities, and surprises in industrial agriculture.

Chapter One: An Early History of the Almond and Bee Industries in California

Introduction

I am sitting across from an almond industry representative, leaning forward, furiously scribbling notes. We have been talking for over three hours about one question, really: What factors contributed to the expansion of the almond industry in California? During our time together in a small café in Fresno, he has woven a riveting narrative that touched on all number of things, but particularly focused on the role that the industry's marketing efforts have played in creating demand for almonds, much of which I discuss further in Chapter Two. We are near the end of our time together, so I ask one of my final questions: What role did bees and beekeepers play in almond expansion?

"Bees?" He sits back, confused. "What do you mean?"

I repeat the question. He shrugs and seems slightly irritated, a marked shift from his energy as we discussed the industry earlier. Beekeepers show up, they pollinate almonds, and then they leave—that is about the extent of their contribution as far as he is concerned.

I heard this sentiment—or something close to it—a number of times when interviewing growers. While the Almond Board has made an extensive effort to talk about the importance of bee pollination and beekeepers on its website and at conferences, this did not translate to growers' reflections on their industry. While the growers and representatives interviewed acknowledged and appreciated the central role that bees and beekeepers play in almond production when asked, all but one grower or representative cited them as a central player in the expansion of the almond industry over the past several decades. This elision is also reflected in historical accounts of the industry. While there are very few extensive published histories of the almond industry, in each of these detailed accounts (Riley 1948; Vaught 1999; Allen 2000), and other shorter accounts (Johnston 2003; W. Micke 1996), there was no reference to beekeepers' role in the development or expansion of the almond industry.

Because bee and beekeeper labor is required for almond production, I consistently found the non-inclusion of beekeepers' contribution to almond expansion puzzling—particularly given that beekeepers are in the same demographics as the growers for whom they work, and are sometimes long-time friends. And yet, the majority of the colonies brought into California, 1.5 million out of nearly 2 million, are brought from out of state by migratory beekeepers. As such, the omission of beekeeper and bee labor to pollinate almonds is embedded in the long historical relationship between California agriculture and its migratory laborers, where their labor in producing California's agricultural landscape is often forgotten, ignored, or made invisible (D. Mitchell 1996).

In this chapter, and in Chapter Three as well, I aim to bring bees and beekeepers' labor and struggles into the narrative of how almond orchards expanded across California's Central Valley. To provide historical context to the chapters that follow, I trace the early histories of both industries from the late 1800s to the 1950s, analyzing them largely as separate strands, while also tying them together at points as their histories intertwine.

I argue that the different organizational structures of the two industries—shaped, in part by the materialities of bees and almonds—helped determine their political economic relationship, their uneven capital development, and their political ecological trajectories (Boyd, Prudham, and Schurman 2001, 556). To demonstrate this, I attend to key moments that occurred in the early development of both industries that played a role in bringing them together in the current almond bloom. I show how changes made to the honey bee hive and U.S. infrastructure helped beekeepers become mobile producers. I highlight research in the early 1900s that verified the necessity of honey bees for fruit and almond pollination and trace the industrialization of agriculture in the U.S. from the 1930s that diminished natural insect populations and created a need for managed bee colonies for food production. What becomes clear is that the seeds for the beekeepers' and almond growers' current interdependence were planted over a century ago.

Almond growers, by producing a tree that could only grow in California's temperate climate, have always been consolidated geographically in California and thus developed a strong grower co-operative, the Growers Exchange, which created new markets and has advocated for grower-friendly state and federal policies since the early 1900s. In contrast, U.S. migratory beekeepers have always been geographically dispersed, and their honey bees and the changing U.S. agricultural landscape have required them to be mobile and increasingly reliant on providing commercial pollination services to farmers for honey producing forage and income. These dynamics have played a central role in the uneven development of the industry's political economies and transformed beekeepers from independent honey producers to migratory laborers and pollination service providers.

Secondly, I argue that the almond industry has been dependent on managed honey bee pollination since at least the early 1920s. Prior to this, nearby managed honey bees and other insects pollinated orchards, but production was low. Since research emerged on honey bees' essential role in almond pollination around the 1920s, beekeepers have played a central role in almond expansion and increased production. I also trace how beekeeping transitioned from small-scale production in the late 1800s to commercial honey-production by the mid-20th century, largely as the result of the queen breeding industry's establishment, the circulation of beekeeping journals, the advent of rail and motor vehicles, the industrialization of agriculture, and finally sugar shortages during two World Wars. After World War II, however, declining honey demand incentivized beekeepers' transition to commercial pollination as a source of income.

The structure of this chapter is as follows. Part One traces the beekeeping industry's early development, paying particular attention to changes beekeepers made to their bee hives that facilitated mobile, large-scale management. From the early 1900s to 1950s, U.S. beekeeping shifted from small-scale production, where bees were valued for the products of bee reproduction (i.e. honey and wax), to a commercial industry at the end of the 1940s, valued primarily for its pollination services. This scaling up of production occurred alongside the industrialization of U.S. agriculture, as farms simplified and transitioned to monoculture agriculture and lost wild insect pollination services. The number of managed colonies hit its peak in World War II due to sugar rationing and the need for substitute sweeteners and beeswax. When sugar rationing ended in 1947, prices and demand for honey dwindled, which incentivized beekeepers to begin supplementing their incomes through commercial pollination in the early 1950s.

Part Two focuses on the almond industry's early history in California and discusses the production and early geography of almond expansion. Research in the late 1800s indicated that almond trees needed cross-pollination to produce nuts, and by 1920, researchers discovered that honey bees were the most effective pollinator to do so. However, though California almonds were an important pollination stop for California-based migratory beekeepers, it did not become a major draw for out-of-state beekeepers until the 1970s and 80s, a process I detail in Chapter Three. During the nascent years of the almond industry's establishment, the California Almond Growers Exchange (which changed its name to Blue Diamond Growers in the 1980s) quelled competition among growers and standardized product quality. The Growers' Exchange played a continual central role in the development of the almond industry, both as an organizing force and a marketing cooperative. Finally, I close with a discussion on these findings and processes, the role they played in transforming beekeepers from producers to migratory contractors, and why this may have contributed to beekeepers' elision from the history of almond production.

Part One: A History of Beekeeping in the United States and California

Designing the modern hive

Nearly all large-scale apiarists in the U.S. have employed the exact same hive for over 150 years, the Langstroth hive, a design that helped beekeeping transition from a backyard endeavor to large-scale production (Crane 1999, 427–29)—and then finally to mobile and industrial production as well.

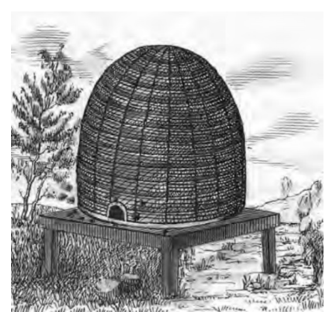


Figure 1.1: A skep beehive (Kritsky, 2010)

Prior to the Langstroth hive, early U.S. beekeepers often kept their bees in "skeps" (Figure 1.1), upside down baskets invented over 2000 years ago where bees could build comb and make honey but had to be killed at the end of the year for the honey harvest (Crane 1999, chap. 31). Beekeepers also kept their colonies in hollowed logs, wooden boxes, pottery vessels, and other containers (Oertel 1980, 2; Crane 1999, 387–98). This posed a challenge to large scale production because it made it difficult for beekeepers to inspect and monitor hives for pests and disease, and it was also impossible to reproduce colonies from one year to the next (Oertel 1980, 3).

Both of these problems stemmed from the hive's design; they were "fixed frame" hives, which meant that the bees built their comb onto the roof of the hive like they would in a bee nest; but similarly to a nest, the comb could only be removed by force and the honey extracted only by crushing the comb (Horn 2005, 66–68). This resulted in more wax, an important commodity for candles and other uses, but also in a lower honey harvest and the death of the colony (ibid.).

Thus, the requirement for the ideal hive was clear: the hive needed to be designed in such a way that the beekeeper could easily inspect the colony and harvest honey without destroying the hive (Kritsky 2010).

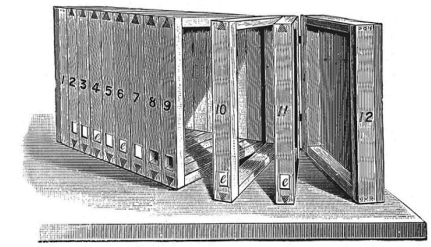


Figure 1.2: Huber's leaf hive design (Kritsky, 2010, 108)

Historian Eva Crane notes that it took two hundred years of "trial and experiment" before beekeepers produced a "satisfactory and effective rational hive" (Crane 1999, 405). Swiss Naturalist François Huber made one of the first successful leaps in hive design, with his "Leaf" or "Book Hive" design, invented in 1789 (ibid.,108). The design was fully moveable, with frames constructed so they could be examined like the pages of a book (Figure 1.2). But there was one problem: the frames were so close to each other that the bees built comb that melded the frames together, so it was nearly impossible to pry the frames apart for examination and harvest without upsetting the colony (ibid., 109).

In 1851, Lorenzo Langstroth—a clergyman, teacher, and apiarist from Philadelphia—discovered that bees will fill any space less than a quarter of an inch wide with sticky resin called propolis, and build excess comb in any space larger than 3/8 of an inch (Horn 2005, 146–53; Crane 1999, 423). The ideal space is now known as "bee space," and every Langstroth hive has its frames interspersed between 5/16 to 3/8 inch to discourage bees from building excess comb (ibid.). This allows for easy frame removal, which means that beekeepers can inspect the hive and harvest honey with minimal damage to the bee colony. Langstroth patented this design in 1852 and several beekeeping historians cite this moment as the birth of the modern age of beekeeping (e.g. Oertel 1980, 3).

The hive (Figure 1.3)[6] is essentially a wooden box with a lid, with eight to ten removable frames inside, topped by two to three shallow boxes with frames. The lowest box or two is termed the brood chamber, because this is where the queen lays the larvae or brood. The boxes above are termed honey supers[7], and usually only contain the hives' honey stores and worker bees. The hive is then protected by an inner cover; this allows moisture to condense without dampening the hives, which would mold the honeycomb. Finally, an outer cover or roof protects the hive from inclement weather.

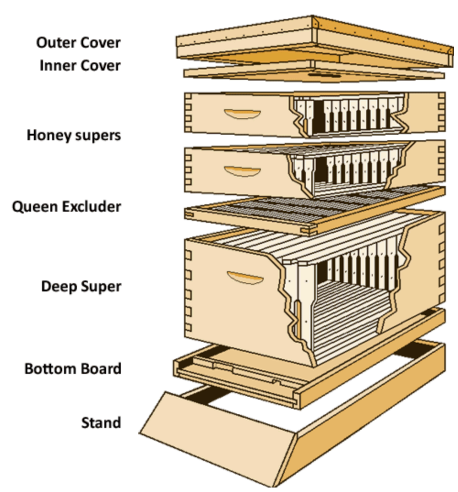


Figure 1.3: The Langstroth Hive (The Old Farmer's Almanac, 2019)

Besides creating a design that allows for easier bee management, beekeepers prefer the Langstroth because of its ability to maximize honey production and "exploit the bees' drive to fill their nests with honey" (Seeley 2010, 31). Though wild honey bees' nesting cavities vary tremendously, biologist Thomas Seeley calculates

[6] Image citation: (Editors 2019)
[7] Short for "super structures," i.e. a structure built on top of another one.

that the honey bees need a nesting cavity able to hold around 18 liters (4 gallons) of honey (ibid.). However, with the much larger nesting space of a Langstroth hive (some 26 gallons of space), beekeepers can take advantage of honey bees' natural drive to fill their nesting cavities with honey—typically more honey than their colony will need to survive winter (ibid.). It is this 'extra' honey that beekeepers historically harvested for their bees, though now—as I show in Chapter Three—beekeepers typically harvest that honey as well and leave bees with nectar and pollen supplements.

In the Langstroth hive, each removable frame is designed to produce the greatest number of worker bees to ensure high honey production. In 1857, German Johannes Mehring invented wax foundation shortly after the Langstroth design was invented and patented (Crane 1999, 458). Subsequently, the Langstroth frames typically had a wax foundation imprinted with a honeycomb cell pattern that guided the size of the brood cells that honey bees build. Drone (male bee) cells are bigger than worker cells, so using wax foundation with worker cells imprinted on it ensured that bees would build worker cell comb on top of the foundation and lay the highest number of productive worker bees. In addition, a screen called a queen excluder placed on top of the first one or two supers restricts the queen to the bottom supers (see Figure 1.3), so she will only lay eggs in the bottom supers. As a result, all the supers on top contain only honey and worker bees and no brood or honey bee larvae. This allows beekeepers to harvest honey from the top supers without fear of injuring the hive's reproduction.

The Langstroth beehive design had a tremendous impact on the political economy of beekeeping, because the beehive's sturdy, easy to stack design was much easier to manage and transport over long distances (Crane 1999, 427). Beekeepers now had an unprecedented ability to transform apiaries into large-scale sources of honey production (Crane 1999, 464). Beekeepers could stack boxes on top of each other, move boxes from one orchard to another, and harvest large enough honey yields that apiarists were soon able to make a living off of honey production alone (ibid.).

The first known commercial beekeeper was Moses Quinby of New York State, whose sole livelihood came from producing honey in the 1860s (Oertel 1980, 5). He and Langstroth were contemporaries and influenced each other's beekeeping practices (Oertel 1980; Nelson 1967). While Langstroth is credited for patenting the modern hive, in 1870 Quinby invented the smoker or bellows (as it was termed then) that is still used today (Figure 1.4) to calm agitated bees with smoke before opening a hive (Nelson 1967; Pellett 1938). This period between the mid-1800s and WWI is often referred to as the "Golden Age of Beekeeping," because of the many inventions and beekeeping contributions made during this time that set the stage for the era of commercial beekeeping in the twentieth century (Watkins 1969; Nelson 1967). In stark contrast to the mechanization of the almond

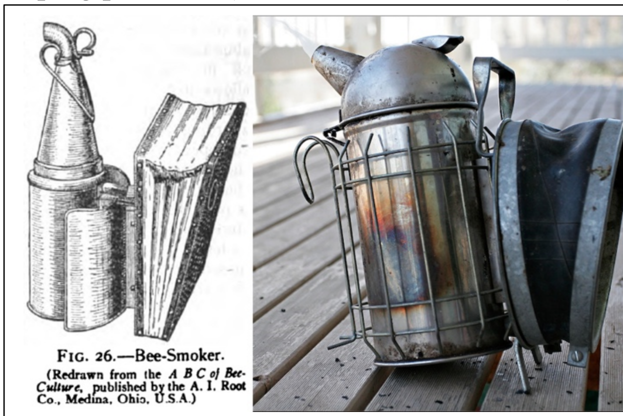


Figure 1.4: Bee smoker in 1911 vs. smoker today (Credit: Wikimedia Commons)

industry discussed in Chapter Two, most of the primary beekeeping equipment is still used by commercial beekeepers today.

Simplifying the bee and the rise of the early queen breeding industry

Not only do most beekeepers employ the same hive, they have also cultivated nearly the same species of bees since the 1860s. Today's commercially managed honey bees (*Apis mellifera*) were brought by European settlers, a product of the Columbian Exchange and early colonization in the United States (Horn 2005). The earliest recorded shipment to North America was to Virginia in 1622 (Oertel 1980, 2). Honey bees were likely transferred in straw skeps (Crane 1999, 355), though these bees were a darker variety often referred to as German or European black or dark bees (*Apis meliffera meliffera*—dark bees moving forward) (Pellett 1938, 32; Oertel 1980, 5).

Bee products were important local trade commodities for the early colonists (Horn 2005, 37; Oertel 1980, 5); wax was used for candles and honey was one of their sole sweeteners (Voorhies, Todd, and Galbraith 1933; Horn 2005). Honey bees also pollinated crops brought from Europe, such as apples (Horn 2005, 24) and later the red clover settlers brought from Europe to feed cattle and help with soil erosion (ibid., 128).

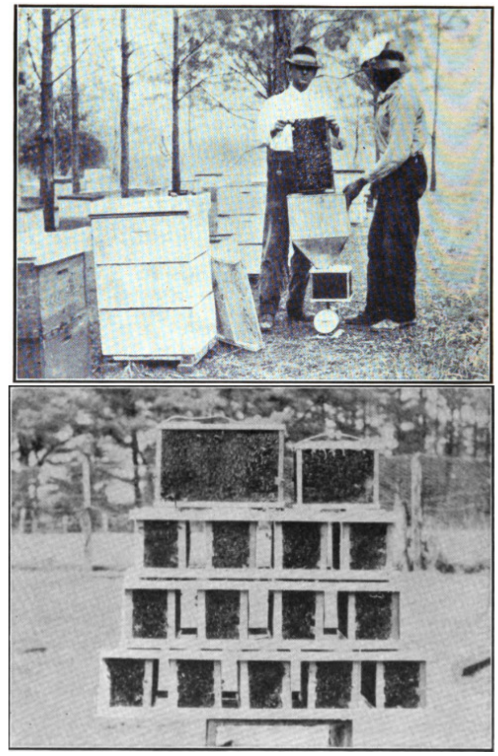


Figure 1.5: Packages of bees prepared for shipment, 1930s. (Source: Pellett, 1938, p. 170-171)

Dark bees (*Apis m. m.*) were the dominant subspecies until the early 1900s (Oertel 1980, 4), when beekeepers began to prefer the Italian bees, *Apis mellifera ligustica (A.m. ligustica),* which originated in Italy and were brought to the U.S. in the early 1860s (Oertel 1980, 4). Only two subspecies of honey bees were cultivated in the U.S. for the next century: *A. m. ligustica,* the Italian bees, followed by *A. m. carnica* from Slovenia, or Carniolan bees often referred to as "Carnies" (Sheppard 2012)—both preferred for their docile natures and heavy surplus honey production (Eckert 1954).

By the 1860s, well-known beekeeping families such as the Langstroths and Dadants (who still sell beekeeping supplies today) were selling Italian queen bees, with records showing Italian queens selling from around $12 to $20 each (Oertel 1980, 4), something close to $600 today (for comparison, the current rate is currently close to $30 for Italian queens from the prime breeders in California). Queen rearing began to develop into a large commercial enterprise in the Southern states, and queen breeders used the preferred Italian variety for breeding (Cobey, Sheppard, and

Tarpy 2016; Schiff and Sheppard 1996). By the end of the 1920s, northern beekeepers had largely replaced their dark bees with the Italian variety by re-queening[8] with Italian queens from the breeders in the south (Schiff and Sheppard 1996). The price had gone down by then to closer to $2 or $3 dollars (Oertel 1980, 4).

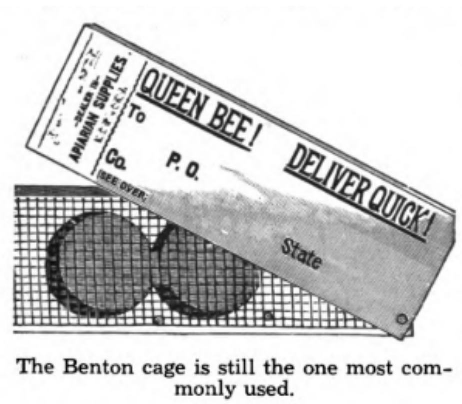


Figure 1.6: The Benton cage, still used to ship queens in 2018, though it now has 3 holes instead of 2. (Source: Pellett, 1938, p. 95)

In a 1938, state apiary inspector and editor of the *American Bee Journal,* Frank C. Pellett described the early queen rearing industry as a "comparatively recent development" (Pellett 1938, 86). In the mid to late 1800s beekeepers experimented with various techniques, developing queen rearing nurseries and new products for large scale queen production. The first honey bee queens were sent by mail as early as 1863 (Pellett 1938, 93). By 1868 Moses Quinby was advertising the shipment of queens short distances by mail (ibid.). The shipments were limited by postal laws, however, which finally changed in March of 1886, when beekeepers successfully lobbied for a new law. Ultimately, the postal law shifted in support for the industry (ibid., 94). Queen breeding and package bees—screened wooden boxes with a small colony of bees and a queen—expanded steadily through WWI.

The success of the industry was aided by the spread of sweet clover in the Plains Region (Pellett 1938, 97), particularly North Dakota, a prolific crop that attracted many beekeepers to produce honey there in the summers (Horn 2005, 165). In fact, Pellet believed that "much of the present day prosperity of the queen breeder is due to the popularity of sweet clover as a farm crop" (Pellett 1938, 97). Eighty years later, many beekeepers would still agree that this is true, as I detail in Chapter Five.

Bee journals connect a geographically dispersed industry

Beekeepers in the U.S. were dispersed far more widely than in Europe, and thus had a harder time meeting to share information on beekeeping practices (Crane 1999, 453). This likely played a role in why journals became a central source of new information on bee culture, more so than local associations or cooperatives in those early years (ibid.). The earliest journal, the *American Bee Journal* was started in 1861 and then taken over by the Dadant beekeeping supply firm in Illinois, which still produces it today (ibid., (Pellett 1938, 124; Crane 1999). A second journal, *Gleanings in Bee Culture* (now *Bee Culture*) was established in 1873 by its first editor A.I. Root, another preeminent beekeeper of that era (Pellett 1938, 129). A number of other journals were established and disappeared throughout the early history of the beekeeping industry as well (Crane 1999), but these two elevated the popularity of beekeeping as a hobby and industry particularly in the northern U.S. after the Civil War was over in 1865 (Horn 2005, 109).

[8] Beekeepers re-queen a colony by adding a queen to a queenless hive or replacing the existing queen with a new one.

Pellett, an editor of the *American Bee Journal*, attributed the rising popularity of beekeeping at the end of the 19th and beginning of the 20th century in part to beekeeping journals. Here he discusses the value of the *American Bee Journal*:

> At the time this first copy of the first bee magazine in English appeared, there were few of the implements now in common use among the beekeepers. Conventions of beemen had not yet been held, a practical smoker had not yet been invented, queen excluders were unknown, comb foundation was still to be perfected, the extractor had not come into use, nor had commercial queen rearing been suggested. Langstroth had invented his hive, but it was not yet in common use. Most of the important events relating to the business of honey production as now practiced have taken place since the birth of this publication. They have been made known to American beekeepers through the medium of its pages, and it has played an important part in the rise of an industry. (1938, 124)

Notably, what made these journals affordable to publish were ads purchased by the nascent queen industry in the U.S., and later ads for packaged bees, beekeeping equipment, etc.—yet another way that the establishment of the queen shipping industry played a central role in the rise of the U.S. beekeeping industry (ibid., 97).

Honey bees recognized as effective pollinating agents for fruit and almonds

By the early 1900s, research began to reveal that honey bees were the most effective pollinating agents for California's fruit and some nuts compared to wind or other pollinating insects (ibid., 264). This was a transformative moment that laid the foundation for honey bees' transformation from honey producers to agricultural pollination laborers.

In an American Bee Journal issue from March 1900, editor George York shared the San Jose *Daily Mercury*'s write-up of a lecture given at Stanford University titled "Bees and Fruit-Growing" (American Bee Journal, 1900, 185). As part of the talk, the lecturing professor explained the rudimentary principles regarding plant pollenization. He explained how some flowers have both pistils and stamens (in other words, they were self-fertile), and how some plants have male and female varieties and required a pollinizing agent to fertilize the flower (a process known as cross-pollination) (ibid.). York quotes the news article below:

> He [the professor, O. P. Jenkins] described the formation of flowers in which the bees operate as pollen-carriers, and showed how bees become useful agents in the work of fertilization, and how thus the plants make use of the bees. "The type of most fruit flowers," said he, "is the same; they have both stamen and petals in the same flower…Contrary to popular belief, the wind cannot fertilize these flowers. It has been known for some time that some varieties of trees do better if they are planted in with other varieties, so that cross-fertilization can take place. *It is this way with the almond*." (ibid., emphasis added)

The lecturer continued to describe experiments conducted by the Department of Agriculture in the cross-pollenization of the pear. Ignorance of cross-pollenization, Jenkins felt, was why many orchards were not productive—they simply were not fertilized (ibid.):

> Of the many insects that visit flowers, some are more adapted for pollen-carriers than others, and the bee is found to be one of the best. From experiments tried it has been found where there are large numbers of fruit trees the bees are insufficient in number many times to do the pollenizing.
>
> "I would think it advisable," said he [Jenkins], "in this valley, where there are so many fruit-trees, for bees to be kept not for their profit [i.e. for honey production], but the more completely to do the work of fertilizing our fruit-flowers." (ibid.)

York (the editor), mentioned a note a beekeeper had sent to him along with the *Daily Mercury* newspaper clipping that stated, "See, we are beginning to get it hammered into them by these learned men—men they must recognize" (ibid.). While the "them" in the note is unclear, one might infer that the beekeeper is referring to fruit growers. If so, then it would indicate that even back in the 1900s, beekeepers had a sense that their bees' value as pollination agents for fruit (and nuts) was not fully recognized.

This knowledge continued to be disseminated by researchers and beekeepers as well. In 1903, the General Manager of the "National Bee-Keeper's [sic] Association", N.E. France, sent out a report to beekeepers to its members titled: "Bees and Horticulture: Their Relations Mutual" about the relations of bees to horticulture and bees as "pollen distributers" (France 1903, 1). In it, the author notes:

> The honey bee as a pollen distributer is perhaps of greater value to this country than the crop of honey produced. It has of late years occurred to scientists that the honey-bee is of more benefit for distributing pollen than all other sources combined. That we are largely indebted to the honey-bee for both quantity and quality of our fine fruits there is but little doubt…
>
> Fruit growers of the present have awakened to the fact that the honeybee is their best friend, and that bee and fruit growing must be closely combined. So it is all along the line of this immense field of labor depending upon the honeybee principally for successful returns. Who could not be a friend to the honeybee, one of nature's gifts to man? (ibid., 1-2)

France detailed new research of bees' role in cross-pollination, particularly for pears and apples (ibid., 3), and reiterates that "the fruit raiser must rely chiefly on honey bees" and that though honey bees may fly two or three miles, the hives need to be within a mile of the orchard for proper pollination (ibid., 4). In a final note, the author—having not mentioned almonds as a bee-dependent crop—does discuss research in Austria on almond, pear, and cherry trees that had borne fruit when their blooming branches were exposed to bees, as opposed to the blossoms that had been covered, which bore no fruit (ibid., 5), suggesting that knowledge about bees' central role in almond pollination was still unclear. It also does not detail what the branches were covered with, but a similar experiment mentioned later in the report stated that blooming branches were covered with cheese cloth to conduct the research (ibid., 8).

Despite this one mention, the report did not further mention almonds. Instead, it largely detailed fruit and vegetable research that demonstrated how bees were likely required for squash pollination (ibid., 5), plums, cherries, pears, red and white clover (a prime honey plant), and apples (ibid., 6). Berries such as gooseberries, raspberries, and strawberries were significantly boosted by pollination, but not entirely dependent on it (ibid., 8).

The report ends with a strongly worded section on "Spraying Fruit Trees" (p. 9) and how bees' increasingly obvious central role to pollination should make growers avoid pesticide application (largely arsenic) while flowers are blooming (ibid.).

> The practice of some unthinking farmers, of spraying trees while in full bloom, is considered by all horticultural schools and by the government experimenters as useless, if not injurious to the bloom, and harmful to the insects which are invaluable assistance [sic] in making fruitful orchards. (Ibid., 9)

A representative from the Division of Entomology from the U.S. Department of Agriculture made the following strong-worded pronouncement on the matter:

> The fact is very apparent that fruit growers are nearly or quite as much interested in the presence of bees as are the beekeepers. Pomologists then may well join hands with the apiarist in demanding and securing a law making it a grave misdemeanor to spray fruit trees while they are in bloom. (Bul. No. 26, Div. of Entomology, U.S. Dept. of Agr.). (Ibid., 11)

These early reports highlight the increasingly important role that bees played in pollination—and the scientific community's knowledge of it and subsequent efforts to communicate this research to fruit growers. Researchers at the University of California's Agricultural Research Stations conducted and then communicated research findings from the early 1900s through 1920s that indicated that honey bees were the most effective pollination agents for a number of fruits grown in California (e.g. Hendrickson 1918; Tufts and Philp 1923; Tufts 1919).

As a result, while some orchardists would keep their own bee colonies, many would rent colonies from a professional beekeeper because "many orchard districts are so specialized that bees find it difficult to collect enough nectar to ward off starvation during the greater part of the year" (Zierer 1932, 264). Migratory beekeepers could earn between $1.50 to $3 for a few weeks of pollination work, increase their colony strength, and produce honey as well (ibid.). I discuss this further as it relates to the almond industry in the next section on the expansion of the almond industry.

Migratory beekeeping in California

Migratory beekeeping had been a key part of California beekeepers' management practices since the late 1800s due to its brief nectar periods, great variations from year to year in nectar secretion by wild plants, long season of blooming plants, and variety of agricultural and climactic conditions (Zierer 1932, 260). Beekeepers hauled hundreds of colonies 20 to 40 miles using four to six horses on special wagons constructed for beekeeping, particularly when sage crops—one of the most valuable honey varietals in southern California—did not produce well (ibid.).

Out-of-state beekeepers also started shipping bees via boat into California from the East Coast and Midwest to over-winter their bees (Watkins 1969). In 1853, Christopher A. Shelton brought the first known hives of dark bees (*Apis meliffera meliffera*) to California (Watkins 1969) (ibid., 239). But it was John Harbison (sometimes referred to as the "Bee King of California") who first established large-scale bee production in California, after he shipped sixty-seven colonies of bees into San Francisco on November 30th, 1857 by boat via the Panama Canal (Watkins 1969, 241). Harbison was another contemporary of Langstroth and Quinby and considered part of the "Golden Age" of beekeeping (ibid., 240). He invented his own movable frame hive that was very popular in California for 25 years until Langstroth's hive took its place, as well as a few other important beekeeping inventions (ibid., 245). By 1875, he was recognized as the world's largest beekeeper and producer of honey (ibid., 245).

Beekeepers started shipping bees by train as well. The first beekeeper to use rail within California was likely John Harbison, who moved his hives from San Diego County into the Sierra Nevada foothills for wild flower honey production in 1876 (Pellett 1938, 113). Another beekeeper, known as Migratory Graham, "boasted" that he had shipped 161 cars of bees in 1918 from Butte County in the northern Central Valley, then down south to Tulare, and then northward to Sacramento county (ibid.).

U.S. beekeeper Nephi Miller was one of the first to ship to California by train from out of state after he made a trip from his home state in Utah out to California to gather information on processing beeswax and noticed California bees pollinating flowers in December (Horn, 148-149). He realized he could send his bees to California to pollinate during winter instead of suffering the usual winter losses in Utah. By 1907, he was sending his bees via rail and began the tradition of out-of-state migratory beekeeping into the state (ibid.).[9]

Other than traveling these short distances, beekeeping was still a fairly local enterprise until WWI, as poor roads and horse-drawn carriages limited the ability of most beekeepers to move their hives over land easily to access new honey producing locations (Oertel 1980, 5), and rail was labor intensive and expensive (Pellett 1938, 113). However, with the increased use of motor vehicles and development of roads, highways, and trucks, beekeepers were able to extend the range and number of their apiaries (Oertel 1980, 5). This increased the viability and attraction of migratory beekeeping in California:

> It was the automobile which made migratory beekeeping really practical. With the perfection of this machine it became possible to load an outfit, move it a long distance, and set it down in the new location within a few hours. Migratory beekeeping became common practice, especially in California, where large areas are devoted to the production of some special crop. (Pellett 1938, 113)

[9] His great-grandson, John Miller, is still a migratory beekeeper along with his sons, and runs one of the larger operations in the nation.

Over 150 species were noted for bee forage in the early 1900s, but only eight principal plants were sources for commercial honey (Zierer 1932, 262). Alfalfa was one of the premier honey crops in California for decades, propagated largely for hay for cattle consumption (ibid.). Beekeepers particularly aimed to find locations where growers were cultivating alfalfa seed, as honey bees could work the flowers until the bloom ended, whereas farmers cultivating hay would harvest the alfalfa before the bloom was over to retain the nutrients for the cattle, which was less desirable for beekeepers (ibid., 269).

As bees' contributions to fruit and nut pollination became increasingly evident and cars provided new mobility, California beekeepers began to transport their colonies around the state. Zierer, in his report on migratory beekeeping in Southern California, described how beekeepers moved their colonies to different orchards for agricultural pollination and honey production, particularly to pear, cherry, and apple orchards (Zierer 1932, 264–65). He notes that in the Central Coast Region "the association between migratory beemen and orchardists is even closer than in Southern California because of the large acreages of fruits and nuts that require insect pollination" (ibid., 265).

Orange honey was (and still is) a highly popular varietal—so much that beekeepers would pay sometimes $15-50 for the use of an apiary site for a few weeks (ibid., 265). Zierer noted that "some migratory beemen winter their colonies along the margins of citrus districts where bees also have access to spring flowers on the foothills and thus avoid making one migration" (ibid.) Cotton fields also began attracting beekeepers in Kern county, and became one of their great honey locations from the 1930s (Zierer 1932, 269) until its decline in the early 2000s.

What is striking about the early accounts of migratory beekeeping is the emphasis on honey production versus the current emphasis on pollination services. In his 1930s article on migratory beekeeping in Southern California, geographer Zierer (1932) writes that "in late winter and early spring the principle task of the migratory beekeeper is to increase the strength of his colonies in order later to produce surplus honey" (ibid., 263). Compare this to the almond-pollinating commercial beekeepers I interviewed, who described how their operation focuses on increasing colony strength (through supplements primarily) during winter, so they have strong numbers of bees for almond pollination in mid-February, a process detailed at length in Chapter Three.

Regulations implemented to protect bee health also limit bee diversity

As beekeeping and bees became increasingly migratory, bees started to spread pests and disease as well. The primary pathogen that defined this era was foulbrood, a highly infectious disease that affects honey bee larvae. European and American foulbrood were both issues, though Italian bees were more resistant to European foulbrood (Vansell 1925, 5; Eckert 1954). Once Italian bees were widely adopted by the U.S. beekeeping industry, American foulbrood eventually became the greater issue plaguing beekeepers for decades to come.

Given the severity of the infection and the ease of transmission, many of the early state and federal bee laws and regulations emerged in response to control the spread of foulbrood and other threats of pests or disease. In 1922, Congress passed a pivotal law known as the Honey Bee Act, which restricted the importation of living adult bees into the United States—only USDA researchers could bring adult bees and sperm into the U.S. for research (Cobey, Sheppard, and Tarpy 2016, 41). The Act was passed to limit the importation of microscopic tracheal mites (*Acarapis woodi*), which were discovered on the Isle of Wight in 1919 (ibid).

While the Act successfully limited the spread of tracheal mite, it simultaneously prevented the continued importation of other global stocks that could diversify the honey bee genetic pool (Cobey, Sheppard, and Tarpy 2016). Prior to the U.S. Honey Bee Act, and partly due to the successful importation of the Italian bees, beekeepers had imported a number of global bee stocks from Egypt (1869), Cyprus and Syria (early 1880s), and another African subspecies *A.m. intermissa* (In 1891) (Cobey, Sheppard, and Tarpy 2016, 42).

Out of 28 distinct subspecies of *Apis meliffera*, seven were introduced to the U.S., and of those only three eventually became attractive to American beekeepers[1] (Cobey, Sheppard, and Tarpy 2016; Sheppard 2012). In short, while the Honey Bee Act prevented the introduction of tracheal mite for decades, it also created a genetic "bottleneck" that, some have argued, may have contributed to present honey bee vulnerability (Cobey, Sheppard, and Tarpy 2016, 42). This has had significant impacts on honey bee health and the viability and genetic strength of bees produced by the commercial queen breeding industry, which I detail at length in Chapter Three.

Two World Wars and the rise of industrial agriculture reshape the beekeeping industry

The two World Wars were a boon for U.S. beekeepers and helped transition beekeepers from small scale to large scale production. In WWI, sugar became more expensive as war efforts cut off established production and sugar import routes to Europe, and by the end of WWI the sugar industry was essentially decimated (USDA 1974, 20). As a result, the Federal Department of Agriculture "began a campaign for increasing the honey crop", creating strong demand for beekeepers and their honey crops (E. F. Phillips 1918, 447). Honey as a sweetener became far more valuable as a result during that period (ibid.).

The price of honey shot up from around five cents a pound to twenty cents or more during the war (ibid.). This was in part because U.S. consumption increased, but also because the U.S. was exporting five to ten million pounds of honey to the front lines for soldiers (ibid). One apiary extension specialist noted how the sugar shortage and increased demand for honey production "wakened an interest in beekeeping," and also hoped that "this interest [would] not lapse when peace is made" (ibid.).

After the war, the beekeeping industry developed and modernized alongside the rest of agriculture from the 1920s until WWII. Commercial honey producers who had expanded their colonies, and subsequently their production, found it increasingly difficult to pack and sell the high volume of honey they produced, so some beekeepers expanded or transitioned their operations and invested in honey packing plants in the 1920s (Oertel 1980, 6).

During WW II, U.S. citizens were again forced to ration their sugar to support war efforts, and honey and beeswax prices soared once more. Japan occupied the Philippines during WWII, cutting off a prime sugar supply from 1941-1947 (USDA 1974, 41), which contributed to a subsequent spike in honey prices. Beeswax also became an essential war-time product; it was used to waterproof canvas tents, belts, and bullet casings, wax down airplanes to cut on fuel expenses, and was a key ingredient in sun creams and camouflage makeup (ibid., 186). During the war, demand for beeswax in the U.S. was double that of domestic production, but a lack of available ships limited both wax supplies (Parker 1944, 193).

In 1942, the Office of Price Administration instituted a formal sugar rationing program, to reduce demand on the existing sugar supply and distribute it equitably, both in the U.S. and also to European allied forces (USDA 1974, 45). In 1946, the U.S. experienced an extreme sugar shortage as newly liberated European regions were re-occupied (by their citizens) and required staples such as supplies of (beet) sugar (USDA 1974, 47–48). This likely also contributed to the high honey prices in 1946 shown in Figure 1.7 (USDA NASS, n.d.).

The high price and demand for honey and wax during both World Wars incentivized beekeepers to expand their colonies, and they did so with assistance from a nascent queen breeding industry developing in the West (in Oregon and California) and the Southern states in California (Horn 2005, 165) (p. 165). Beekeepers were able to purchase package bees (a screened in box of bees with a queen) that they could place in a hive and start a new colony (Pellett 1938, 171). As a result, colony numbers peaked to the highest populations ever seen in U.S. history.

By 1947, however, Cuban shipments of sugar brought sugar and honey prices back down and the U.S. ended sugar rationing programs (USDA 1974). Consumers returned once again to their usual consumption of sugar, and honey demand slumped as a result (ibid.). Figure 1.7 highlights the sharp price drop from 1947 to 1949 as American consumers resumed their sugar consumption and curtailed their honey use. This began a long, remarkable decline in honey income and bee colony numbers (See Figure 1.8) —both of which set the economic stage for commercial beekeepers to transition to providing pollination services for agriculture.

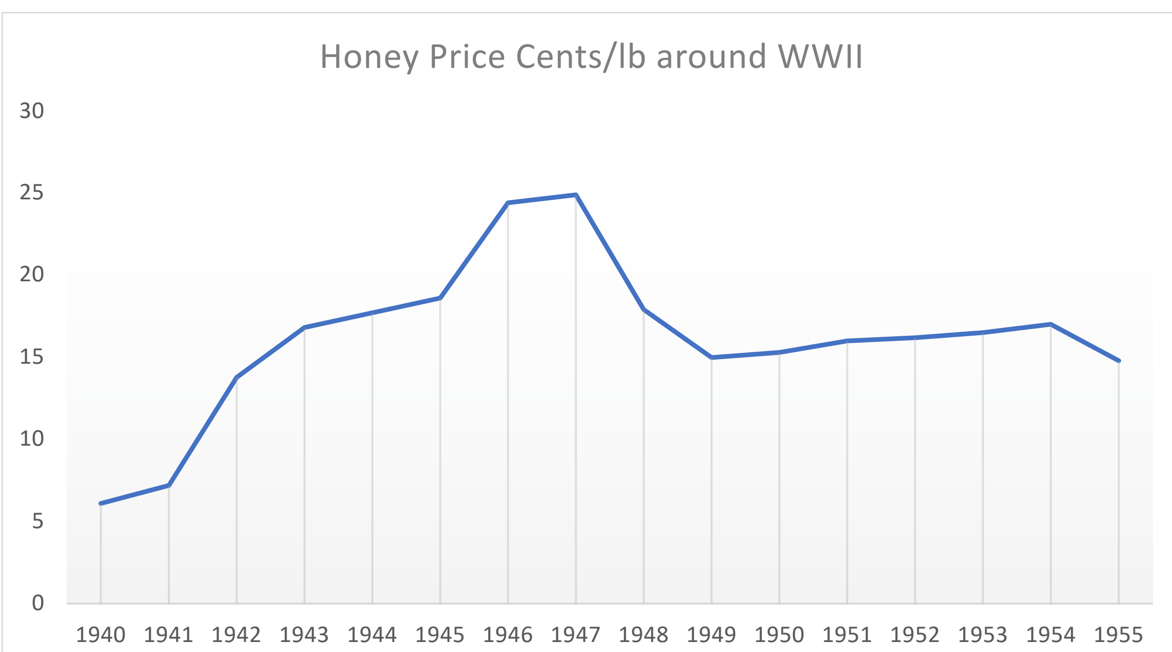


Figure 1.7: Honey prices during and after WWII. Source: USDA NASS Honey Production Database, 1942-1956.

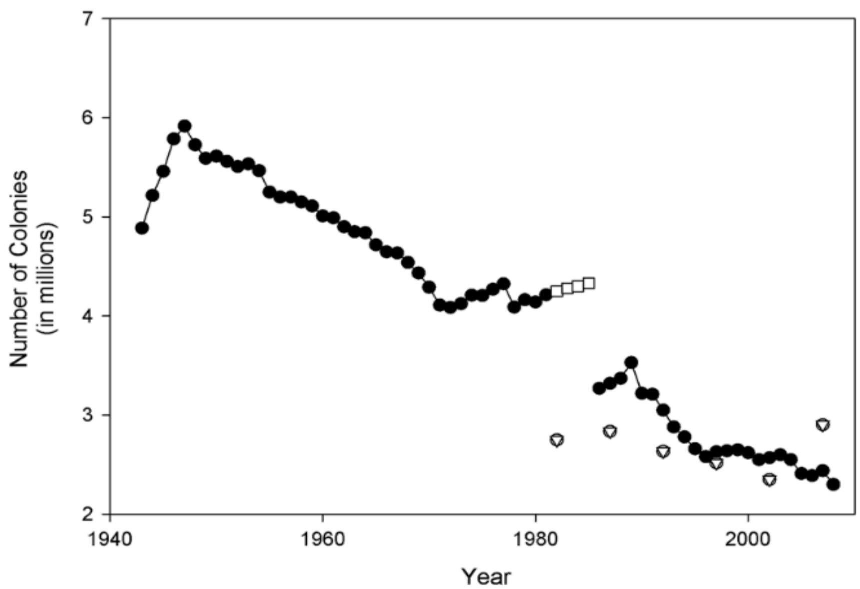


Figure 1.8: Numbers of managed bee colonies in the U.S., 1944-2008. (Adapted from: vanEngelsdorp and Meixner, 2010). See footnote for an explanation of the gap in colony numbers. The data for this figure comes from the USDA's annual Honey reports, and the gap in the dots represents when the survey was discontinued from 1982-1985 and then restarted again. During these years, estimates are provided by the USDA Agricultural Stabilization and Conservation service, represented by hollow squares. The strong dip in numbers reflects the USDA's changing methodology in the Honey report. After 1985, they only collected data from producers with five colonies or more (Champetier de Ribes 2010).

The Rise of the Industrial Farming and Monoculture Agriculture

In addition to the decreased demand for honey, another important process paved the beekeeping industry's path towards commercial pollination: the rise of input-intensive, large-scale monoculture agriculture in the U.S. As agricultural productivity increased through fertilizers and a new suite of agrochemicals (Nimmo 2015, 10; Altieri 1998, 61), farms moved from diversified farming practices—where native insects and feral bees were able to do much of the pollinating (Aizen et al. 2009) to specialized, monoculture production (Altieri 1998). This reduced the diversity of year-round blooming crops, and the new suite of herbicides and pesticides that emerged after WWII played a significant role in reducing plant and insect biodiversity on farm as well (ibid., 61).

The landscape simplification that occurred over the following decades both posed a challenge and created an opportunity for beekeepers. As year-round honey plants on diversified farms diminished, beekeepers had to become migratory to make honey year-round (Horn 2005, 200). At the same time, as farmers lost insect diversity and the subsequent benefit of natural pollinators (Altieri 1998, 64), they needed managed bee colonies to fill that pollination niche (Horn 2005, 200). With increased access to an ever-expanding infrastructure of roads and railways, beekeepers could increasingly transport their colonies to distant locations as their pollination services became more valuable (Zierer 1932).

Beekeeping historian Tammy Horn (2005) describes this process that occurred just after World War II:

> When America redefined its position as a major power in world politics after World War II, the country also had to redefine its relationship with beekeepers. If indeed America would become…the industrial countryside, the country would need beekeepers to provide pollination not just to almond groves, but to pumpkins, blueberries, cucumbers, cherries, and strawberries. When American became a world supplier of food, pollination became a major way for beekeepers to supplement their incomes. (Ibid.)

This meant that beekeepers in other states around the U.S. began to migrate year-round for honey production much like California beekeepers had been doing for several decades given their already highly monoculture, capitalist agricultural system (Walker 2005). However, as figure 1.8 demonstrates, this also meant that beekeepers had to pollinate an ever-expanding industrial agriculture on an ever-decreasing number of colonies. As the next section on the almond industry demonstrates, this contrasts significantly with the ever-expanding acreage and geographic and socio-political consolidation of the early almond industry in California.

Part Two: Almond Expansion from the late 1800s to the 1950s

In contrast to the geographic breadth of commercial beekeeping, almonds were nearly always a California phenomenon. European colonists brought almonds to the U.S. in the 1800s, primarily stocks from southern France called Languedocs (W. Micke 1996). It quickly became clear that in the U.S., almonds only thrived in California, in large part because almonds bloom in February, earlier than most other stone fruits. This meant that almonds needed to be planted in a Mediterranean climate, where it was warm enough for insect pollination during bloom, and also warm enough that frost would not significantly diminish the bloom or developing nutlets (Tufts and Philp 1923, 3).

California growers started planting almonds in the mid-1800s (W. Micke 1996, 1). The earliest orchard on record was in the Sacramento Valley in 1843, and by 1856 trees became available in nurseries (W. Micke 1996, 1). The first commercial planting was undertaken by A.T. Hatch, who planted over 200 acres in Suison Valley (between San Francisco and Sacramento) that he later used to conduct breeding experiments that would transform the industry. Almonds were primarily produced from seedlings during this time, grown on drought-tolerant almond-seedling rootstock and sometimes the root stocks of other fruit varieties, such as the peach, though grafting onto peach stocks at that time sometimes led to decreased production (Wood 1937, 37).

Over time growers and researchers realized that almonds did best in temperate climates, where they would not be exposed to frost (Anderson 1901, 137). Trees were often planted on hillsides without irrigation, similar to how they were cultivated in Europe (W. Micke 1996, 2). Almonds did not seem to do well with fog though, so growers kept their almonds on the hillsides, elevated above the thick fog that settled in the valleys below. As a result, during these first stages of expansion, almonds were planted from Shasta county in the far north all the way to Riverside county in the south, with orchards concentrated primarily in the Sacramento and northern San Joaquin Valleys, as well as San Luis Obispo County (See Figure 1.9) (Wood 1937; Geisseler and Horwath 2016).

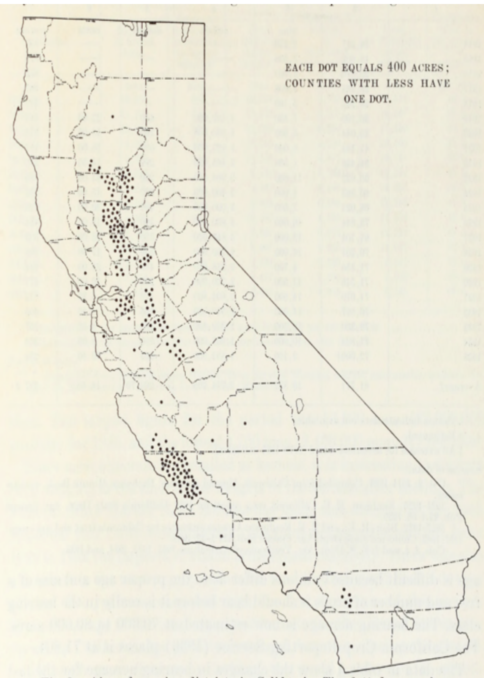


Fig. 3.—Almond-growing districts in California. The dotted areas show the main districts.

Figure 1.9: Almond-growing districts in CA, 1937 (Wood, 1937, p. 5)

The central role of bees and cross-pollination in almond production

The original California varieties were European imports that struggled in large part because growers were unaware of almond trees' need for cross-pollination (e.g. Geisseler and Horwath 2016). A key moment that thus shaped the early development of the industry was Hatch's selection of inter-compatible almond varieties (W. Micke 1996, 1; Tufts and Philp 1923, 3). Hatch reportedly planted over 2500 seedling varieties in 1878-1879 (Wickson 1926), and out of these, selected three varieties that he observed grew well together: Nonpareil, I.X.L., and Ne Plus Ultra—all but the I.X.L. are still planted. Hatch planted these three varieties in various parts of the state, and as the subject of increasing almond productivity gained more attention, he became recognized as an authority and greatly influenced the plantings in the state (Anderson 1901, 137). Another grower, Wilson Treat, selected a fourth popular variety, the Peerless (ibid.), which is also still planted in low numbers (CDFA 2018).

Researchers discovered that most almond varieties were self-sterile by the late 1800s (Anderson 1901, 138), meaning that they were incapable of pollinating themselves and required another variety for pollination. In the early 1900s they also discovered that some varieties were also inter-sterile, in that they could not even pollinate each other (Tufts and Philp 1923). Experiments continued throughout the early 1900s and played a role in which varieties were planted and in what formation on the orchard. Hatch's Nonpareil variety quickly became the industry's premium variety, for their size, taste, and texture (Adams 1927, 33), and remains the industry premium today. The other trees served as pollinizers that fertilized the Nonpareil and produced almonds as well. These varieties thus bloomed before, during, and after Nonpareils to make sure the Nonpareils had maximum pollination, as demonstrated in Figure 1.10.

By 1919, extension specialists began to disseminate research on how growers should arrange their orchard to best take advantage of cross-pollination (Tufts 1919). They encouraged growers to plant the pollenizing variety (e.g. the varieties pollenizing the Nonpareil) methodically throughout the orchard. One extension researcher advises: "For convenience in harvesting, it is best to plant two rows of one kind, then two rows of the pollenizing variety, and so on…or…four rows of the favorite variety and then two rows of the pollinizer, and then repeat" (ibid., 355). This research dissemination greatly helped growers increase their harvests.

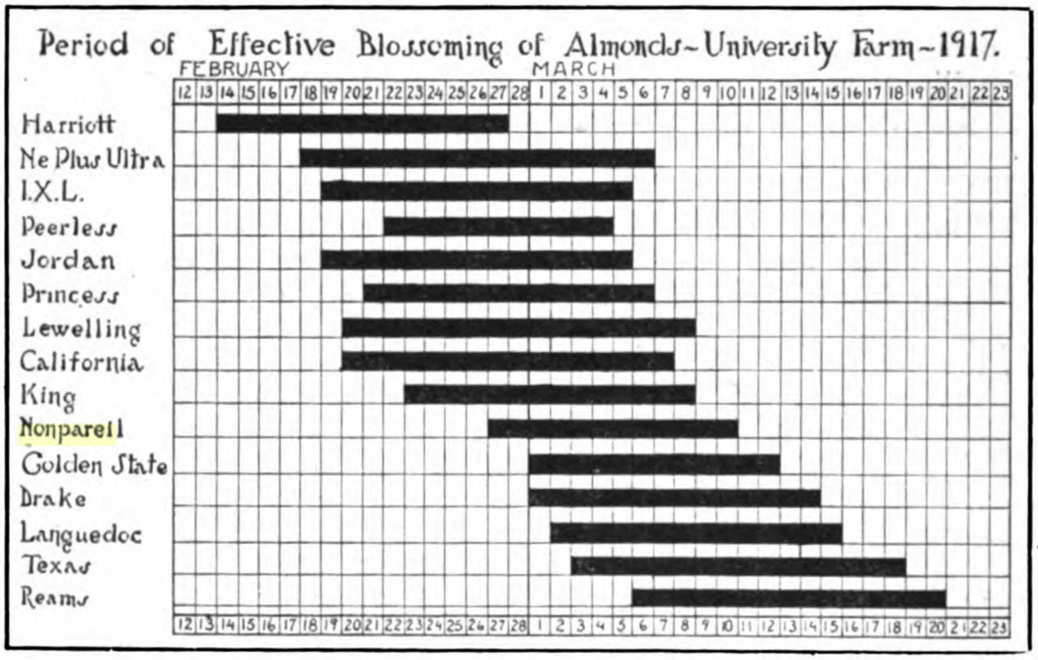


Figure 1.10: Blooming period of almond varieties (Tufts and Philp, 1923, p. 6), Nonpareil (the industry premium) highlighted.

Though growers understood the importance of cross-pollination by the end of the 19th century, they did not fully understand what transferred the pollen, i.e. wind, insects, honey bees, or all of the above. This changed at the turn of the 20th century, as discussed in Part One. Research was also conducted on almonds to determine which pollinizer was the most effective for almond trees. By the early 1900s, it was clear that honey bees were effective pollinizers, but it was not until about 1919 that researchers had concluded that honey bees were definitively the *most* effective of all insect pollinators (Tufts 1919):

> After having planted inter-fertile varieties the orchardist should, by all means, provide an agency for the transfer of pollen from the trees of one variety to those of another. The common honey bee is by far the best carrier of pollen and it will pay the grower to keep bees although he may not care to go into the honey business. Bees, however, are a very profitable side line for the orchardist…*about one hive of bees to an acre of bearing orchard should be provided*. (Tufts 1919, 354, emphasis added)

Tufts advised that growers should scatter the hives throughout the orchard during blooming season and then concludes:

> Experiment and experience have shown that *little reliance can be placed on the efficacy of wind and insects, other than the honey bee*, in effecting the transfer of pollen from tree to tree, or in fact, from flower to flower. (ibid., emphasis added)

U.C. researchers and extension specialists encouraged growers to rent bees from beekeepers to maintain higher yields as early as the mid-1920s, and evidence shows that growers did so. An agricultural extension specialist conducted a broad study of the cost of producing almonds in California, a study that encompassed most of the major almond-growing counties in California (Adams 1927). He observed that "in all districts, pollination was well cared for by the use of interfertile varieties and frequently by the keeping of bees during blossom time, some growers renting hives of bees for this specific purpose" (Adams 1927, 32, emphasis added).

One publication encouraged growers to consider raising their own bees for almond production: "It will pay the grower to keep bees although he may not care to go into the honey business. Bees, however, are a very profitable sideline for the orchardist" (Tufts and Philp, p. 23). However, by 1937, extension researchers acknowledged that most growers "find it inconvenient to keep bees" (Wood 1937). The researcher went on to describe the method many growers used at the time to secure pollination:

> A beekeeper is usually hired to move his colonies into the orchard during the blossoming period. He is commonly paid a certain amount per hive and also gets the honey made from the almond blossoms, which is bitter and can be sold only to the confectionary trade. (Wood 1937, 29, emphasis added)

A 1932 California agricultural extension report titled "The Pollination of Deciduous Fruit Trees by Bees" also noted the relationship between the grower and the beekeeper:

> The fruit grower is usually too busy with orchard problems to become an efficient beekeeper. Bees require considerable attention throughout the year if they are to be strong in numbers at the end of winter. Only strong colonies will prove of much value during early spring… Generally*, the most feasible plan for securing pollinating insects is to rent bees from highly skilled beekeepers*. (Philp and Vansell 1932, 24, emphasis added)

And finally, a 1936 beekeeping publication manual detailed the rental income beekeepers might access by providing pollination services:

> The orchardist and the seed grower, having long realized the value of the honeybee, are usually glad to furnish locations for apiaries in the vicinities of their fields. In many instances, bees are sold or rented solely for pollination purposes during the fruit-blossoming period, and rentals of $1.50 to $3.00 a colony are not unusual. In regions where bees have been seriously injured by spray poisoning, such rentals are generally higher. (Eckert 1936, 5)

These passages demonstrate that managed honey bees were considered essential for almond production as early as the 1920s, and that growers were encouraged to have one colony per acre of almonds. They also suggest that almond growers rented honey bees and paid beekeepers for pollination by the 1930s, given the challenges of maintaining a bee colony on a monoculture farm with few floral resources to sustain a colony year-round.

This data contributes to historical research on beekeepers' role as paid pollination service providers. Leading bee historian Eva Crane writes that the first beekeepers paid for pollination services were in Denmark, sometimes in the 1930s, and that by the 1940s beekeepers in other countries were taking payments for crop pollination services as well (Crane 1999, 476). However, as I demonstrate here, beekeepers were being paid to pollinate almonds at least a decade earlier than Crane's research asserts.

Lastly, these findings underscore a key reason that growers would have paid beekeepers rather than the other way around: almond honey is bitter and has a very small market for resale. As mentioned in Part One, beekeepers typically only paid citrus growers because the honey was such a high value (Zierer 1932, 265). This emphasizes why beekeepers have historically (and currently) get paid substantially more for almond pollination services than any by other industry dependent on honey bee pollination (USDA 2017).

Almond Production in the early 20th Century

Despite the importance of this newfound research into how cross-pollination worked, almond bloom occupied only one month out of an entire year of production tasks and was also the one that took the least effort for the grower compared to the rest of the year's production tasks for the early almond industry. Interestingly, given that little about the culture of almonds has changed, the tasks remain largely the same today, though they are now highly mechanized and use very little labor. The details on almond production below provide context on growers' other annual tasks, and also provide an important contrast to how mechanized almond production became in the decades that followed.

Fig. 11.—Harvesting almonds by knocking onto sheets spread on ground.

Figure 1.11: Poling almonds at harvest. (Source: Taylor and Philp, p. 29)

By the 1920s and 30s, almond production was still fairly human-labor intensive, though significantly less than so than other stone fruits or table grapes (Vaught 1999, 64). The red spider mite and peach moth were their most problematic pests, but growers were able to control them by spraying homemade sulfur solutions (ibid.). If pests were kept under control, and the grower had sited and spaced the trees properly, then almonds tended to "bear heavily and regularly" without many complications (ibid.).

Almond harvest, however, still required somewhat intensive physical labor to harvest the nuts off the trees and remove the hulls. Harvest typically took (and takes) place August through October—a period that growers still consider their busiest and most stressful. To knock the nuts off the trees, growers and their crews used 16 to 20 foot wooden or bamboo poles during harvest (Figure 1.11), which ran from August through October (though farther south could start as early as mid-July) (Taylor and Philp 1925). Growers caught the almonds on 2 large canvas sheets, usually 12 x 24 feet wide, which were spread under trees side by side to catch the almonds (Adams 1927, 31; Taylor and Philp 1925, 30). They used a combination of sleds and horses and human labor to haul the sheets from one tree to another, though some were able to mount almond sheets on wheels (Figure 1.12) (Adams 1927; Taylor and Philp 1925). After harvest, growers would gather all the nuts into a long box (typically 20-24' long and 3-4' wide) which was built on wheels or runners and then it was either sacked, boxed, or dragged to the hullers, where the almonds would be removed from their hull and sometimes their shells as well (Adams 1927, 31–32). This harvest process remained fairly consistent until the mid-1900s (Vaught 1999).

Fig. 12.—Portable almond sheets mounted on wheels as used by N. J. Lund, Oakdale, California, 1916.

Figure 1.12: Catching almonds on horse-drawn sheets. (Source: Taylor and Philp, 1925, p. 30)

By the mid to late 1920s, some growers still did their own hulling, but by the mid-1930s most growers only did their own hulling for very small plots (Wood 1937, 87). Many took their almonds to a receiving warehouse managed by the California Grower's Almond Exchange (Blue Diamond's earlier iteration) or to a private buyer (Adams 1927). One of the earliest hullers was designed and used as early as 1880 (Wood 1937, 87); it was a fan that blew the nuts against a wall to knock off the hulls (ibid., 88).

Large machines were later built that used an elaborate system of screens to separate the nuts from the hulls, leaves, twigs, stones, and other debris (ibid., 88). These machines still required hand labor, and careful attention to the machine: if the machine ran too fast, the almonds could get "broken and injured", too slow and many nuts would not be hulled (ibid., 89). Growers discovered that if the almonds hung on the trees too long and were not harvested quickly, the hulls became dry and leathery, making it more difficult to hull the nut. Certain nut varieties were also easier to hull than others, the Peerless, I.X.L., California, and Ne Plus Ultra were easy to hull, while the Nonpareil and other 'soft-shell' varieties were difficult to hull without breaking the shells, but much easier to shell by hand (ibid., 89).

Immediately after the hulling, nuts were sorted and left in the sun to dry in shallow fruit trays, almond-drying trays, or large bins—the latter of which required regular shoveling and turning to dry out the almonds. Once dry, the nuts were bagged up for sorting and then, depending on the variety, bleaching. Consumers at the time preferred almonds to have a "bright, golden-yellow shell", so in-shell almonds were sprayed with water to moisten the shell and then exposed to sulfur fumes for 10 to 30 minutes—processors took great care to not over bleach, as the shell could get "sickly yellow or whitish" and the kernel deteriorate and "taste soapy" (ibid., 89-92). After the bleaching and drying, kernels were then graded by hand (Figure 1.13), a process that developed in 1925 out of a partnership with the USDA and California Almond Growers' Exchange, as well as other firms (ibid. 92). During the grading process, inferior nuts were separated into classes (first through fourth grade designations), and then graded within each class from high to low quality.

Things like stained or cracked shells, width and thickness of kernel, and insect damage could all play a role in the grading process. Growers had their nuts "test-graded", where a smaller, representative portion of their delivery was tested so growers could receive an accurate value for their product (ibid., 93). After the grading, bleaching, and drying processes were complete, almonds were either shelled or sacked in burlap bags about three times the size of a grain sack. When the bags were filled they weighed between 80 to 130 lbs., depending on the variety (ibid., 96). Then the almonds were shipped off to buyers for further processing or wholesale retail.

Fig. 44.—Sorting unshelled almonds. Since the inferior nuts are removed from the best ones as they pass over the belts, a fine grade of nuts is assured. (Courtesy California Almond Growers' Exchange.)

Figure 1.13: Sorting and grading almonds. (Source: Wood, 1937, p. 91)

In the 1920s through the 1930s the demand for almonds was primarily for in-shell nuts purchased during the holiday season (Wood 1937, 22). This was one reason the Nonpareil became so popular; it was a 'soft shell' variety that was fairly easy to crack open by hand. Besides shelled almonds, there were a variety of other almond products. Salted almonds were quite popular and sold for $1.50 to $2 a pound; sellers made sure to keep the "choicest varieties both as to appearance and flavor…for the salted almond trade" (Sievers and Ribak, p. 2). Some other popular almond products were almond butter (ibid., 3) "a new product considered worthy of flavor by the public," and "almond confection", a combination of ground roasted kernels, confectioner's sugar, salt, and water or oil mixed to a paste (ibid., 4). Other popular products were almond paste and almond flour for macaroons, a popular desert at the time (Wood, 1937, p. 24).

For all of these products—in-shell, shelled, and processed almonds—a key concern arose in the early 1900s: the challenge of creating consistency in almond product quality. For example, California's specialty crops, particularly peaches, were being shipped by train cross country, but some of these crops were unripe low-quality fruit that "should never have been permitted to leave California" (Vaught 1999, 108). This became a source of embarrassment for California growers and the agricultural industry writ large (ibid., 109) and provided motivation for the grower cooperatives that began to emerge throughout the fruit and nut industries.

The establishment of the Almond Grower's Exchange

As California fruit and nut growers began competing with U.S. and European markets, they realized they had to cooperate with other growers in their industry to have an edge up on these markets. A committee of fruit growers and shippers met in November 1909 and drew up a formal set of rules for packing the region's prominent fruit crops: peaches, cherries, plums, apricots, and pears (Vaught 1999, 109). They determined that shipping boxes had to be uniform in size and reinforced, and that fruit had to be uniform, graded by size, and consist only of "fully matured and carefully picked" fruit. They then hired a 'corps of independent inspectors' to oversee these specifications. By the end of 1920, standardization and cooperation within the California fruit industry had become its own movement, and as trust built up in the fruit industries, buyers began to pay sometimes double the previous year's price for peaches and plums (ibid., 109).

The burgeoning almond industry was going through a similar process as almond growers began to see the value of cooperating rather than competing with one another on the market to create a standardized product and garner a higher price. Growers established nine associations around the state, and each asserted the superiority of their product (ibid., 110). However, competition among these associations actually benefited wholesale buyers the most, as they played various grower associations off one another in a bid for the most competitive price. For example, from 1898 to 1909, most growers received 8 to 10 cents a pound, occasionally netting up to 14 cents. Almonds grown on the retail market, however, went for closer to 30 cents (ibid.).

Observing these trends, a novice grower, John P. Dargitz, began to visit the various associations and argue for the creation of a central body composed of their nine different associations. Historian Vaught noted that "Dargitz's evangelical tone and 'practical sense' proved especially effective on the heels of a 1908 bumper crop whose proceeds barely covered production costs" (ibid., 111). On May 6, 1910, the representatives gathered from each association and incorporated into the California Almond Growers' Exchange (the Exchange), a co-op that would later become the Blue Diamond Growers Exchange.

Initially, The Exchange emphasized the importance of locality; each sack that shipped had the name of the local association as well as the cooperative, and each association served on the board of directors to help guide the selling of the almond crop, so growers did not have to (ibid., 111). However, Exchange officials also quickly realized that the market was becoming centralized and that their approach might need to be centralized as well. They hired a sales manager, Thaddeus Tucker, who quickly became the general manager of the Exchange and guided sales for the co-op's next 25 years (ibid., 112). Every spring and summer, he toured the eastern buyers to determine the "most willing price" buyers would pay, and in the summer, he surveyed growers to estimate the upcoming crop to set the price (ibid., 112-113). From 1910 to 1914, almond acreage tripled from 11,000 to 35,000 acres, while membership grew from 230 to 900 members. The co-op controlled over 80% of the state's total almond crop (ibid.). In short, the Exchange was a nearly instant success, allowing growers to retain a sense of community, receive a fair price, "all without involving themselves directly 'in the business'" (ibid., 113).

World War I also gave a boost to the Exchange and the almond industry more broadly. Until 1915, European and California growers had nearly entirely separate markets; California growers supplied over 95% of its crop in the shell and nearly 85% of Europe's imports were shelled almond meats (ibid.,163). This was due in part to the popularity of the Jordan almond, a variety that California growers had struggled to cultivate (Wood 1937, 25). In addition, its hard shell had to be cracked by hand, which could be accomplished in Europe with cheaper labor costs (ibid.).

With the onset of WWI, however, Europe experienced a decline in fruit and almond exports (Rowley 1914). The Exchange took advantage of this opportunity to increase their share of the shelled market. They sent investigators to Spain to study European shelling methods, and then built a shelling plant near its central warehouse in Sacramento in 1915 to shell Nonpareils (Vaught 1999, 163). Though the Nonpareil was considered an inferior almond at the time, eventually confectioners and other buyers transitioned to the Nonpareil and established the beginnings of the shelled almond market for California growers, the bedrock of almond growth from the 1950s onward.

In one of the few early histories of the almond industry, one scholar analyzes the period of expansion from 1850-1934 and concludes that the most important agency in the almond industry's early establishment and expansion was the California Almond Growers Exchange (Riley 1948):

> This co-operative has been instrumental in placing the California almond on the national market. Furthermore, it has raised the price for the grower and has tended to stabilize the market. The association has made remarkable progress in the shelled almond market since 1926 by its development of its own process of shelling as well as by the actual marketing of these shelled nuts. (ibid., 125).

She also notes a number of efforts the Exchange made to solidify the industry. First of all, they established increased membership throughout the state (ibid.). They successfully "led the battle' for reduced transportation rates for almonds shipping eastward to compete in East Coast markets, when the government (who owned the railroads in 1919) hiked up shipping rates in the 1920s (ibid., 127). The Exchange also advocated for a tariff that protected almond growers from cheaper European almond imports in the early 1900s (ibid.). These activities highlight how central the Exchange was to supporting almond expansion in its early development. It continued to play a central role in the expansion of almond acreage moving forward, as discussed in Chapter Two.

Factors that facilitated the Expansion of Almond Acreage from 1900 to 1950

The University of California's *Almond Production Manual* (1996)[10] labels four different periods for the development of the almond industry, which are helpful when thinking about how to understand these important early decades in the industry (see Figure 1.14). The authors term the period from the mid-1800s until the early 1900s the 'Introduction stage', and then from 1900-1925 the 'Development stage'. From 1915 to 1935 almond growers' average yields remained stable at around 210 pounds/acre of shelled almonds (Geisseler and Horwath 2016). However, once growers began to widely adopt irrigation, yields and acreage began to increase. For example, in 1914, bearing acreage was listed as 14,947 acres, but by 1935—just a few years after irrigation became more widely adopted by growers—acreage had expanded nearly five-fold to 72,000 acres (Wood 1937, 6). Growers were able to produce an average of 337 pounds per acre during that same period (ibid.).

Between 1920 to 1950, a number of factors fueled industry growth. In addition to the Exchange's efforts to market and advocate for growers, researchers and growers discovered a number of important production factors. For example, almond trees preferred "fertile, deep, well-drained

[10] This manual is still the industry standard for almond production, written and edited by U.C. Division of Agriculture and Natural Resources.

soil" and also responded well to irrigation and fertilization (W. Micke 1996, 2). This meant that yields were "doubled and tripled over yields in marginal, non-irrigated conditions" (ibid.).

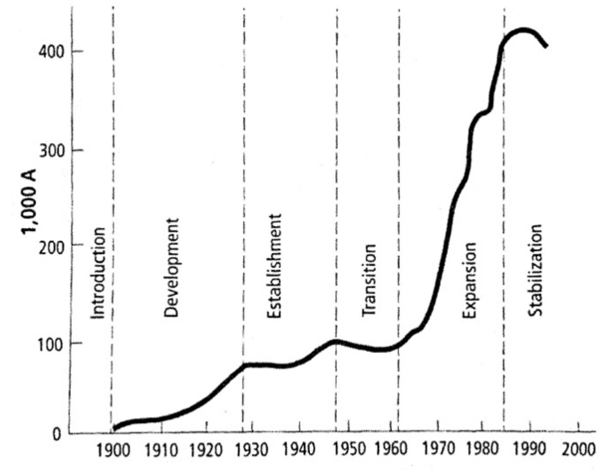


Figure 1.1 California almond acreage planting trends since 1850.

Figure 1.14: Stages of almond expansion since 1900 (Source: Micke, 1996, 2)

Similar to beekeepers, growers also increased their production during World War I as European imports decreased, and more orchards were planted (Riley 1948, 100). After the war, growers advocated and obtained an increased tariff that protected their almond crop against foreign imports (ibid., 101). Their demands were based largely on the difference in cost of producing almonds in the Mediterranean versus California. The cost of producing unshelled almonds in California, for example, was 14.3 cents per pound of almonds, while in Europe, it was 3.6 cents per pound of almonds (ibid., 104). Eventually growers, led in large part by the Exchange, were successful and the tariff was increased (ibid., 111).

These discoveries and processes—in addition to the provision of managed bees by California beekeepers—led to a period of stable growth from the 1930s through the 1950s, solidly establishing almonds as an agricultural stronghold in California. By 1950, almond acreage had grown to nearly 100,000 acres, where it held steady until the next wave of expansion in the mid-1960s (Geisseler and Horwath 2016), which I discuss in Chapter Two.

Discussion

In Frank Pellett's *History of Beekeeping* (1938), he opens with a reflection on the changes in the industry that occurred during the period covered in this chapter. His one-page introduction not only summarizes the major transformation the beekeeping industry underwent from the late 1800s to the mid 20th century, it also highlights a key difference in the development of the beekeeping and almond industries during this period.

On the cusp of another World War full of dramatic changes for the beekeeping industry, but not cognizant of it yet, Pellett noted how the period following World War I had transformed the industry, with its emphasis on the production and marketing of honey. During this time, beekeeping largely transitioned from "an interesting diversion, as it long had been" (Pellett 1938, vii). Instead, thanks to the high prices beekeepers witnessed in WWI (and again in WW II), "expansion became the rule, and the rank and file of beemen [sic] became honey producers rather than beekeepers of old" (ibid.). Then he waxes a bit more poetic:

> One thing is very clear; we have abandoned the old paths. The old-time beekeeper was something of a naturalist, interested primarily in the behavior of his bees. The beekeeper is now a business man interested primarily in the sale of enough honey to maintain the present standard of living and give his family the things that the new generation demands. (Pellett 1938, vii–viii)

This passage helps set up one of the major contrasts between the beekeeping and almond industries: most almond growers were in almonds as a commodity crop from the beginning, while beekeeping really transitioned from small-scale commodity production and a semi-naturalist pastime to a commercial industry focused on larger-scale honey production by the 1950s. This is partly a difference dictated by husbandry; beekeepers tend living insects, while almond growers grow trees. Yet this chapter made clear how the materiality of different socionatures played a central role in the development of the two industries and landscapes as well.

What Pellett could not quite predict at the time was how the metabolic rift (Foster 1999; Marx 1981) that occurred from the 1920s-1950s as farms across the U.S. industrialized, would subsequently create a growing need for bee pollination services, as feral and native insect pollination became less available (Aizen et al. 2009; Altieri 1998). Shifting from honey production to commercial pollination comes with a different set of risks and—perhaps more importantly—a new set of social relations for beekeepers, as they move from honey producers to hired contractors providing a service for an increasingly industrialized agricultural system. In this process, bees also transition from insects producing a commodity to *commodities themselves*, (non-human) laborers whose pollination services provide a key input to commodity production. This dynamic, particularly in California, shifted beekeepers' power dynamic with growers from that of equals as primary producers, to that of contracted migratory laborers subject to a wage labor relation.

While these social relations between beekeepers and growers were and are nothing like what traditional migrant laborers might have faced in California, it does set up beekeepers (and bees) to have their role in almond production diminished or made invisible, like migratory laborers in California (D. Mitchell 1996). In a commercial pollination social relation, bee pollination simply becomes another input, like nitrogen or pesticides. This might help explain interviewed growers and industry representatives rarely cited the central role that the beekeeping industry played in supporting its own expansion across the Central Valley.

Conclusion

This chapter traced the parallel histories of the early almond and U.S. beekeeping industries from the 1850s to 1950s, as well as the intertwined histories of the California beekeeping and almond industries during that same era. Beekeepers and managed bees played an essential role in almond expansion, despite their relative invisibility in published and narrated[11] histories of the industry. Knowledge about bees' essential role was established by the 1920s, and extension specialists encouraged almond growers to supply at least one colony of bees per acre of almonds. By the

[11] By growers and industry representatives.

1930s, evidence indicates that beekeepers were paid from $1-3 per colony for their pollination services, indicating that managed bees have played a central role in almond pollination and the expansion of the industry for over a hundred years.

This chapter also attended to how the different materialities of almonds and bees shaped their early political economies. An almond is a hard nut on a tree fixed in space, consolidated in one watershed (the Central Valley). While orchard production comes with its own set of issues, such as a long turnaround time (Mann and Dickinson 1978), the early almond industry also *benefitted* from some key material limitations that the almond imposed. For one, its finicky growing needs consolidated almond production not only to California, but specifically the Central Valley and a few locations along the coast. It thus became easier to form geographic cooperatives that could disperse the costs of processing labor, as well as investments in fixed capital for hulling and shelling. Growers were also able to organize under a common, standardized commodity brand to counter the pressures of European imports. Finally, while their harvest labor needs were high, they were nothing like that of fruit growers in the state. Almonds would dry out if left for too long on the tree, but they would typically not rot if harvested correctly. The industry was thus able to organize and expand production, and then increase their market presence, as a result of the almond's materiality.

Compare that to the nascent beekeeping industry in the United States. Because of the geographic needs bees have for forage, beekeepers were and are dispersed throughout the country, making it harder to form co-operatives to organize labor and disperse the costs of machinery that could help beekeepers industrialize. Instead, the early industry was defined less by cooperatives than by innovative beekeeping entrepreneurs who pushed beekeeping equipment technologies and management practices forward. The dispersal of this information came through publications, most notably *The American Bee Journal* and *Gleanings in Bee Culture*, still highly active and relevant publications today. This dispersal has made it more challenging to form any kind of national or regional brand, and more importantly, to have a standardized product for the market, either honey or pollination services. This is one thing that growers often complained to me about in interviews: the huge variety from beekeeper to beekeeper of the quality of their colonies.

Yet despite the fact that beekeepers are dispersed, the industry relies on queen and bee package industries that interconnect them and also make it easier to spread pests and disease. This fear of pathogen spread led to the Honey Bee Act, which barred the importation of bees into the U.S., but subsequently also limited the importation of new and diverse bee species, thus setting the stage for future honey bee vulnerability. In addition, beekeepers became more mobile as roads, trains, and trucks enabled them to access new forage sites and pollination contracts, but it also made it easier to spread the same pests and disease. In Chapter Three, we see how this became particularly problematic as almond acreage, and subsequently colony density, increased.

These various processes led to shifting social relations between beekeepers and almond growers (as well as other commercial agriculture industries) and established the conditions for the social asymmetries that continue to define beekeepers' relationships with growers and farmers. In Chapters Three through Five, I show how these social relations have emerged largely from beekeepers' transition from producer to contractor/laborers that add value to agricultural commodities.

Chapter Two: Going Nuts—The Expansion of the Almond Industry from 1950-2016

Figure 2.1: An oil pumpjack towers over almond fields in Kern County (photo by Sarah Craig, used with permission)

Introduction

At the annual Almond Board Conference in 2017, a group of marketing sessions took place in a side room adjacent to the main conference hall. The session's topic was how to market to global consumers, and the presenters opened their talk with a discussion on Chinese markets. How could the industry better target Chinese consumers to increase market demand? They shared a slide that overviewed their current marketing message: "The California [almond] gives you a taste of California sunshine that helps your skin look luminous and radiant, glowing from the inside out." They then showed a video of their latest advertising campaign.

The lights in the room darkened. Cheery music began to play as a female voice narrated in Chinese. On screen, an Asian woman in a blue sun dress walked through a restaurant. Her hair flowed down her back, her skin and smile radiant. A man watched her walk by, gaping, until his girlfriend scowled and smacked him on the shoulder. The woman continued walking, now through an intersection. Another woman sat in her car and saw her walk by, grabbed her compact, and frantically pat face powder on her nose. The woman in the blue dress then walked on the beach, wind lifting her hair, face luminous. Five muscular Caucasian surfers walked past her and stared, heads turning as she passed them by.

The woman stopped. She pulled out a small tin full of almonds. She placed one in her mouth as the sun silhouetted her profile. In the next scene, almonds overflowed into her outstretched hands and then we cut back to the woman, who raised her arms in celebration and turned in a joyful circle in an almond orchard. The video delivered every aspect of the message the Almond Board was trying to send: almonds will make your skin, and you, beautiful—and transport you to California with every bite.

The presentations expanded their targeted geography, through the UK, France, Germany, Denmark, India. The Almond Board was seeking something very specific: to be the number one "top-of-mind" nut that consumers think about snacking on—beating out walnuts, cashews, and pistachios. The Board's advertisers did this in part by making almonds synonymous with the California landscape: by consuming almonds, you consume and experience California as well (see Figure 2.2).

Figure 2.2: Chinese almond advertisement (Source: Almond Almanac 2017, p. 25)

California almond growers produce 99% of all almonds in the United States and 80% of the global supply (Boriss and Brunke 2012, 2005)—a demand for almonds and complex global supply chain that has grown continually over the decades thanks to advertising campaigns like the one described in this session. This market growth has been accomplished in part by almond acreage expanding constantly from 100,000 bearing acres in 1965 to 1.1 million bearing acres in 2018 (USDA 2018), as well as doubling production from 721 lbs per acre in 1965 (USDA-NASS 2014) to 2,150 lbs per acre in 2018 (USDA-NASS 2018a). When viewed over time, the expansion is staggering. Almonds now occupy nearly 14% of harvested agricultural land in California (Sumner et al. 2012; USDA-NASS 2018a)[12] and use approximately 9.5% of the state's agricultural water (Almond Board 2017b).

What factors have driven this rapid expansion, particularly the exponential growth from 1970 to 2016 (Figure 2.3)? And with what environmental and social costs? To some extent, this chapter extends one of the central arguments in Chapter One, demonstrating how the almond's materiality has facilitated almond expansion, such as almond trees' need for a Mediterranean climate, which has limited commercial almond production in the United States and around the world. Almonds are highly durable and can be shipped long distances or stored throughout the year without going rancid like walnuts or rotting on orchard floors like stone fruits. They also have a neutral flavor profile that makes them easy to market globally as whole nuts or value-added commodities.

[12] One-quarter of California's landmass is used for agriculture—about 25.4 million acres. Just over half of this total is pasture and range, and 37.3 percent is cropland (2007). Harvested cropland covers about 7.6 million acres. About 37 percent of California's harvested cropland is planted to orchards and vineyards, 23 percent to hay, and 15 percent to vegetables (2007). (Sumner et al. 2012)

Some factors that have supported expansion are technological, such as the industry's ability mechanize the harvest process—again possible because of the almond's materiality. And some factors are highly political, such as some corporate growers' ability to secure land and irrigation rights in regions west of the San Joaquin Valley and Kern county, which has seen some of the greatest recent growth in acreage with the lowest precipitation of any county in the Central Valley (PPIC 2016).

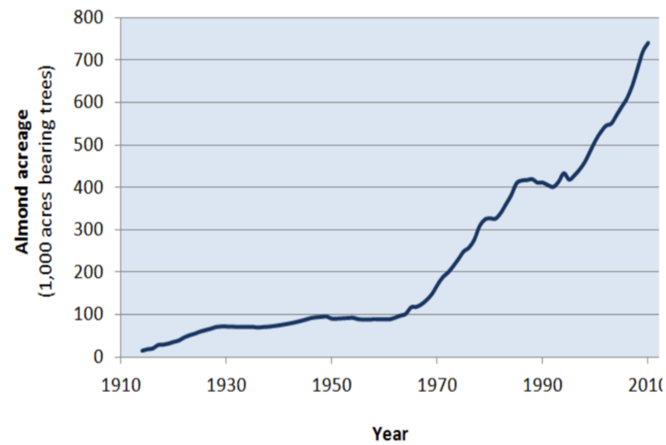


Figure 2.3: Area of bearing almond trees in CA since 1914 (Geissler and Horwath, 2016)

While I give some attention to these influences, in this chapter, I argue that the industry's marketing and breeding efforts played a central role in helping increase production and support geographical expansion, while also staving off crises of overproduction that could lower almond prices long-term, and disincentivize land conversion into almond orchards.

To highlight the role that the industry's marketing has played in almond acreage expansion, I trace the industry's expansion and development from the early 1950s, with an emphasis on the 1970s to 2016, when almond growers in the San Joaquin Valley began to require out-of-state beekeepers to meet their pollination demands. During this period, the industry's market strategies elicited cooperation among competing almond growers, created new domestic and international markets, kept the value of almonds high, and subsequently encouraged California growers, landowners, and other investors to convert agricultural lands into almond production. The second major driver, horticultural science and varietal breeding, helped the almond industry overcome barriers that the almond and California landscape posed to industrial production. To extend the reach of almond plantings, the industry's breeders and nurseries helped develop new root stocks (the lower part of the tree) and almond scions (the upper part of the tree grafted onto the root stock) that allowed the industry to expand into increasingly diverse climates and soil types and constantly increase production.

Yet while these processes largely staved crises of overproduction that could result in lower prices, I argue that they have also created ecological contradictions that threaten the industry's (and other industry's) future growth by degrading and diminishing the ecological components—namely water and pollination services—that the industry requires for its reproduction. Not only has the expansion of the almond industry put enormous strain on managed honey bees as discussed in Chapter Three, almond growers have also increased their use of California's ground water which threatens the future of their industry, as well as that of fisheries and the agricultural labor communities who lose access to water as groundwater wells dry up.

What we begin to see then, to return to the marketing session on Chinese consumers, is that the almond industry has expanded in large part by selling an aestheticized California landscape that ignores the environmental degradation required to produce it. As consumers around the world become new sites of accumulation for the almond industry, they also literally consume the California landscape as well, as its water and bee pollination services are embodied in the almond form and shipped to consumers around the world.

The remainder of this chapter proceeds as follows. Part One focuses on the first part of the argument, specifically how marketing, breeding, and mechanization helped increase production and expand acreage throughout the Central Valley. Specifically, I look at the establishment of the industry's Marketing Order and the Almond Board and key decisions the board made that shaped the industry. One such decision includes a lawsuit that froze the industry's marketing funds for three years. I highlight how the Board made strategic decisions to turn what could have been a crisis for the industry into an opportunity that fueled the next stage of expansion. I also trace almonds' transition from a snack to a commodity, which created a new round of products that helped stave off oversupply in the 90s and 2000s.

Part Two considers some of the environmental consequences of almond expansion, particularly those which threaten the almond industry's future production and have had consequences for other industries and laborers as well. As the almond industry has expanded, growers have increased ground water consumption through well drilling because almonds require more water than the row crops they replaced and cannot be fallowed like row crops during a drought. This water usage not only threatens growers' future access, but also that of fishing industries, endangered fish species, and agricultural worker communities in nearby counties. In addition, as the almond industry has paid a steadily increasing amount for honey bee colonies (prices driven upward by the challenge of raising bees), breeders have created new self-fertile almond varieties that aim to make almonds independent from bee pollination. I close with a discussion of these findings.

Part One: How marketing and breeding drove almond expansion

New technologies that drove almond acreage expansion from the 1950s to 1980s

From the 1950s to around 1965, almond acreage stayed fairly static, but major technologies were developed during this time that set the stage for rapid expansion from the mid 1960s through the 1980s. One of the most important was the development of new root stocks for almonds, particularly the USDA's Nemaguard root stock in 1959 (FPS 2018).

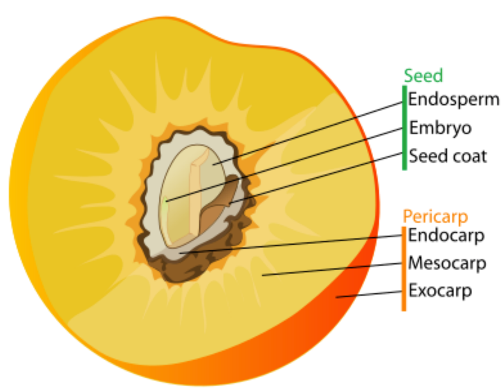


Figure 2.4: Anatomy of a peach/stone fruit (Source: Wikimedia Commons)

Almonds (*Prunus dulcis*), botanically speaking, are actually not a nut. They are a 'drupe', what is commonly known as a stone fruit, a species characterized by a fleshy fruit exterior and a hardened seed inside (Awker and Buttrose 1980). Almonds, plums, apricots, peaches, nectarines, and cherries are all subspecies of the genus *Prunus* (family Rosaceae) (Janick 2005), and are characterized by a fleshy mesocarp (the fruit), surrounding the endocarp (the pit or stone) (Rost 2006, 225). Figure 2.4 illustrates how the seed inside of a peach closely resembles an almond, but the almond's mesocarp is significantly diminished (ibid.).

As a subspecies of the genus *Prunus*, almond scions (the top producing part of the tree) and the scions of other stone fruits listed above, can be grafted onto each other's root stocks somewhat interchangeably (Edstrom and Viveros 1996, 61–63)[13]. This is helpful for several reasons: some root stocks have developed resistance to certain pests or pathogens, some can grow in certain soil types better than others, and also—like many agricultural crops—it is best to plant a new genetic variety into soil when the old one has finished production to avoid pest and pathogen growth. Nemaguard, a peach root stock resistant to the root knot nematode, helped expand almond acreage and production because nematodes thrive in sandy soils and can cause damage such as stunted growth and defoliation (Nyczepir et al. 2008). The introduction of Nemaguard root stock facilitated the expansion of almond acreage southward from the Sacramento Valley into San Joaquin Valley's sandy soils (W. Micke 1996, 2), where the majority of almond acreage is planted today (CDFA 2018).

Mechanization through new harvesting technologies also increased production and incentivized land conversion into almonds (W. Micke 1996, 2). The geographic consolidation of the industry played a central role in helping the industry industrialize: growers could access machinery for harvesting and hulling through nearby huller/sheller co-ops, neighbors, or nearby machine rental facilities. In the 1950s, growers shifted from hand harvesting on canvas sheets to mechanical harvesting, a factor that growers and industry representatives constantly cite as instrumental to making almonds an attractive crop for California growers.

Instead of using human labor to pole the nuts off a tree, harvesting machines called 'shakers' now clamp onto almond trees at the trunk and shake until nearly all the nuts fall down to the ground (Figure 2.5)[14]. The nuts stay on the orchard floor for about a week until dry, and then another machine, a 'sweeper', drives through the rows and sweeps the almonds into 'wind rows' using fans and built-in brooms. Finally, a third machine, a harvester or pick-up

Figure 2.5: Almond tree shaker. The machine grabs the root and shakes until most of the almonds fall off the tree. (Source: Almond Board.)

[13] The root stock is the bottom portion of the fruit tree and the scion is the top part which can come in numerous different varieties. For example, the Nonpareil is a variety of almond scion, and a Nonpareil can be grafted onto peach, plum, or hybrid root stocks.
[14] Image citation (Almond Board 2018b)

machine, drives over the wind rows and picks the almonds off the orchard floor. The harvester then carries the nuts to a cart at the edge of the field, or otherwise nearby, and then the almonds are loaded via nut elevator into trailers and taken to the huller/shellers who remove the hull and shell (see Fig. 2.6).

Figure 2.6: Parts of the almond fruit (Source: Almond Almanac 2017, 13)

Other than the driver who operates the machines and carts, little human labor is required at harvest. For comparison, one grower who switched from growing olives to almonds in the 1990s explained that if you had 100 acres of olives, you would need 100 olive pickers, while you would only need three to four people for 100 acres of almonds (interview, Nov. 15, 2018). Because of considerations like this, mechanized harvest provided a big incentive for growers and farmers to switch acreage into almonds in the 1950s and 1960s to the present, particularly the conversion of orchards from stone fruit crops and grapes into almonds (W. Micke 1996, 2; Olmstead and Rhode 2017). This mechanization has extended into almond processing as well: lasers and new technologies now help grade nuts and conduct every step of almond processing.

The industry also found new outlets for it its bi-products. Once almond growers harvest their nuts, they are sent to a huller/sheller that hulls and shells their nuts (if shelling is requested) before they are sent to the processor. These huller/shellers are then left with almond bi-products such as sticks, twigs, and stones, fibrous shells, and also nutrient rich hulls (remember that the hulls are the equivalent of the fleshy part of a peach). Almond hulls are around 55-60% sugar and starches, and 17% crude fiber (Aguilar, Smith, and Baldwin 1984; Miller 1949).

These hulls, a close nutritional equivalent to alfalfa, are mixed with sileage or hay and fed to dairy cattle (ibid.). The hulls are also attractive because of their high volume of soluble sugars which are fermented in the cows' rumen without causing the buildup of lactic acid (Robinson n.d.). This is a cheaper alternative to corn and alfalfa, particularly in years when both commodities are strong on the market, and yet it also provides an income to huller/shellers for what would otherwise be compost or waste they would have to pay to dispose of (C. Lee 2008). In some years, the income from almond hulls was so profitable that huller/shellers did not charge growers to hull their nuts before they were sent to the handler (multiple interviews).

Finally, researchers made numerous new discoveries about the pollination science driving almond production—particularly the number of bee colonies needed to effectively pollinate an acre of almonds. As mentioned in Chapter One, growers were previously encouraged to place one colony of bees per acre for maximum production (Philp and Vansell 1932, 24; Tufts and Philp 1923, 23) However, research conducted in the 1950s and 60s indicated that two to three strong colonies should be placed in a hive (McGregor 1976; Traynor 2017)[15].

[15] I detail what qualifies as a strong colony in Chapter Three.

A USDA document notes the importance of placing colonies in orchards, and how neglecting to do so might actually decrease almond production:

> In the San Joaquin Valley of California, a commonly held idea is that almond production at bloom time can be increased more with less investment by having adequate bees than with any other expenditure, all other factors being equal. In general, this would indicate that not enough colonies are being used for maximum production of almonds. (McGregor 1976)

This increase in colonies needed per acre likely played a role in the need for out-of-state bees for pollination. One study analyzed the point at which (1) almond growers exceeded the pollination service capabilities of California beekeepers, and subsequently required out-of-state beekeepers for pollination, and (2) when their demand exceeded what Oregon and Washington beekeepers could provide as well (Rucker, Thurman, and Burgett 2012). Assuming that 90% of California's bee stock were brought into almonds each year, and then that 90% of the bees in Oregon and Washington were also brought to pollinate almonds, the authors conclude that it was in approximately 1973 that the almond industry exceeded the California population of beekeepers able to pollinate its orchards, and 1977 when it exceeded the capacity of Oregon and Washington beekeepers as well (Figure 2.7) (Rucker, Thurman, and Burgett 2012, 965). These dates do line up somewhat with beekeeper interview data and accounts by the beekeeping industry of this process (Traynor 2017).

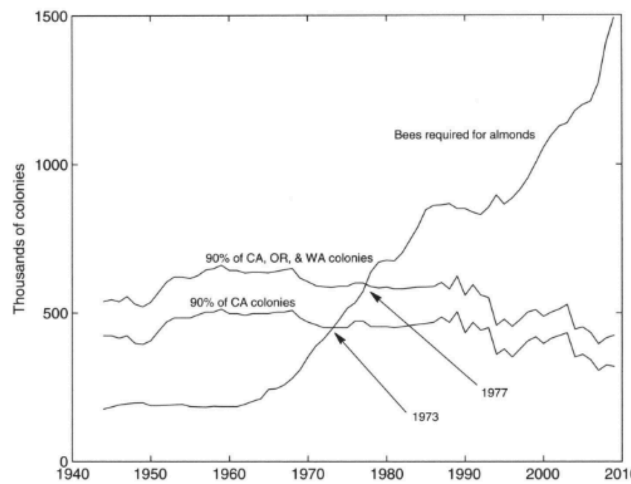


Figure 2.7: Years when the almond industry exceeded the capacity of CA colonies (1973) and CA, OR, and WA colonies for annual pollination (1977). (Source: Rucker, Thurman, and Burgett 2012

Two other factors played a central role in quadrupling almond acreage from 100,000 acres in the 1960s to 400,000 acres in 1985. Irrigation was one of the first and foremost, driven by the California State Water Project (SWP), which was launched in 1960 and helped deliver water to the west side of the San Joaquin Valley (Johnston and Mccalla 2004; Johnston 2003). The SWP is a system of dams that store water in large reservoirs in the northern part of the state, which is then delivered via Sacramento River canals through state-determined allocations.

Almost half the water that growers access in the Central Valley comes from SWP and another federal water project, the Central Valley Project (CVP) (Johnston and Mccalla 2004). The SWP opened up Kern County (Traynor 2017), which only had around 340 acres of almonds in 1960, and now has over 220,000 acres (Figure 2.8)[16]. By 1970, almond production had moved its

[16] Data compiled from Kern County Agricultural Commissioner's Reports, 1950-2016. See Appendix I: Methods, for details.

center from Sacramento Valley to the San Joaquin Valley, where growers could take advantage of better soils and warmer climates (warmer bloom-time temperatures and climate), largely due to the new irrigation projects (Geisseler and Horwath 2016; Johnston 2003, 50).

But water alone cannot explain the mass expansion into almonds, since numerous crops could have taken advantage of this newly available surface water. This is why I argue that the development and marketing of almonds and innovative value-added products (Johnston 2003), was the second major factor that contributed to almond acreage expansion during this period. Expanded markets kept almond demand robust (ibid.), making almonds attractive for growers looking to cut labor costs, or those struggling with stagnant or dropping commodity prices crops such as grapes, cotton, and other stone fruits. This marketing was driven nearly entirely by the Growers' Exchange and the newly California Almond Board.

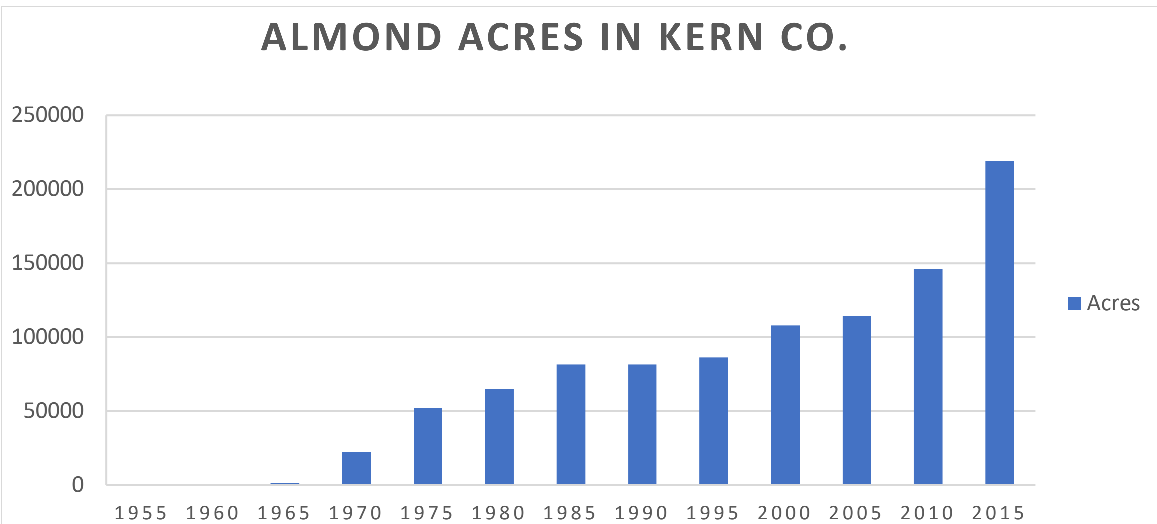


Figure 2.8: Acres of almond orchards in Kern. The State Water Project was launched in 1960.

The establishment of the Almond Board of California

One policy that underpinned the development of California's agricultural system in general, and the almond industry very directly, was the Agricultural Marketing Agreement Act of 1937 (AMAA). AMAA—and its California counterpart the California Marketing Act (CMA), also established in 1937—provide the authority for federal and state 'marketing orders' and agreements (Carman and Alston 2005). Marketing orders authorize three broadly defined categories of activity: commodity volume control, quality control of the products, and market support such as advertising and research (Johnston 2003, 109).

Marketing orders are binding regulations initiated by the industry that apply to an entire industry, are tailored to the industry, and are paid for by the industry as well (Carman and Alston 2005; Johnston 2003). The bones of most marketing orders are this: growers or processors take a small portion of the commodities they sell (e.g. two cents of every dollar from almonds) and set it aside as an "assessment," funds that the industry can use to finance 'collective goods' for the industry such as commodity-specific promotion, nutrition and market research, industry public relations, agricultural research and development, and the enforcement of grade and packaging standards and quality regulations (Alston et al. 2005, 3; Johnston 2003; US Congress 2007).

Marketing orders allow agricultural producers to “act collectively through a legal structure to control various aspects of the marketing of their products” (Johnston 2003, 107). Federal marketing orders tend to cover production regions in more than one state and focus on quality regulations and volume controls, while state orders typically only apply to the state’s boundaries and focus on research programs and promotion (ibid.). Marketing orders have funded some well-known agricultural commodity advertising, producing campaigns and slogans such as the dancing California raisins in the 1980s, and “Beef, it’s what’s for dinner,” “Got Milk?” and “Pork, the other white meat” (Carman 2007). These are promotional efforts that support a generic commodity, rather than any specific producer or regional product (ibid.).

Marketing orders were developed to solve the kinds of issues that almond growers faced in the early 1900s: how does an industry maintain a high quality, reliable product industry-wide? How do you standardize packaging? How do you regulate the flow of the product to the market to control the price? How do you pay for general marketing research, advertising, and the establishment of new markets? (USDA AMS 2018). Growers, including those in the almond industry, first attempted to solve these issues through local grower associations, and then by joining co-ops like the Exchange or working with other ‘handlers’ that work on solving these questions for the grower (Crespi 2005).

In 1950, the industry established the Almond Board of California in Modesto to administer their Federal Marketing Order under the supervision of the U.S. Department of Agriculture (U.S. Congress 1937). Initially, the Board’s focus was on compliance issues and was called the Almond Control Board (Almond Board 2018a). In 1973, however, the Board amended the marketing order to address the market side of the industry and help increase the demand for almonds; at this time, it changed its name to Almond Board of California (ibid.). Around the time of this shift, the Board expanded into other areas such as production, nutrition, and market research; advertising and promotion in domestic and international markets, quality control, technical and regulatory issues, and statistical analysis of production and dissemination of this information (Almond Board 2018; interviews).

The Board is composed of ten members—five growers and five handlers—who are elected annually from throughout the state (ibid.). Once members are elected, they elect the chair and vice-chair—all of these members serve voluntarily without compensation (ibid.). Under the almond industry’s marketing order, the handlers (those who buy the almond product from the grower after it has been hulled and shelled) pay the assessment to the Almond Board, who then determine what to do with the funds (ibid.).

In the 1970s, the newly minted Almond Board began to establish new market channels (interview, Oct. 2, 2018). One boon for the U.S. almond industry was that the Italian almond industry experienced a steep decline in almond production in the 1960s through the 1990s; during this time, the Italian almond industry contracted by about 70% (Anania and Aiello 1996, 56). The declines were due to a variety of reasons, among them small farm size, not incorporating new production and harvesting techniques, and a lack of product homogeneity (ibid., 58).

As of 1961, Italy was one of the top world producers of almonds, producing over 43% of global production, followed by Spain (26.9%) and then the United States (8%) (ibid., 59). Due to the new irrigation water resulting from the SWP, almond acreage had expanded enough in San Joaquin Valley to meet the production gap that developed in the 60s and command a strong price on the global market, and by the 1970s, the U.S. became the global leader in almond production, with 40% of the market share (ibid., 62). By the 1990s, U.S. production had increased nine-fold, supplying over 70% of the market (ibid., 59). Today, it supplies over 80%.

These market successes—facilitated by the adoption of machinery, new forms of pest management, and the other practices that helped increase agricultural productivity—subsequently incentivized a massive push of acreage conversion into almond orchards (Johnston 2003; Olmstead and Rhode 2017). California growers and farmers transitioned crops such as alfalfa, barley, stone fruits (particularly peaches), and rangeland into almond orchards (and cotton fields) and consequently set the stage for a multi-industry agricultural surplus that would strike the nation and the almond industry in the 1980s.

How Blue Diamond marketing addressed market oversupply in the 1980s

Almond growers participated in the same 1970s boom of production in the U.S. that contributed to excess market supply in the late 70s and early 80s that helped drive the price of many agricultural commodities below the price of production (Stam et al. 1991). For the almond industry, it meant that "the 1980s were dedicated to moving volume" (interview, Oct. 2, 2018); in other words, the industry was devoted to finding new distribution channels for its high volume of almonds. In the early 1980s, the industry's almond supply so far exceeded demand that it led to a sharp decline in almond prices around 1982 (ibid.). For example, the price of almonds in 1980 was $1.47, and by 1982, it plummeted by half to $0.78 (W. Micke 1996, 5). The Exchange, for example, had over 400 million pounds of almonds, but only sold around 200 million pounds that year (interview, Oct. 2, 2018). By the end of 1982, the industry already had a two-year supply, and more supply just kept coming in (ibid.). This high production, coupled with a strong dollar that limited export sales, kept almond prices low until the mid-1980s (Moulton 1996, 5; Allen 2000, 160).

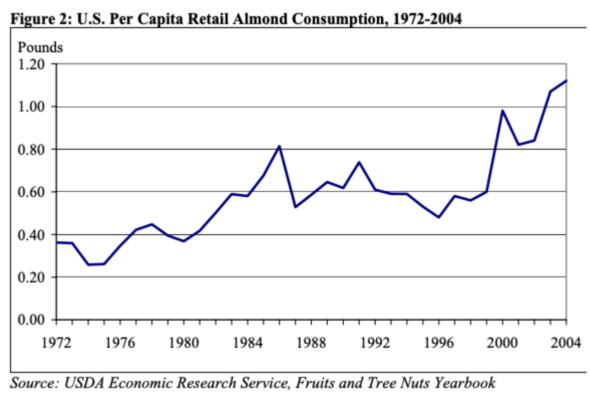


Figure 2.9: U.S. Per Capita Retail Almond Consumption (1972-2004) (Source: Boriss and Brunke 2005)

The Exchange focused on expanding their markets through value-added products under their Blue Diamond label. This was a challenge in the early 1980s, given a strong dollar that made almonds from the United States much less competitive on the international market than they had been in the 1970s (Allen 2000, 160). In response, the industry sponsored a big advertising push to increase demand from U.S. consumers. Johnny Carson endorsed Blue Diamond almonds on the Tonight Show and Blue Diamond pursued customers on multiple fronts for their flavored snack almonds on the radio, prime network television, and consumer and trade magazines (ibid.).

Blue Diamond also leaned more heavily on its Almond Research Center, a laboratory that came up with new almond products including almond butter as well as new uses for almond oils (ibid., 160-161). They expanded their marketing reach by bringing in other nut varieties under their brand such as filberts, macadamias, and pistachios to their product line through marketing agreements and purchases (ibid.). They also signed a distribution agreement with the H.J. Heinz Co. to put Blue Diamond products on their order books, so that when sales representatives called restaurants and other large-scale food institutions, they would sell Blue Diamond products alongside ketchup, mustard, and other cooking ingredients (ibid.). During this period, U.S. almond consumption climbed 110% percent from 1972 to 1984 (Boriss and Brunke 2005)

By 1985, the almond industry had grown their annual production from 305 million pounds of almonds in 1981 to 564 million (W. Micke 1996, 5). To create outlets for this increased supply, the Exchange built up its sales in the Soviet Union and India and expanded markets in the Middle East (Allen 2000, 162). Successful efforts were made to lower almond duty tariffs in the EU, Taiwan, and Mexico (ibid.). The industry also received matching funds from two cost-share programs under the 1985 Farm Bill: The 'California Export Incentive Program' managed by CDFA, and the Foreign Agricultural Service's 'Targeted Export Incentive Program' (U.S. Congress 1985). This helped Blue Diamond fund advertising in Canada, Asia, the Middle East, and Europe (Allen 2000, 162). Despite these efforts, the industry still faced what one representative described as an "extreme" supply glut in 1984 and 1985 (interview, Oct. 2, 2018); 1984 delivered a record crop, followed by another record crop in 1985 (Moulton 1996).

On November 1986, Blue Diamond launched a new advertising campaign on television (Allen 2000, 165). The ads featured actual almond growers, waist-deep in over 2.5 million almond kernels (ibid.). The ads were designed to be humorous and featured actual growers of all ages in overalls and baseball caps, holding cans of Blue Diamond Almonds and imploring the TV audience to eat more almonds: "A can a week, that's all we ask" (ibid.). The commercials subsequently generated millions of dollars in free advertising in newspaper and magazine articles, talk show interviews, and television news (ibid., 166). To Exchange representatives, this meant they had successfully put almonds on the map as a go-to snack, achieving that important "top-of-mind" awareness for almonds (ibid.)—a move that likely played a role in moving the almond surplus from two years of record harvests.

Figure 2.10: Photo for the "A Can a Week" ad, featuring actual almond growers. (Source: Blue Diamond Growers)

A weather event also helped (temporarily) balance the surplus as well: a brutal winter during pollination season in 1986 (Keppel 1986).

Crop damage was severe for growers in the San Joaquin and Sacramento Valley. The industry yielded around 235 million pounds of nuts—down from 444 million pounds produced in 1986 (Moulton 1996). This likely played a role in driving the price back up to closer to $2/lb after years of historic lows (ibid., 5). One representative stated that "after 1986, the industry got healthy again" (interview, Oct. 2, 2018): there were finally less almonds to move and more markets to absorb production.

At the same time, a major division in the industry's organization came to a head in opposition to the marketing order and the Almond Board. This internal division would later lead to a historic lawsuit that, rather ironically, helped launch the next stage of almond marketing and subsequent expansion of acreage.

A lawsuit against the USDA Marketing Agreement triggers the next wave of expansion

To simplify marketing and name brand recognition, the Exchange officially changed its name from the California Growers' Exchange to Blue Diamond Growers in December of 1987 (ibid., 166). At this time, Blue Diamond Growers handled over 92% share of the almonds sold in grocery stores (Crespi 2005). The almond marketing order allowed for bloc voting, which meant that an almond cooperative could vote on behalf of its members, and the larger the cooperative, the more votes it could cast (ibid., 53). Because of this process, Blue Diamond—which represented more than half the growers in the industry at the time—was able to hold the majority of the seats on the Almond Board, 6 out of 10 (ibid.). "[We were] kind of like OPEC," one representative joked (interview, Oct. 2, 2018).

The almond order was unique compared to other marketing orders during the 1980s. Handlers could receive a credit for their own advertising programs as long as they met requirements set by the board—the major requirement was that the product advertised had to be more than 50% almond content (Crespi 2005, 53). Some handlers (processors/marketers) believed that these requirements favored Blue Diamond Growers, who were the largest almond marketers and held a majority vote at the Almond Board at the time (Crespi and Secton 2001, 20).

In the mid-80s, large growers from various US agricultural industries began revolting against their commodity marketing orders, situating their arguments as a violation of their First Amendment right to free speech (Crespi 2005, 50). One of these challenges came in 1987 from within the almond industry by grower Cloyd Angle (Crespi and Secton 2001, 21). Angle was the CEO of one of the top four almond processing companies in the nation, Cal-Almonds, which was processing around 25,000 tons of almonds annually—nearly 10% of San Joaquin Valley's total almond production at the time (Doyle 2009).

Angle joined other almond growers who had taken the Act to task. One was Saulsbury Orchards and Almond Processing, who had withheld assessment payments from 1984-1986 under the same premise as Frame's complaint against the Act (US 9th Circuit 1993; Crespi 2005, 53). Saulsbury Orchards protested the Act because they had been selling and marketing almonds to companies who used them in confections and cereals but did not receive price matching by the Almond Board for their expenses because the products were not composed of greater than 50% almonds, as Almond Board regulations dictated (ibid., 52-53). The U.S. Department of

Agriculture sought an injunction in a federal district court and ultimately rejected the claim that the Act violated the First Amendment. Saulsbury Orchards was forced to pay $300,000 in owed assessments (US 9th Circuit 1990).

Angle, equally unhappy with the assessment fees for similar reasons, brought his case to the 9th Circuit in 1993 (ibid., 54). During the period of Angle's litigation and the courts' subsequent reviews of the constitutionality of the Marketing Order, the Almond Board was restricted from promoting almonds during for a period of three years (Crespi and Sexton 2005). Because the assessment was 2 cents per pound of almonds at the time, the harvests from 1994-1997 would have resulted in a total of approximately $33.6 million to spend on advertising (Crespi and Sexton 2000)[17]. Without an outlet to spend this money, the Board had to decide where to direct the proceeds.

This decision—as told by several representatives and growers—changed the course of the industry. The Board decided to direct the funds into research during the advertising suspension period, working with Loma Linda University (LLU) in Southern California in 1995 (Carman 2007, 182). The CA Walnut Commission was the first California-mandated marketing program to use the assessment to fund health and nutrition research, when it contracted LLU to research the protective benefits walnut consumption might have on cutting the risk of coronary heart disease (ibid.). The Almond Board subsequently initiated a Nutrition Research Program in 1995 and channeled the funds it would have used for marketing into health research (ibid., 182).

The LLU research gamble had a big payoff for the industry. In 1997, LLU determined that the frequent consumption of nuts (a serving of 1 oz or approx. 23 almonds a day) may lower the risk of cardiovascular disease by favorably altering serum lipid and lipoprotein concentrations (Jambazian et al. 2005). Around the same time this information came out, the Supreme Court overturned Angle's lawsuit (and numerous other challenges to the Marketing Order) and the Almond Board was free to market almonds again (Crespi 2005; Crespi and Sexton 2005). This time, the Board decided to change their messaging. They brought in a new batch of marketers and started pushing their health research as part of their messaging. The partnership continued to yield research that the industry could use to market their crop: high almond consumption could help reduce metabolic syndrome (Wien et al., 2003) and improve insulin sensitivity in adults with prediabetes (Wien et al., 2010).

Economists estimate that the advertising suspension from 1994-1997 cost the industry as much as $200 million dollars (Crespi and Sexton 2005), which highlights not only the economic blow of the marketing suspension but also the important role that the Act plays in bringing profits back to almond growers. Industry representatives, however, cite the Angle lawsuit—and the subsequent decision to channel funds into research—as a game changer that not only increased the value of almonds on the market, but subsequently led to further acreage conversion into almonds. One Blue Diamond representative joked, "Growers should go by Angle's grave and tip their hat for making the industry what it is today" (interview, Oct. 30, 2018). This next round of expansion continued to transform the landscape of the Central Valley as cotton, wine grapes, and ranching lands converted to almond production—and would lead to the next supply glut that the Board's marketing team would have to solve once again.

[17] $15.3 million in 1994/1995, $7.7 million in 1995/1996, and $10.6 million in 1996/1997

Diversifying the Almond Industry's root stock portfolio

The Almond Board and Blue Diamond had to constantly create new markets in part because of advances in plant breeding that facilitated the expansion and increased production of almond orchards throughout the Central Valley (Johnston 2003). As mentioned in the beginning of Part One, a central problem facing growers is replanting new trees in the same ground where an almond tree once stood, because of the possibility of pathogen spread (bacterial canker), nematode damage, and potential lost production (Curtis and Ludwig 2011). The Almond Board started funding rootstock research around the mid-1990s (ibid.), and root stocks subsequently became an essential technology that helped sustain and expand industry acreage (W. Micke 1996, 2). For example, the Lovell, a peach root stock, became popular up in the Sacramento Valley in areas like Butte County which receive a lot of rainfall, since the stocks can handle heavy, wet soils and substantial rainfall (Edstrom and Viveros 1996).

Figure 2.11: A root stock infested with nematode galls (left) v. a normal root stock (source: USU Vegetable Guide)

Hybrid root stocks are a newer breeding innovation that has gained popularity with growers over the past 20 years (Edstrom and Viveros 1996). In the past, breeders have grafted a single scion (e.g. an almond) onto a single *Prunus* root stock (e.g. a peach, plum, nectarine, or almond root stock). Hybrid root stocks, however, are a combination of root stocks that a single scion will be grafted onto. The Krymsk-86, for example, is a peach-plum root stock from Russian plant breeders. This variety is replacing the Lovell up in the Sacramento Valley, where growers need stock that can tolerate wet soils or are looking to plant out old rice paddies (interview, Nov. 17, 2018). The Viking, a peach-plum-almond-apricot hybrid, is popular in the northern San Joaquin Valley where growers deal with nematode issues and sandy soils (interviews with nursery breeders, Nov. 16 and 17, 2018). This stock often replaces the Nemaguard, the industry standard for decades. Peach-almond hybrids have become particularly popular for alkaline soil conditions. They have good anchorage (meaning, the tree will not blow over in the wind), are relatively drought tolerant, and are highly resistant to the root knot nematode (interviews with nursery breeders, Nov. 16 and 17, 2018) (see Figure 2.11)[18].

These peach-almond varieties have not only helped increase production and expand the planting zones for almonds, they have also transformed the almond nursery/plant breeding industry that propagates these stocks. For various reasons, typical peach root stocks are propagated through almond bud clones in the nursery or lab, transplanted and grown in the ground, then dug out just before selling to a grower who then has to plant them shortly after (interview, Nov. 17, 2018).

Peach-almond hybrids, however, motivated one of the largest nurseries that produce almond stock, Duarte's Trees and Vines, to completely redesign their production (interview, Nov. 17,

[18] Image from Utah State University's Vegetable Guide website (USU 2019)

2018). Digging a live tree out of the ground requires the nursery to cut into the root ball to dig out the tree and forces the grower to replant the trees shortly after purchasing them from the nursery (ibid.). Peach-almond hybrids allowed Duarte's to switch to containerized tree production, where the trees are propagated through genetic cloning in their nursery lab, then grown in containers rather than in the ground in a medium that can be composted and processed after use, to kill off any bacteria (ibid.). This helps produce what they call "clean" root stocks that have their root stock intact and have not been pre-exposed to pathogens and pests in the soil at their nursery that would then transfer to the grower's orchard (ibid.). In addition, the trees are available nearly year-round. In the past, growers typically had to buy their almond trees in spring. With this innovation, growers can now avoid planting trees during a wet spring and can even replant after harvest, thus expanding not only the geographic reach of almond trees, but the timing of such plantings as well. This convenience makes growing almonds an increasingly attractive prospect.

Got (Almond) Milk? Acreage expansion from 2000-2016

Buoyed by health research on almonds and its steady market value, as well as new almond varieties that pushed back the barrier to expansion posed by soil and climate, growers began to convert other crops into almond acreage in the mid-90s. Advances in irrigation also played a major role in this process. For example, cotton growers on the West Side of the San Joaquin River started planting almonds with the advent of micro-sprinklers (Figure 2.12) and drip systems opened up hilly areas like ranching lands.

Figure 2.12: Micro Sprinkler (Source: John Deere)

Micro-sprinklers were more popular at first because "you could actually see the water dripping down" (interview, Oct. 2, 2018) and you could spray them during a frost to warm the orchard and protect the crop. Dripline irrigation installation also increased, particularly in the south where frost was not as much of an issue; drip is one of the most popular irrigation strategies in the state. Madera county, for example, had barely grown almonds before because the soil was so alkaline that flood irrigation (where growers literally flood the orchard) would make the ground seal up so that water could not soak in (ibid.). Micro and drip irrigation emitted slowly enough that the ground did not seal. This helped open up agricultural lands west of I-5 such as Arbuckle and Colusa, as well as the west side of Sacramento Valley, and the hilly ranching lands in the Eastern foothills. In the 1990s, Modesto and Madera converted cotton, grapes, and dairy in the 1990s, and then fresh stone fruits in the 2000s. In Stanislaus, cotton, wine grapes, and ranching lands converted in the 1990s[19].

These plantings started to come into production around the late 1990s, and once again the industry had an oversupply of almonds on its hands in the early 2000s that threated to drive

[19] Data compiled from County Agricultural Commissioner's Reports for San Joaquin Valley counties, 1970-2016.

down the price of almonds (Allen 2000, 190). Two solutions, both driven by Blue Diamond, helped deal with this glut of product. The first was a strategy led by the president of Blue Diamond at the time, Walter Payne, which stabilized the European market (ibid., 191). The second was a new innovation in almonds that led to almonds' transition from a snack food to a staple.

In the late 1990s, one representative described how the almond market was being manipulated by EU traders who would buy and sell positions on almonds like a futures trader, without a regulatory entity like the Chicago Board of trade to regulate these trades—a dynamic highly reminiscent of the early market manipulation of growers by buyers on the East Coast (interview, Oct. 2, 2018). These EU traders were able to suppress the market from 1995-2001 by calling one processor/seller (such as Blue Diamond or their many independent competitors) to ask what their price was for almonds (ibid.). Then they could say that some other handler was selling for less and ask the seller if they could come down on the price, essentially playing almond sellers against each other (ibid.).

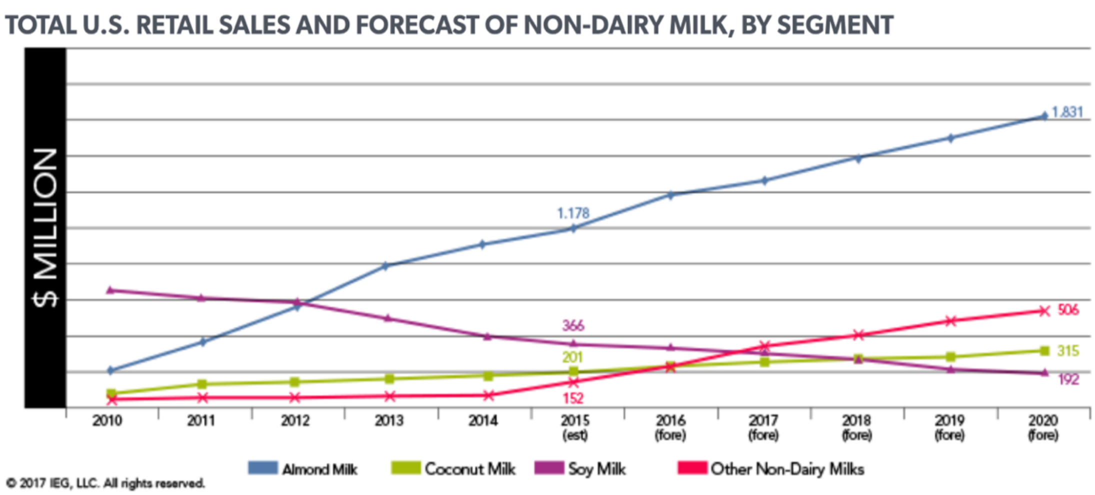
In 2000, the Almond Board established a commodities-trading group called the California Almond Export Association (CAEA) (Commerce 2000). At the time it was established, CAEA was a coalition of 20 California almond processors that represented more than 60% of the California crop (Allen 2000, 192). They set up a monthly CAEA meeting that competing processors could join and attend. Blue Diamond would introduce market information and share what they felt the price should be for export. The co-op had a lot of respect at the time and this created a sense of solidarity. This meant that buyers abroad could not drive down prices by playing handlers against each other (Lamb 2000); over time, it strengthened the industry's ability to leverage a stronger price in the EU market (ibid.). A processor could now send Blue Diamond an email and confirm the price a European trader had said Blue Diamond was selling Nonpareils at, for example, and Blue Diamond (or any other handler) could refute that they were selling for that price.

This industry organization helped stitch the industry together in response to the EU market and stabilize the export market for U.S. growers once again (Lamb 2000). This was an important move, given the yields the industry produced in 1999, jumping from 520 to 833 million lbs. in one year (USDA-NASS 2018a). The price of almonds subsequently went down from $1.41/lb in 1998 to $0.86/lb in part due to the sudden oversupply (ibid.); growers were once again selling for less than the cost of production like they had in the early 1980s. However, in part because they were able to stabilize their EU price—while continuing to open key markets in India and China—the industry was able to move the crop and get the price back up to $1.57 by 2003 (ibid.). With a stabilized price and new markets to move product into, almond acreage and production continued to grow once more.

Other Blue Diamond value-added innovations helped create new markets for subpar or damaged almonds. There are two types of these sub-standard almonds: ones caused by insect and rodent damage, which are considered rejects and cannot be used for human or animal consumption. These damaged nuts are pressed into oils that might be used for makeup or lubricants (interview, Aug. 5, 2018). The second type of almond rejects are chipped and broken almonds (ibid.), and in the late 1990s, the Blue Diamond Research Center made several innovations that both tapped into health markets and found new outlets for these subpar almonds (Allen 2000, 187).

In 1997, Blue Diamond launched a gluten-free cracker made from rice and almonds, called Nut Thins, and in 1998, released Almond Breeze as a milk alternative for lactose intolerant consumers (ibid). Since Almond Breeze was launched, almond milk sales and other plant-based milk alternatives have steadily climbed. In 2013, almond milk sales overtook soymilk as the most popular plant-based milk (IEG 2017). Almond milk sales have grown 61% since 2012 (Mintel Press Office 2018), and global sales of non-dairy milk alternatives reached $2.11 billion dollars in 2017. Americans consume non-dairy milk for numerous reasons, from concerns over weight loss, heart health, and lactose intolerance (Mintel 2016; Parrish 2018).

This growth has taken place as dairy milk has seen a decline in the United States; Americans now drink an average of 37% less cow milk today than in 1970, and consumption has dropped from 1.5 cups of milk per day to 0.80 cups a day (Ferdman 2014). Now, research indicates that nearly half of Americans consume some kind of non-dairy milk (Mintel 2016), the largest percentage of which is almond milk (Figure 2.13). This will continue to drive almond demand, in addition to health concerns over gluten that have increased the sales of products like almond flour and other almond-based products as well. These products, almond flour and almond milk, cemented the transition of almonds from a snack to a household staple, making almonds an essential part of the American diet and ensuring future markets for almond harvests to come.



Source: Information Resources, Inc., InfoScan Reviews; SPINS; USDA Economic Research Service; U.S. Census Bureau; Economic Census/Mintel.

Figure 2.13: U.S. Non-dairy milk sales; almond milk is the top line on the right. (Source: IEG 2017)

Part Two: Bees and water threaten industry growth

In this second section, I review two key barriers to almond expansion and the industry's efforts to overcome these natural barriers, demonstrating that while the almond industry's marketing and breeding efforts helped almond acreage expand throughout the Central Valley, it has encountered socionatural barriers to its expansion as well. The first barrier is bee pollination, which growers have experienced through ever-increasing pollination expenses driven by the increasingly difficult task of producing bees for almonds, detailed in Chapter Three. I discuss the production of self-fertile almond varieties created by breeders working closely with the industry to overcome this obstacle to accumulation. The second barrier is keenly felt by all growers and the industry at large: water. In the section on water, I discuss how regulations have created water conflicts around surface water and groundwater in the state, and how lost access to these resources threatens the industry's future expansion. I then discuss efforts the industry is taking to limit its water use and stem critiques of its water use and access as well.

Independence from Bees? The expansion of bee-free almond acreage

In a talk given to California almond growers on the cost of production increases in almond production, an extension specialist noted the increasing cost of almond pollination for growers (Figure 2.14) (Klonsky 2013). Though interviewed growers rarely expressed concern that honey bee losses would limit future expansion, nearly every grower expressed frustration with the rising cost of pollination fees. The specialist's presentation demonstrated how pollination costs have required an increasing percentage of growers' annual expenses. For example, in 2013 these per acre costs were only exceeded by the cost of land, and were comparatively equal to material costs, which includes agrochemicals.

One way the industry and its breeders have responded to this issue is through the creation of self-fertile almonds such as the Independence almond bred by Zaiger Genetics. The company was started by Floyd Zaiger, a plant breeder who bred one of the original peach-almond hybrids that helped increase almond production and acreage back in the 1960s. Zaiger was also the breeder behind varieties such as the Pluot, May-glo Nectarine (one of the earliest fruiting nectarines), Aprium (apricot-plums), NectaPlums (nectarine-plums), and numerous other new *Prunus* hybrids. Fruit hybrids are what Zaiger Genetics is famous for, though they are also working on almond varieties as well. The small company has an exclusive relationship with the Dave Wilson Nursery (as of 2019), which holds the primary propagation and licensing to their product until the patents expire.

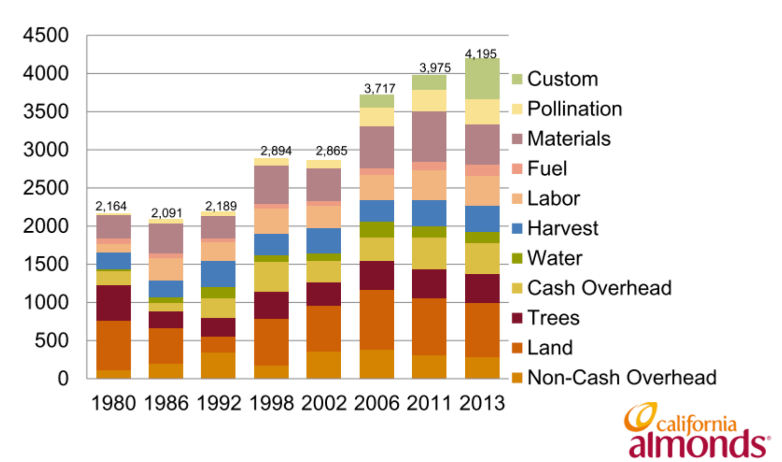


Figure 2.14: The increased cost of pollination services for California almond growers. (Source: Klonsky, 2013). Pollination is the top segment through 2002, and then second from the top in 2006-2013.

The Independence almond is a bit of a contentious varietal among beekeepers (and even among some growers), because it is self-fertile and does not *technically* require bees for pollination, though there is a heated debate about this within the almond industry. Several growers I interviewed, as well as some Blue Diamond representatives and university extension specialists, shared that their Independence almond trees produce more prolifically when they have one colony of bees per almonds. They also commented that by putting at least one colony of bees out per acre, they are also being good neighbors during almond bloom. They explained that their almond-growing neighbors who rented bees worry that their bees will fly to their neighbor's orchard and pollinate Independence almonds. Subsequently, they will diminish their rented pollination services as well as support the Independence grower's belief that she does not need bees because her almonds end up with a solid crop each year.

It is hard to know from field observation whether the Independence requires bees or not, because it is difficult to find almond orchards isolated from other almonds and managed bees. As one extension specialist writes:

> Even though [the Independence] may set a commercially acceptable crop, the presence of bees may increase nut set, thereby increasing yield. I have been recommending growers to consider at least one hive per acre to aid in pollination as I believe there is a yield benefit — as well as appeasing neighboring almond growers. Again, only time will tell if these observations are more than anecdotal evidence. (Doll 2012)

A representative from Zaiger Genetics tells me that this is "hogwash," and that he has always had prolific harvests without bee colonies as long as the nuts were irrigated properly (interview, Nov. 18, 2018). Another common complaint about the Independence is that it is not as sweet and creamy as the Nonpareil. However, the Zaiger representative countered this claim by citing a double-blind taste test conducted by the almond company Stewart and Jasper, where the Independence tested higher in the taste category than some Nonpareils (ibid.).

Nonpareils currently have the highest global demand and garner the highest value for growers. CDFA statistics demonstrate that the Independence variety was one of the top 3 planted varieties from 2007 to 2017 (Figure 2.15), with steadily increasing plantings until 2015 (CDFA 2018).

The Zaiger Genetics representative argued that the Independence variety does not simply cut down on pollination expenses, it also cuts down on dust and harvest expenses. Each variety has a different harvest time, and an orchard typically has two to three varieties. This means that a dust churning harvester must lumber through each orchard several different times—at least once per harvested variety—which can really increase dust. This is particularly relevant to the almond industry which faces strong state regulation on dust production during harvest because of its impact on air quality (Faulkner and Capareda 2012).

Another environmental benefit for the self-fertile varieties, the representative argued, is that growers would have to apply less fungicides. Growing only the Independence variety means that not only is the harvest time more compact, the bloom time is too. Typically, a grower has two to

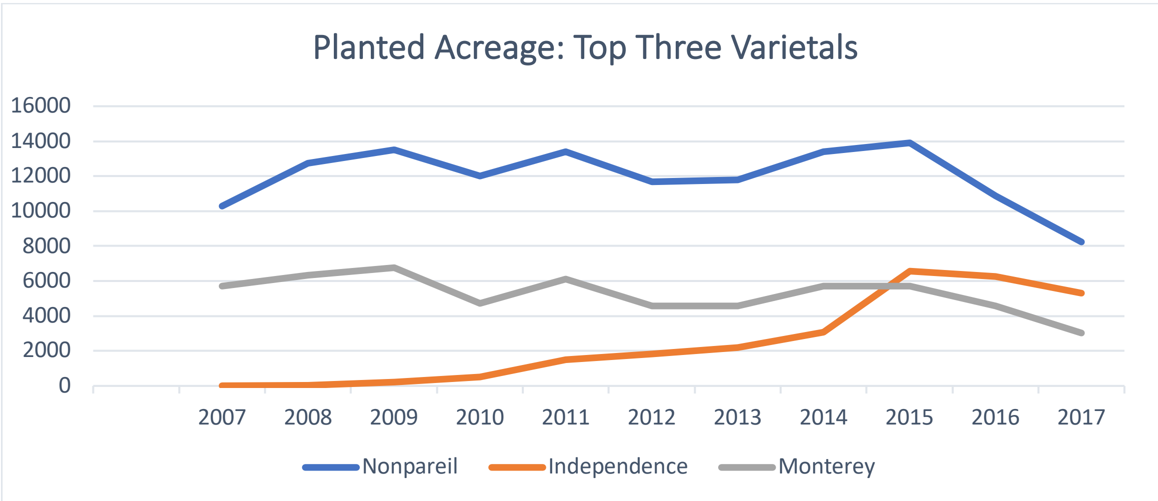


Figure 2.15: CDFA Statistics on top three almond varietal plantings (CDFA 2017). Independence are the bottom line in 2007.

three varieties blooming over a period of four to six weeks, which means that the grower must potentially apply fungicides for four to six weeks as well. For a self-fertile variety, such as the Independence, the bloom time would be cut by half, meaning that growers would have to do less passes through an orchard with fungicides if they grow a single variety.

Independence has its problems, however. Growers have complained (to Zaiger representatives and in interviews) that they used to garner the same price for Independence almonds as they did for Nonpareils but now they have less value at some of the big processors like Blue Diamond because of concerns about visual appeal, flavor, and consistency. In addition, the Independence nuts can be “sticky” and hard to shake off the trees at harvest time, which invites Naval Orange Worm (NOW) infestations, the industry’s biggest pest problem. If growers continue seeing price instabilities with the Independence and if problems continue with Naval Orange Worm, then it might discourage growers from continued plantings (B. Johnson 2018).

Self-fertile almonds are not the only solution to address the rising costs of pollination services. Another possibility might be a bee-dependent variety like the Bennett-Hickman that is highly productive and so similar to the Nonpareil that it can garner the same premium price. Most growers plant two to three varieties: one Nonpareil and two other pollinizers, which typically get a lower price than the Nonpareil. The Bennett (as it is called) offers a unique alternative to the Independent because it produces, looks, and tastes comparable to a Nonpareil—and has a slightly longer bloom period so it can pollinize the Nonpareil during its full bloom period. Bee colonies are still needed for pollination, but because the Bennett yields the same premium price as the Nonpareil, growers would have two premium trees in an orchard as opposed to just one, which would more than cover the cost of pollination—if the grower can secure enough bee colonies. These new varieties coming online such as the self-fertile or Nonpareil equivalents highlight the ecological contradiction growers face as their industry’s voracious pollination needs expand beyond the capacity of the U.S. beekeeping industry.

Water and almonds: When the rain does not follow the plow

In every single interview of growers and industry representatives that I conducted, when I asked what most worries growers in their day-to-day management and what will limit future expansion, the answer to both questions was quick and decisive: Water. When I asked about whether they were worried about bees, the response was mixed. One grower laughed: "Bees? No, I'm not worried about bees. The beekeepers complain and make a big fuss, but I still have my bees every year" (interview, Oct. 4, 2018). Another industry representative said, "No, we're not worried about bees because we're moving away from them. Growers are planting self-fertile varieties and soon there will be so much acreage that we won't need as many bees as we have" (interview, Aug. 5, 2018). A third industry representative in a senior position since the early 2000s told me he could not remember hearing of a single time when a grower could not get the bees he needed (interview, Oct. 2018). Only one representative told me that there was a shortage he could remember. The shortage was in 2004 and mentioned in the dissertation introduction, when previously planted almond acreage was mature enough for pollination, and beekeepers experienced some of their worst winter losses in decades and had to travel from around the country to meet the almond industry's pollination demands (interview, Oct 2, 2018).

Water, however, is another story. As mentioned earlier, the almond industry is a major water consumer and uses nearly 9.5% of California's agricultural water (Almond Board 2017b). When California's extreme drought hit in 2013-2015, news articles began emerging about which industries were using more water than anyone else, and suddenly the almond industry was thrust into the spotlight. Mother Jones ran a series of critical articles on the industry, starting with "Your almond habit is sucking California dry" (Philpott 2014b), followed two days later by "Lay off the almond milk, you ignorant hipsters" (Philpott 2014a). The articles, and numerous others in varied newspapers and magazines (e.g. Hamblin 2014) had several basic points, all of which generally argued that the almond industry was using more than its fair share of California's water during the drought.

To understand these claims, it is helpful to briefly overview how California water regulation works, and where it falls short. California farmers have access to water typically via ground water (i.e. through drilled wells), and/or surface water allocated by water districts (i.e. through canals, provided by the State Water Projects). In California, there are hundreds of local, state, and federal agencies with a diversity of governance structures and financing mechanisms that manage and regulate water. Growers who rely solely on district water alone can find themselves in a challenging situation, as the allocations allowed to certain districts vary. As one grower explained, "district water can mean that one guy can have water next door and the other doesn't if they're in different districts" (interview, Aug. 5, 2018).

District water is subject to varying annual water allocations, which growers typically will not find out about until right before their growing season begins. During the drought, for example, many farmers/growers received 20% of their typical allocations in 2013, and then absolutely no water allocation in 2014 (Krieger 2014). This lack of surface water, the stress of uncertainty, and comparatively loose regulation around groundwater (PPIC 2016) encouraged numerous growers to drill wells for water access in 2014 (Figure 2.16) (Krieger 2014).

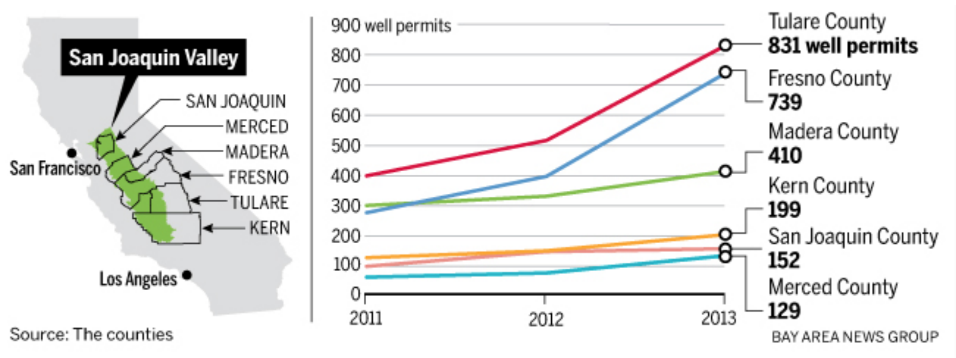


Figure 2.16: Increase in well-drilling permits in 2013 during drought (Source: Kreiger 2014)

Using well water as the primary water source comes at a price for long-term sustainability. Well water comes from California's underground aquifer, a limited water resource, whereas surface water is replenished each year, held in reservoirs, and distributed via California's elaborate canals system (PPIC 2016). To use a highly simplified metaphor often employed when discussing California's groundwater, groundwater can be compared to money in a bank account. If you withdraw money at a faster rate than you replenish it, you will start to deplete your savings and have account-supply problems (USGS n.d.).

Similarly, pumping groundwater faster than it can be replenished in the basins can lead to supply problems as well, such as drying wells, reduction of water in streams and lakes, deterioration of water quality, land subsidence, and increased pumping costs (ibid.). This ecologically damaging process is described as "overdrafting", and it is primarily occurring in the Central Valley and particularly in Kern County (Figure 2.17) (PPIC 2016). Kern County is the county in the Central

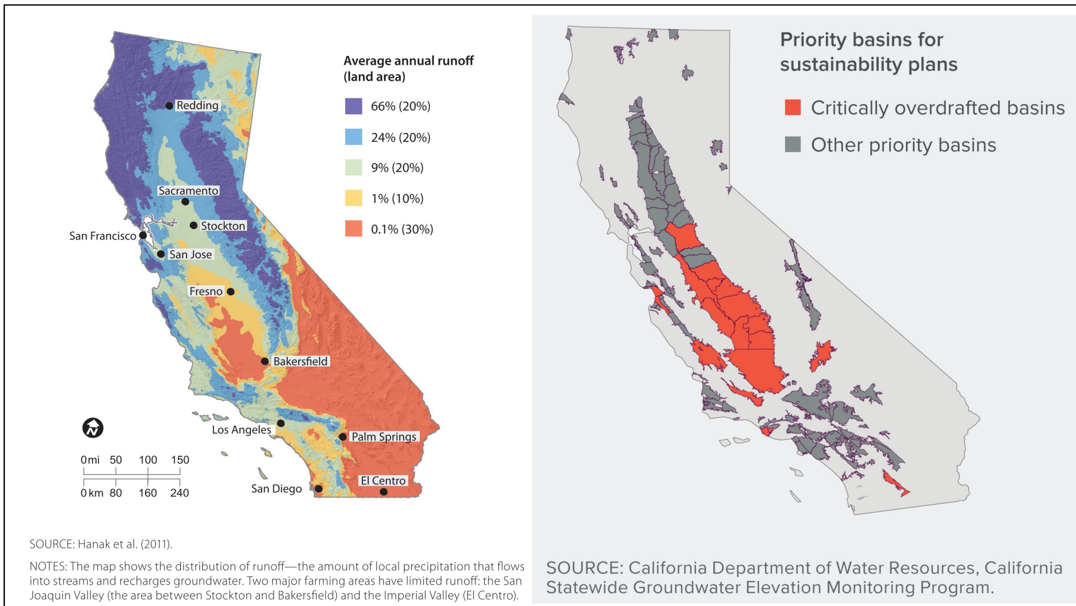


Figure 2.17: Figure 1 (Left) shows the distribution of runoff water that flows into streams and recharges the groundwater. Figure 2 (right) shows the critically overdrafted basins in California. Note that both areas are where the highest acreage of almonds are planted. (Source: PPIC, 2016)

Valley with the lowest precipitation runoff, i.e. water that flows into streams and recharges groundwater (PPIC 2016), and also where the highest acreage of almonds are planted in the state (CDFA 2018).

Figure 2.18: Subsidence in San Joaquin Valley (Source: USGS)

This process has occurred in large part due to loose state regulations on groundwater in agricultural areas, which only changed recently with the implementation of the Sustainable Groundwater Management Act (SGMA) in 2014 (PPIC 2016). As a result of largely unregulated well drilling, many of the water basins in California are in overdraft, which occurs when excess pumping leads to long-term reserve declines. These low levels not only increase the energy costs of pumping, but also dry out shallow wells, reduce water flow to rivers and wetlands, and allow seawater intrusion in coastal areas (Hanak et al. 2012; PPIC 2016).

Overdrafting water basins has also led to land subsidence through the depletion of California's aquifer. An aquifer is an underground layer of permeable water-bearing rock that liquids and gasses can pass through (USGS 2019); water in aquifers plays a key role in keeping the ground from subsiding and collapsing (Galloway, D. L. Jones, D. R. Ingebritsen 2000). As water is pulled out for irrigation, the remaining rocks and soil dry out, compress, and compact, a permanent condition that cannot be reversed by re-wetting the soil (ibid.). This subsidence ends up diminishing the storage capacity of the aquifer—an irreversible process—but perhaps even more dramatic, is that the land sinks as a result (ibid.) (Figure 2.18). In 2013, for example, a USGS survey found that 1,200 square miles of land in the Central Valley (an area twice as big as Los Angeles) has been sinking by an average of nearly a foot per year (Gordon 2013). As water retreats and the ground subsides, growers must dig increasingly deeper wells to pull the water they need for their orchards.

This is how almonds started getting their bad press, particularly almond growers like the Resnicks, Los Angeles billionaires who run their company Wonderful Farms largely out of the Lost Hills in Kern County. The Resnicks have planted over 121,000 acres of almonds, pistachios, pomegranates, and mandarins in dusty dry oil field lands, surrounded by working oil wells (Arax 2018). Here, one journalist describes magnate Stewart Resnick:

> At age 81, [Resnick's] gotten so big, he doesn't know how big. Last time he checked, he told me he owned 180,000 acres of California. That's 281 square miles. He is irrigating 121,000 of those acres. This doesn't count the 21,000 acres of grapefruits and limes he's growing in Texas and Mexico. He uses more water than any other person in the West. His 15 million trees in the San Joaquin Valley consume more than 400,000 acre-feet of water a year. The city of Los Angeles, by comparison, consumes 587,000 acre-feet. (Arax 2018, emphasis added).

During the recent drought, journalists began to wonder how the Resnicks were able to acquire water for their orchards in Kern county when the State Water Project severely limited its surface water allocations to the region during the drought, and winter rainfall is negligible (PPIC 2016). Both *The California Sunday Magazine* and *National Geographic* ran exposés on Resnick's water acquisitions and uncovered secret, backroom water deals that helped Resnick acquire the water he needed to irrigate his almond orchards. Some of these deals allegedly occurred with the knowledge of the Lost Hills Water District, the manager of which is a former employee of Wonderful Orchards (Arax 2018; Zenovich 2017).

Resnick has ensured water for orchards while communities of impoverished farmworkers nearby only have access to poisoned tap water (Arax 2018; Zenovich 2017), if they have access to water in their homes at all. And yet, despite these findings, no observable consequences have come to the company as a result.

The Resnicks, and other large-scale almond growers in Kern County who are able to access water, are largely outliers in the industry, where nearly 75% of almond orchards are 100 acres or less (USDA 2014). In my interviews, some growers and nursery operators expressed discomfort with the Resnick's water tactics. Not only are they taking water from farmworkers and other agricultural industries, a few mentioned, they are taking water from other growers too. One nursery operator told me that Wonderful scares him because they are so politically entangled and desirous of keeping everything to themselves (interview, Nov. 17, 2018). He told me that some farmers he knew needed water that Wonderful had acquired, but Wonderful would only give it to them if they sold and processed their almonds with Wonderful, which would negate the growers' long-term relationships with their other handlers. "Everyone speaks in hushed tones about Wonderful" he said (ibid.). I asked another grower in Kern county how Wonderful gets their water and he shrugged and said, "Power. Money. Wells." (interview, Aug. 5, 2018).

Growers will continue to struggle with water access, particularly as conflicts over water allocation continue in the state and the socioecological consequences of growing almonds become more broadly known. One such struggle mentioned in many interviews was with fishers and environmentalists advocating to save endangered Chinook salmon and Delta smelt (Dept. of Fish and Wildlife n.d.; Kay 2015; Hanak et al. 2015). The conflict between irrigated agriculture and fish centers around surface water allocations rather than groundwater regulations, but it explains why many growers have turned to well drilling.

One way that growers receive water is through surface water allocations that come from water released from state dams, but advocates for Chinook salmon and Delta smelt want to time those water releases, and the amount released, to support the smelt fisheries and salmon spawning rather than irrigated agriculture (Hanak et al. 2015). Diverting too much freshwater supply to farms and urban users creates an imbalance of brackish water in the estuary, which not only stresses the smelt but other species that feed on them. Saltier brackish water has all but decimated the chinook salmon population and commercial salmon fisheries (Obegi et al. 2008).

During the drought period, both of the state's largest water providers, the Central Valley Project (CVP), the State Water Project (SWP), and local water districts all dramatically reduced water deliveries to agricultural consumers (Hanak et al. 2015, 4). Many growers I spoke with described how fisheries conservation was crippling their operations, cutting off their surface water supply, and skyrocketing their water costs as they turn to less-regulated well-water to supply their water needs.

But drilling wells has become increasingly difficult as the aquifer gets increasingly depleted. One grower in the Tranquility water district described how their water table had dropped 85 feet over the past 5 years. If you put in a new well, he said, you have to go down 1000-1200 feet to get water now (interview, Nov. 15, 2018). Another grower stated:

> We have a ranch on the San Joaquin River, and it's 70 feet down to the water table there. Twenty miles away, it's 300 feet down. And then on the West Side (of the San Joaquin River), it can be close to 1500 feet deep to water—and there's lots of salt too. Some growers will pump instead of using irrigation water. That's just crazy. (Interview, Nov. 15, 2018)

This grower described how their family's orchards were 98% on dripline irrigation and argued that every grower should be on drip. "Farmers are their own worst enemy," he said. "Grapes were big in the 1980s, and it's almonds now. Everyone's planting so many, I worry there might be a bubble of sorts" (ibid).

One of the issues with almonds, and other tree crops during drought, is that is that they cannot be fallowed during periods of drought. Row crops are planted annually (like tomatoes, melons, cotton, berries, lettuce, etc.) and can be fallowed during periods of water stress and extreme drought (R. Johnson and Cody 2015, 8). Orchard trees, however, cannot; if a tree does not receive adequate water one year, the tree will likely be so stressed that it will have little to no yield the following year (R. Johnson and Cody 2015, 8). So, once a tree is planted, it is a twenty to twenty-five-year annual water investment. This is problematic in places like Kern county, where row crops like cotton are increasingly displaced with almond orchards and vineyards that are more difficult to fallow in droughts (PPIC 2016) (Figure 2.19).

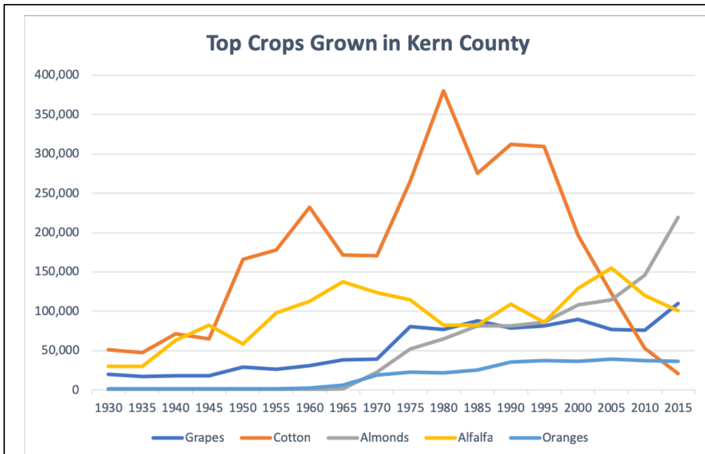


Figure 2.19: Acreage of top crops grown in Kern County. Note the decline of cotton, a row crop, versus the rise of almond orchards and vineyards that are significantly harder to fallow in droughts (PPIC 2016). Data compiled from Kern County's annual agricultural commissioner's reports 1930-2015.

The Almond Board's counter argument is that this water is being used to support a high-nutrient food commodity, despite the high cost per unit of food. An independent U.C. Davis study funded by the Almond Board conducted a water impact assessment of almond production, which accounts for the water used to create a commodity at all levels of the production and consumption of a particular good (Fulton, Norton, and Shilling 2019). The study compared almonds to the nutritive content of 43 different

California food crops and the economic value of 44 other California crops (42 were the same as the other study, but the researchers added alfalfa hay and wine grapes because of their economic value) (ibid., 712).

Their findings indicated that on a per-nut basis, the total water footprint of almonds was three to four times higher than previous media estimates of around a gallon a pound (Tom Philpott and Julia Lurie 2015). This means that the water footprint of almonds is closer to three to four gallons of water *per nut,* or between 69 and 92 gallons of water per recommended serving of 23 nuts, or 1 oz of almonds (Almond Board 2019). The study also noted, however, that while almonds have a larger water footprint per unit weight than other foods/crops, when they were "normalized" to consider nutritional contributions or market value, the water used per nutritive content was on par or better than the other foods in the study (Fulton, Norton, and Shilling 2019, 716).

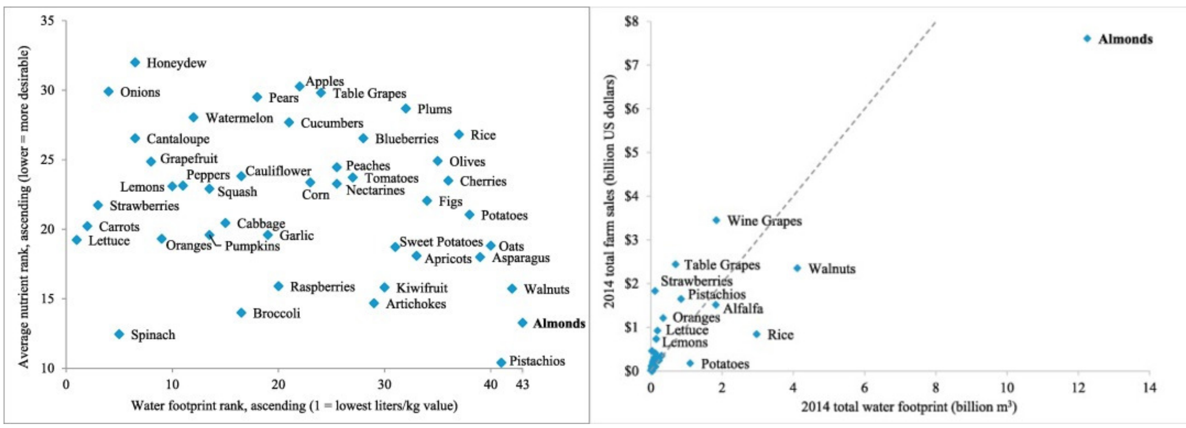


Figure 2.20: (Left figure) Almond's water footprint vs. nutrient ranking—note that almonds are one of the highest water users, but also one of the highest nutrient foods. (Right figure) Almond's water footprint vs. farm sales—almonds have the highest water footprint and highest sales out of all other crops. (Source: Fulton, Norton, and Shilling, 2019)

However, some (e.g. growers, industry representatives, and also journalists) have taken issue with pitting almonds against other fruits and vegetables, when they provide a vegetarian source of protein (e.g. Charles 2015; N. Johnson 2015). Instead, they expressed, a better equivalent to compare almond's water use would be to animal proteins. For example, a pound of almonds milk uses approximately 1,288 gallons of water (Fulton, Norton, and Shilling 2019) and delivers 99g of protein. A pound of chicken, for comparison, uses 3,500 to 5,700 gallons and has 123 grams of protein; while a pound of beef uses 3,962 to 20,000 gallons[20], and has 117g of protein (Peter H. Gleick 2011; USDA 2019).[21]

The almond industry has also taken steps to adopt responsible water practices in almond orchards. Nearly 80% of almond growers use micro-irrigation, nearly twice the 42% average of farmers who use micro-irrigation on California farms (CA DWR 2015). A Stanislaus county grower mentioned the water issue and argued that while almonds may use a lot of water, little of it goes to waste. "With peaches for example, if there are peaches on the ground then they can

[20] The large variation determined by diet, climate, and other variables

[21] Data on water use from (Peter H. Gleick 2011). Data on nutrition content from USDA's FoodData Central portal (USDA 2019). Table from (Fulton, Cooley, and Gleick 2012).

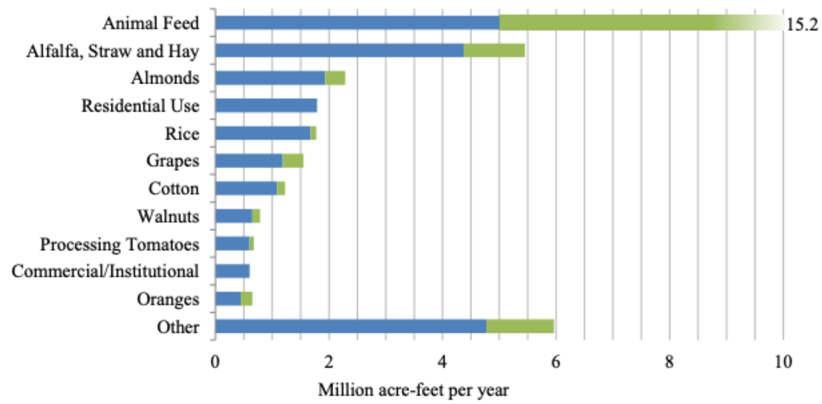


Figure 2.21: Blue water (surface or groundwater) and green water (precipitation and soil moisture) directly consumed by growing the listed crops in California. (Source: Fulton, Cooley, and Gleick, 2012)

spoil—you can waste a lot with peaches. But you can get every nut out of the orchard, so there's no waste. All that water is precisely utilized" (interview, Oct. 5, 2018). An industry representative also pointed out that "yes, almonds use a lot of water, but it's in line with other tree crops. It's just that because there are so many almonds that they have a big target on their back" (interview, Aug. 3, 2017).

Additionally, a 2015 study indicated that the industry has a low carbon footprint, given that 1 kilogram of California almonds typically produces a 1.5 kilogram equivalent of CO_2 emissions, a much lower carbon footprint than other protein rich foods (Marvinney, Kendall, and Brodt 2015; Kendall et al. 2015)[22]. In addition, the industry is aiming to be carbon neutral or even carbon negative with respect to greenhouse gases (Almond Board 2015).

Despite these efforts, the industry face numerous challenges to its share of California's agricultural water particularly due to its contribution to water basin overdrafting, aquafer depletion, and its effects on fish ecologies and other communities who struggle to gain water access. Because over 68% of the almond crop gets exported out of the country (Almond Board 2017a; USDA-NASS 2018a), the argument that the almond industry is producing food, and therefore deserves California's water, holds less weight since the commodity is largely being consumed not only out of California, but out of the country. That means that almonds are not only one of the top agricultural water users, but that all the water embodied in almonds is getting shipped overseas. Given the industry's 2017/2018's crop of 2.25 billion pounds of almonds produced, 1.53 billion pounds of which are exported and require approximately 1,288 gallons of water per pound to produce[23], over 1.97 trillion gallons of California's water are shipped overseas each year.

When I asked a senior industry representative what he thought about this, he shrugged and said, "I don't have anything to say to that."

[22] It should be noted that this study was supported by grants by the Almond Board and CDFA Specialty Crop Block Grant Program, conducted by independent researchers at U.C. Davis.
[23] Since a single almond uses 3 to 4 gallons per almonds, that is an average of 3.5 gallons per almond, 23 almonds per oz (80.5 gallons), and therefore 1288 gallons per pound of almonds (16 oz/lb).

Conclusion

In *Dust Bowl* (1979), Worster described the kind of agriculture that America offers the world as "producing an incredible bounty in good seasons, using staggering quantities of machines and fossil fuels to do so, exuding confidence in man's technological mastery over the earth, running along the thin edge of disaster" (Worster 1979, 234). He argued that the Dust Bowl, and the Great Depression with which it aligned, was a crisis of capitalism, brought about because the "expansionary energy of the United States had finally encountered a volatile, marginal land, destroying the delicate ecological balance that had evolved there" (ibid., 5).

The extravagant spread of almond trees throughout the Central Valley has overcome range and marginal lands, stone fruits and vineyards; and row crops such as cotton and tomatoes, as most of these transitioned into almonds. With ground water left largely unregulated, farmers are digging wells deeper to feed these thirsty almonds—particularly during times of drought—and getting increasingly frustrated at state water allocations that favor conservation projects over their farms. The near extinction of the Delta smelt and endangered Chinook salmon, significant land subsidence, increased water pollution and salinization, and the current lack of water for many Central Valley residents indicate that the Central Valley's delicate balance has already been tipped. This is not solely due to the almond industry of course, but they are undoubtedly putting an ever-increasing pressure on the state's water supply.

But water is not the only factor in almond expansion. As I have shown, the materiality of the almond played a distinct role in the industry's expansion and success from the 1950s to 2016. Because of the almond's durability (as opposed to a stone fruit or grape), growers could mechanize production in ways that lowered labor expenses and made almonds easy and attractive to produce. The almond's long shelf life facilitated a strong international export market, which has helped constantly create new circuits for accumulation and kept the price of almonds strong. Almonds also have a high nutrition profile and a creamy, slightly sweet flavor that allows them to be used in a variety of ways: in milks, flours, as snacks, toppings, in trail mix, etc. Most importantly, the almond is a drupe, or stone fruit, that could be grown on the scions of other compatible drupes through hybrid cloning. This allowed the almond industry to create new varieties of almonds that could grow in a variety of soils and climates, thus increasing the industry's reach throughout the Valley.

Almonds' need for the Central Valley's Mediterranean climate had another unique benefit: the marketing order that growers pay into only benefits the California almond industry. Typically, any marketing order can only promote the commodity generically, even if the commodity is produced outside the country. So, any beef advertisements supported by the federal marketing order (which ranchers pay into) just support beef, even if that beef comes from Australia. The almond industry, however, produces 99% of the almonds consumed in the U.S., so almond growers benefit entirely from every cent they collect and subsequently spend on marketing and research. Very few other, if any, commodities have this benefit.

It was not simply the almond's materiality that aided its expansion, these processes were also facilitated by agricultural policies such as the almond marketing order, which facilitated industry growth through assessments levied on almond handlers. These funds supported the Almond

Board's efforts to seek out and create new markets for almonds in the U.S. and around the globe, where it now provides over 80% of the world's almonds. At the same time, loose water regulation allowed growers to drill wells during droughts and obtain water through backroom water deals, securing water in the arid regions in western Kern county and supporting continued expansion.

While these material and sociopolitical factors may have facilitated the industry's expansion, they have also led to ecological contradictions that threaten the industry's sustainability. The industry's requirement for bee pollination, and the increasing expense for beekeepers and growers, has encouraged the industry to bypass this natural barrier to production and produce self-fertile almonds. In addition, the industry's extensive water footprint, detailed in the final section, has put the almond industry at odds with fishers, laborers, and other agricultural industries in California—even, sometimes, against other almond growers as well.

During the drought, when regulations around surface water tightened, growers made ecologically and economically contradictory decisions. From the almond growers' perspective, it made economic sense to plant a high-value crop that helped them afford surface water expenses, or drill to access groundwater. And yet, while this may have solved growers' immediate needs, it created short and long-term access issues for agricultural and urban residents dependent on well water, and has led to environmental degradation such as land subsidence and the endangerment of fish species over time.

In *Conquest of Bread* (2005), Walker evokes agrarian social theory about the limitations to full capitalist penetration of agriculture and argues that California has always been an exception to these theories. In the book's conclusion, Walker cites Richard Lewontin's (1998) support of agrarian exceptionalism, summarized in five points. First, ownership of farmland is unattractive to capital because it cannot be depreciated and farmland investments have low liquidity. Second, the labor process on large farms is hard to control because farming operations are "spatially extensive". Third, economies of scale are hard to achieve beyond that of mid-sized producers. Fourth, risks due to natural elements such as weather, diseases, and pests, are hard to control. Fifth, the cycle of reproduction cannot be shortened (ibid., 302).

Walker points out how the history of California agriculture refutes this assertion, arguing that:

> Capitalism has been there from the beginning of modern California, boring from within, spreading its tentacles smoothly across city and countryside alike, fixing its grip on one and all, workers, rivers, and machines. That emergent production system has grown up big and strong and healthy in the summer sun, achieving a degree of bronzed, agrarian perfection that is hard to find anywhere else on earth in the three hundred years after the English revolution set loose the beast upon the globe. (ibid., 305)

The case of almonds most certainly falls in line with Walker's analysis, even though the almond industry is surprisingly absent from his analysis. And yet, I would argue that water, and quite possibly also honey bees, will not so much limit capital penetration into agriculture, but do and will continue to act as barriers to its unlimited spread across California's countryside, challenging its "bronzed perfection."

Chapter Three: Feedlot Bees/Unruly Bees—The Industrialization of Honey Bees for Almond Pollination

Figure 3.1: Bee colonies in a holding yard prior to almond pollination.

Introduction

Sandy Lindberg, a migratory beekeeper, started beekeeping on her first date with her then future husband. One evening, she was supposed to go and meet his parents for the first time. Instead, they drove past the house to a bee yard. He gave her a men's long-sleeve work shirt to wear over her jeans, and a hat and veil—she is pretty sure he didn't have any protective gear on. As they cracked open a hive and looked inside, it became clear to Sandy how important his bees were to her, because he wanted to show them to her before even meeting his parents. As their relationship developed, they would go in the late afternoons and pop the lid off a colony and her husband would 'show her around'. He had finished high school with 24 colonies and then doubled them the year after, so he had fifty colonies by the time he introduced her to his bees. Growing up in a wheat farming family in Montana, Sandy had sworn she would never marry a farmer. "I used to think it's such a horrible life," she laughs. "And now I'm a beekeeper—it's almost worse."

As time passed and they got married, they purchased bees and some marginal land from various beekeepers that they could keep their bees on. By the time they got to 1200 colonies in 1985, they decided to head west to pollinate almonds, largely because they had their bees on unirrigated marginal land and the region was experiencing a seven-year drought. Beekeeping was much easier then; the only thing they worried about was American Foulbrood (ABF), a disease so virulent and persistent that beekeepers whose colonies had ABF had to burn their colonies and equipment to stop it from spreading. The major transitions were in the equipment they used and the way they packed and shipped their bees. They put started putting their bees on pallets, and transitioned from boom loaders to fork lifts, and borrowed a flatbed to move their bees. Income became a major driver to head to almonds each year—the chemical sprays weren't bad yet and they could re-queen their hives by producing their own queens each year.

And then things started to change. Lindberg noticed a difference in the mid-90s. All of a sudden, they had to feed their bees more syrup throughout the year. By 2005, she could tell something big was going on. In the past, a bad year was losing 12% of their colonies over winter. Suddenly, they found themselves losing 20-30% in 2003, and then even more in 2005. They started going to national meetings and realized they were not alone.

"It starts hitting you, and you're wondering what the heck's going on." They started calling researchers to try and figure out what was wrong. The strangest thing was experiencing the CCD symptoms: mostly empty hives with no bees in them. "Beekeepers, especially back then, used to blame themselves. You think, I must not have fed them enough. You just rationalize what you must have done wrong" (interview, May 8, 2017).

Lindberg's experience sounded very similar to other beekeepers who described the changes that began around 2003 or 2004 and heightened through 2006 and 2007. Around this same time that beekeepers were started to struggle deeply with their bees, Lindberg tells me, the almond industry started increasing its vigilance of colony health, hiring more bee brokers and inspectors to test hive strength. Growers started requesting strength contracts, where they would demand a minimum number of frames in each colony to be considered an active colony.

"Now you have to have bees where a grower wants them, as strong in February as they would normally be [in April]" (ibid). They started feeding their bees pollen supplements and finally figured out how to make their own. At the two national meetings that they attended, information started coming out about how bees needed more nutrition, and other beekeepers were talking about their successes. At those meetings, they would listen to beekeepers in the hallways about what was going on with them, and what had worked. For Lindberg, beekeeping has become a collective process of trial and error, a giant experiment on how to raise bees for almonds, conducted by her and the rest of the commercial beekeeping community.

In this chapter, I argue that producing bees for the almond industry has contributed to honey bee vulnerability. To demonstrate this, I trace how beekeepers have changed their management practices to produce bees for almonds, industrializing their management practices so that beekeeping has become far more input intensive, bees are worked year-round (instead of hibernating over winter), and beekeepers rely on one subspecies of honey bee that is more vulnerable to bees' primary pests. As beekeepers have shifted their operations from prioritizing honey production to commercial almond pollination, this shift has transformed honey bees' value from producers of commodities, i.e. honey and pollen, to commodities themselves—almond pollination laborers. This transformation into laborers for the almond industry has played a central role in honey bee vulnerability.

As outlined in Chapter One, beekeepers have been paid to pollinate almonds since at least the early 1900s and bees have been produced for their pollination labor for centuries—if not millennia. Additionally, some commercial beekeepers have produced bees solely for pollination labor for decades. What is new and different about almond pollination now, however, is the immense scale of the industry's production that requires beekeepers to import bees from out of state, high frame counts that force beekeepers to constantly stimulate their colonies, and the suite of agrochemicals applied by growers and beekeepers. These factors all coalesce with a context in which cheap honey is flooding the market and lowering the price of honey, at the same time that beekeepers are losing access to forage for honey production nationwide (Durant, 2019). On top of this, beekeepers have been struggling with parasitic mites since the mid-80s that have growing increasingly virulent and resistant to treatment.

Yet with the high value almonds demand on the market outlined in Chapter Two, growers can afford the increasingly high cost beekeepers demand for pollination services, a high cost that largely reflects the current challenge of keeping bees alive and ready for pollination in February. This economic incentive, coupled with an increased inability to earn enough profit from honey production to support a large operation, has incentivized many beekeepers to transform how they value their bees. As the almond industry has increased the value of honey bee (and thus beekeeper) labor, beekeepers have been incentivized to industrialize bee production to take advantage of this economic opportunity, but in ways that increase bees' susceptibility to pathogens and pests in turn.

Empirically, this chapter traces the why and how beekeepers changed their management practices to pollinate almond bloom in February, transforming from honey producers in the 1980s to almond pollinators by the 2000s. I demonstrate how honey bee bodies became increasingly vulnerable as beekeepers shifted from valuing bees for their honey and pollen to valuing their insect labor power. Theoretically, honey bee commodification provides a unique case that speaks to literature on the commodification of nature, and livestock in particular. I draw from the concept of "unruly nature" to demonstrate how bees provide a particular challenge to capital penetration and industrial production.

The chapter proceeds as follows. I begin with a brief overview of bee social science about honey bee declines, and how the concept of "unruly nature" helps us understand why honey bees are particularly hard to commodify and thus prone to vulnerability. I follow this with some background to explain some of the major factors that drove beekeepers into almond pollination in the first place, with a particular focus on how cheap honey flooded the market and drove honey prices down. The chapter then traces how beekeepers have changed their management practices to have strong bee populations ready by February. This has entailed major changes in annual inputs, overwintering practices, and shifts in pest and disease management as mite-related colony losses have intensified. Next, I discuss the rise of the *Varroa* mite and the efforts beekeepers must make to keep their bees alive as a result. This is followed by a discussion of the intensification of queen breeding and the production of simplified bee stock, due to several genetic bottlenecks since the 20th century. One of these genetic bottlenecks—I argue—is the almond industry's need for robust bee colonies in mid-February, which has driven the production of a bee that is particularly vulnerable to the pest pressures that plague the beekeeping industry. I conclude with a discussion of these findings and a consideration of what this tells us about the almond-honey bee dynamic.

Toward a Theory of Unruly Bee Nature

In his research on how modern honey bees have become technologies of national defense, Kosek (2010) engages with the question of honey bee declines and argues:

> It is not enough to ask, 'What is happening to the bee to cause this crisis?' Instead, there is a more fundamental question: How has the changing relationship between bees and humans brought the modern bee into existence in a way that has made it vulnerable to new threats? (*ibid*. p. 651)

Kosek details some of the 'remakings' of the modern honey bee over the last century that reflect this changing relationship between honey bees, beekeepers, and the agricultural communities that rely on their pollination services. Social and ecological drivers have shaped honey bees' exoskeleton, their nervous systems, digestive tracts, and collective social behavior. He points out that there are "many sites (from federal laboratories to the backyards of beekeepers), as well as many pressures (from industrial agriculture to global climate changes), involved in the remaking of the bee" (*ibid*. p. 651)

Recent social science research has aimed to highlight some of the sites and pressures that have remade honey bees into a more vulnerable species. Single-cause explanations about what contributes to honey bee vulnerability—such as a particular pesticide or mite—are increasingly considered insufficient given the varied complexities of environmental and political change (C. Phillips 2014). To contextualize some of these complexities, recent social theorists have joined the conversation on honey bee declines, applying a critical lens to the factors contributing to honey bee vulnerability.

Suryanarayanan and Kleinman's collective body of research, as well as that conducted by Maderson and Wynne-Jones (2016), brings attention to not only the 'hierarchies and exclusions' of knowledge in policy making (Maderson and Wynne-Jones 2016, 94), but also the way that social processes shape regulation, science, and ultimately land management practices that either hinder or protect honey bees. These processes emerge, in part, because the system of industrial agriculture prioritizes the input needs of industrial agriculture (such as pesticides) over beekeepers' need for a toxin-free environment for their bees (Suryanarayanan and Kleinman 2017, 71).

Becoming industrial pollinators has also meant that beekeepers are serving an industrialized, monoculture agriculture (Nimmo 2015), and in many ways, this form of agriculture has remade bees in its own image. As James Scott once noted, "Cultivation is simplification" (Scott 1999, 254), and simplification necessarily implies the subsequent loss of resiliency and increased vulnerability (Boyd 2001, 663). For example, William Boyd traces the broiler chicken's transformation into an agro-industrial commodity, particularly how chicken breeds were reconfigured to meet the needs of the meat industry (ibid., 652). And yet, though breeding efforts succeeded in "extending the biological potential of the chicken," these efforts resulted in distinct trade-offs that resulted in genetic susceptibilities and breed performance (ibid., 661).

Similar to the conclusions drawn from Boyd's broiler chicken analysis, I argue that simplifying the honey bee for almond production has made it more vulnerable in turn. Though honey bees are categorized as livestock and their production has been intensified and industrialized in ways reminiscent to the broiler chicken, as a commodified nature honey bee mobility and reproduction pose barriers to capital development that make it challenging to produce them industrially. Though the process of commodifying any nature is problematic, contradictory, and rife with barriers to capital, I argue that honey bees are particularly "unruly" natures that submit less easily to capital production than other forms of livestock.

What is an unruly nature? On the one hand, the term captures the way nature challenges human efforts to control and dominate it:

> By implying that natural forces have somehow broken human rules, the term unruliness reveals a deep-seated belief that humans can and should dominate the world around them. Unruliness emerges when environmental conditions disrupt human efforts to impose order, often creating fear and financial loss. (Krishnan, Pastore, and Temple 2015)

While all fictitious commodities pose barriers to capital, the materiality of some natures offer more resistance than others, a quality that implies an unruliness against industrialized production in particular. As mentioned in the introduction, "unruly" natures might be resource frontiers not yet fully governed under the authority of the state because they pose a particular challenge to capital, and even inspire alternative management regimes (Karlsson 2011, 6). Unruly environments are "places difficult to control and categorize", spaces and natures that "remind us of the limits of environmental control in an era of technological and institutional hubris." (Krishnan, Pastore, and Temple 2015, 5). Nature's unruliness thus poses a challenge to the domestication and domination inherent in capital development, and constitute the "edges and seams of imperial space" that challenge capital's purview and traditional property regimes (Tsing 2012).

Though honey bees and almond trees have long been domesticated alongside humans for millennia, honey bee mobility and reproduction make industrialized production far more difficult for honey bees than broiler chickens, and particularly the almond trees they pollinate. Bees are also highly mobile, which is why they are commodified in the first place (to pollinate crops and produce honey). However, this mobility is also an unruly quality that leads to their vulnerability. For example, bees can fly into neighboring properties where toxic pesticides have been applied. Bees' reproductive needs are also unruly: queen bees require an airborne mating flight with a multitude of often male drone bees, some of whom are likely feral or could have undesirable genetic properties, like Africanized bees. This makes it challenging to breed bees that are both docile, and resistant to *Varroa* mites. In addition, bees often fly into other colonies when these colonies are situated closely enough, which makes it easy to spread pathogen and pests. As such, I frame honey bee vulnerability as not only the result of intensified production, but as a barrier that resists capital development because of bees' "unruliness" as well.

Loose regulation and cheap honey imports drive down honey prices

In the dissertation introduction, I argued that three major processes drove East Coast and Midwestern beekeepers into almonds in 2004-2007, a process that led to a spike in pollination fees and incentivizing beekeepers to prioritize producing bees for almond pollination. The first process was lost access to a diversity of forage where beekeepers could produce honey, a process detailed in Chapter Five. The second reason was the loss of citrus in Florida due to growers applying bee-toxic pesticides on citrus. Citrus honey production occurs at the same time as almond pollination, so when this honey (and income) source dried up, beekeepers with enough capital to ship their bees were available to pollinate almonds as well.

In this section I discuss the third reason: low honey prices that made it challenging for beekeepers to recoup the costs of production. In this section, I argue that the price of honey declined in large part because the National Honey Board's promotional efforts, coincided with loose honey regulation and incentivized the importation of cheap (sometimes adulterated) honey that cheapened the price of honey on the market. I discuss the policies that underpinned these processes and its effect on beekeepers as well.

To understand why the National Honey Board was established, it is helpful to examine an earlier policy implemented 40 years earlier in the 1940s, the Honey Price Support Program. After the 1940s, U.S. beekeepers experienced a sharp decline in honey demand and subsequent loss of colonies nationwide. This was problematic for the nation's agriculture system, because managed bees were also needed for agricultural pollination services (Muth et al. 2003). Beekeepers argued to legislators that they needed economic support to keep their colonies alive for these services (Horn 2005, 203).

To address this, Congress legislated a honey price support system, the Agricultural Act of 1949, to help support the flagging beekeeping industry along with several other commodities (Sullivan 1980). The House Committee on Agriculture justified the Honey Price Support program by stating:

> Since the close of the war, the price of honey has dropped to the point where beekeepers are finding it impossible to obtain their costs of production…If these vitally important insects are to be maintained…the beekeeping industry must have immediate assistance. Until the time comes when beekeepers can receive an adequate return from pollination services, the committee believes that a price support program for honey, as provided in this bill, is the only answer to this problem. (Ibid.)

In this quote, the House Committee essentially acknowledges that the price of honey has dropped so steeply that beekeepers cannot make enough profit to cover their costs of production. This was particularly problematic in the late 40s because bees were needed to pollinate legume seeds for farmers looking to replenish nitrogen in their soil after planting nitrogen-depleting plants throughout the war (Muth et al. 2003, 482–83). Prior to the war, wild bees had provided this pollination service, but due to the use of new insecticides, the destruction of wild bee habitat, and the drainage and burning of fence rows for intensive farming during WWII, wild bees were no longer able to provide this service (ibid.). Thus, until beekeepers could make enough money providing pollination services to secure their operations, the honey support program would help subsidize the industry.

Under the honey price support program, beekeepers could use their honey as collateral to obtain a loan from the Commodity Credit Corporation—a government owned and operated entity created to stabilize, support, and protect farm income and prices (ibid., 484). If they were able to sell their honey above the designated support price, then they would pay the loan back, plus interest. If they were unable to sell their honey above the support price, they could forfeit the honey to the government and keep the original loan proceeds (ibid., 484-485).

From 1952 to 1970, hardly any beekeepers forfeited honey to the government. Economists argue that this was because the price of honey on the global market was always higher than the government's support price (ibid.) and beekeepers had no incentive to forfeit their honey since they could sell it on the market for a more competitive price (ibid.).

Things changed from 1981 to 1988, when forfeitures to the CCC rose dramatically, averaging around 100 million pounds annually from 1983 to 1985 (ibid., 485). These forfeitures largely occurred because the support price had increased to a point where it exceeded the honey price beekeepers received on the global market (ibid.)[24]. At the same time, there were almost no restrictions on imports, so domestic honey purchasers bought less expensive imported honey, which increased continued imports in turn, exacerbating the problem for domestic beekeepers (ibid.). During this time, some producers used their honey as collateral to obtain a loan from the CCC, then received the loan rate and used the funds for operating expenses. Finally, they would forfeit on the loan when they were unable to sell their honey at a price above the price support loan rate (ibid.). As a result, the CCC eventually developed large stock piles of forfeited honey from beekeepers who had defaulted on loans (ibid.). By 1985, it owned over 72% of the domestic honey stock, even as large volumes of honey were being imported from abroad (Forker and Ward 1993, 134).

In response, beekeepers requested that Congress authorize the establishment of a research and promotion (R&P) board in 1984, the Honey Research Promotion and Consumer Information Act (98th Congress 1984). The National Honey Board would collect an assessment from U.S. beekeepers to apply towards generic marketing as the USDA orders required, and hopefully create demand to move the government stock (Forker and Ward 1993, 85).

The Honey R&P is different from the almond industry's federal marketing order in several key ways, though there are many similarities, which are helpful to review first. Both programs are authorized and overseen by the USDA's American Marketing Service (AMS), and both are funded by industry assessments collected from packers or handlers who market or sell the commodities. For example, the current assessment rate for honey is $0.015 per pound of honey (USDA AMS 2019), and any honey packer or handler (a commercial operator who packs and sells honey), must pay this fee to the National Honey Board, while almond handlers pay their fee to the Almond Board (ibid.). Much like the Almond Board, the National Honey Board collects the funds and then uses them to maintain and expand markets for the commodity through

[24] For a detailed explanation of this process, see (Muth et al. 2003).

"research and development, advertising and promotion of honey and honey products, consumer education, and industry information" (ibid.).

However, the two regulations have different sets of "tools" in their "toolbox" (USDA AMS 2017)—and the federal marketing order's tools are more comprehensive. While both are designed to provide funds so the industries can create and maintain markets, the National Honey Board—and commodity R&P programs more generally—can only focus on research and promotion. With a marketing order, the industry can not only fund marketing and research, but also impose quality regulation through standards on products shipped. In addition, they can control the volume of product on the market to ensure market stability, and also impose quality regulation on imported commodities to ensure that high quality products are on the market (USDA AMS 2017).

Several beekeepers shared with me that the decision to agree to the R&P assessment and creation of the National Honey Board (NHB) was a contentious one that divided the industry. Back in 1969, a faction of beekeepers in the American Beekeeping Federation (the only national beekeeping organization at the time) disagreed with pursuing the R&P, and split off to form what is now the only other national beekeeping association, the American Honey Producers Association (AHPA) (AHPA 2018 and personal communication). Their contention was that the marketing order would be detrimental to beekeepers and keep the price so low that beekeepers would be unable to stay in business (ibid.).[25]

Their concerns were prescient. From the 1960s to 2012, U.S. beekeepers saw a 40% decline in honey production, while honey demand rose as a result of NHB's marketing (Ward 2014, 5). As this production declined, honey imports began to rise significantly during the 1980s, dropped off for a few years, and then steadily climbed through the 2000s (ibid.). Figure 3.2 thus tells an interesting story. When U.S. beekeepers first floated the act in the mid 1960s (the far left of the

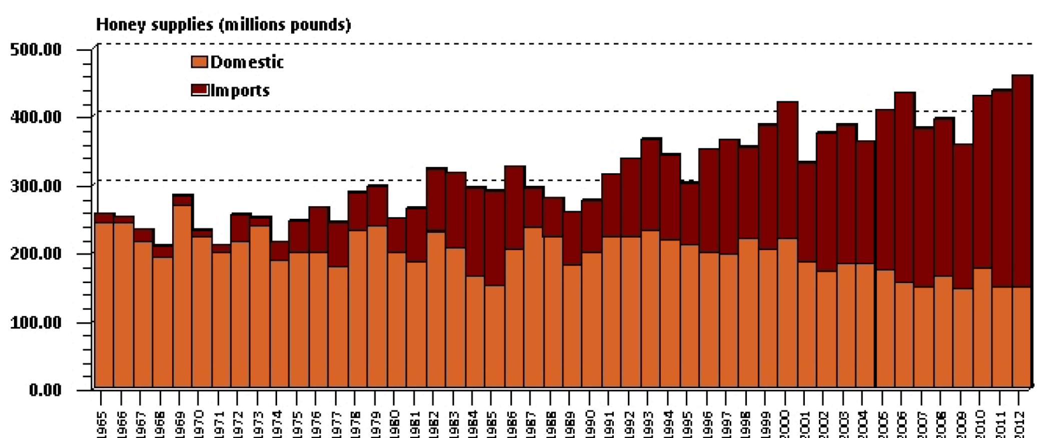


Figure 3.2: Honey supplies in the U.S., domestic and imports (Ward, 2014, p. 7). In 1965, imports accounted for 5% of domestic supply, but by 2012, imports accounted for 68% of the total supply. (Source: Ward, 2014, p. 7)

[25] I attended the annual AHPA meeting in January 2019 and in both several presentations and numerous informal interviews found that the beekeepers in this association still felt the research assessment played a role in their struggle to make money as honey producers.

graph), they were supplying 95% of U.S. honey supply (ibid., 7). In the early 1980s, when the Act was proposed again to Congress, beekeepers were still providing the majority, approx. 70% of the nation's supply (ibid.), and still ostensibly benefited from NHB marketing.

However, in the years that followed, honey imports grew, and beekeepers had little regulation to protect their domestic, more expensive honey from these less expensive cheaper imports, which increasingly came from China. For example, from 1989 to 2000, Asia suppled 36.5% of the imported honey, while South America supplied over 40%. Then, from 2000 to 2012, Asia's supply grew to 47.6% of the imported honey—a volume increase of over 135% (ibid.). This flood of cheap honey subsequently drove the market price of honey down as some beekeepers had feared.

Beekeepers noticed these trends and began to take regulatory action to protect their market. In 1994, the American Beekeeping Federation and the American Honey Producers Association filed a petition with the U.S. International Trade Commission (USITC) alleging that the U.S. honey industry was threatened by Chinese imported honey (Strayer, Kennedy, and Everstine 2014). The USITC reviewed these claims, and then in 2000 imposed an antidumping[26] tariff against Chinese and Argentinean honey (also suspected of dumping), and in 2002, Europe passed a tariff against Chinese honey as well, which led to a surplus of Chinese honey on the market (ibid., 11).

The tariffs seemed to work. Honey imports from Argentina and China into the U.S. both dropped to 4% in 2002 (ibid.). At the same time that Chinese honey shipments seemed to be declining, there was a parallel increase in honey imports from countries that historically did not produce or export large amounts of honey (ibid.). It turned out that, to avoid the large tariffs, Chinese honey manufacturers had set up transshipment routes to the U.S., in other words, they were transporting honey through intermediary countries to conceal the true country of origin.

This process is also referred to as "honey laundering" (ibid., 9). Chinese importers would simply ship it through Thailand, India, or Malaysia to get it through customs. A report conducted indicated that nearly a third of the U.S. honey supply is honey smuggled in to the U.S. from China using transshipping methods (Schneider 2011), and quite a few news reports document honey smuggling/laundering as well (e.g. Olsen 2017; Philpott 2011). Not only is Chinese honey's origin concealed, it is often adulterated as well. In fact, honey is the third most adulterated food imported into the U.S. (J. C. Moore, Spink, and Lipp 2012). Honey is often adulterated with antibiotics, cut with corn or fructose syrup, or simply not honey at all (J. C. Moore, Spink, and Lipp 2012; Strayer, Kennedy, and Everstine 2014).

Figuring out how to identify a honey's location has proven difficult because pollen traces offer the only fingerprint to a honey's origin. Many Chinese honey packing companies use a process known as ultra-filtration or ultra-purification to remove any pollen so that the honey will not crystalize, a trait that U.S. consumers prefer (Olmsted 2016). Because of consumer preference, U.S. honey producers also use this process, despite the fact that it is contested by one of the leading national beekeeping organizations, the American Beekeeping Federation, which defines honey as containing pollen (ibid.).

[26] Market "dumping" is defined as exporting large quantities of a commodity at less-than-market value (Strayer, Kennedy, and Everstine 2014).

One challenge that the NHB poses to beekeepers is that, like federal marketing orders, the NHB can only generically promote honey as a commodity, and cannot promote any particular brand, or even domestic honey over imported honey. So, although the NHB's efforts have increased consumer demand for honey (Ward and Boynton 2010, 24–25), and although the demand for honey has grown over the years, U.S. producers can only fulfill one quarter of this demand. This has left a large supply gap for importers to fill, without proper regulatory oversight to stymie the flow of cheap honey that lowers the price of honey on the market. This has made it increasingly challenging for beekeepers to maintain their operations off honey production alone.

Some beekeepers also do not feel represented by the National Honey Board. The NHB is entirely funded through assessments levied on honey packers and handlers, not beekeepers. The 10 members of NHB are appointed by the Secretary of Agriculture and consist of three handlers, two importers, one importer-handler, three producers (beekeepers), and one marketing cooperative representative (National Honey Board 2019). This demonstrates how a majority of the Board ultimately represents handler, packer, and importer interests, with the beekeeper in the consistent minority. The almond industry's Almond Board, for comparison, is composed of 50% growers and 50% handlers.

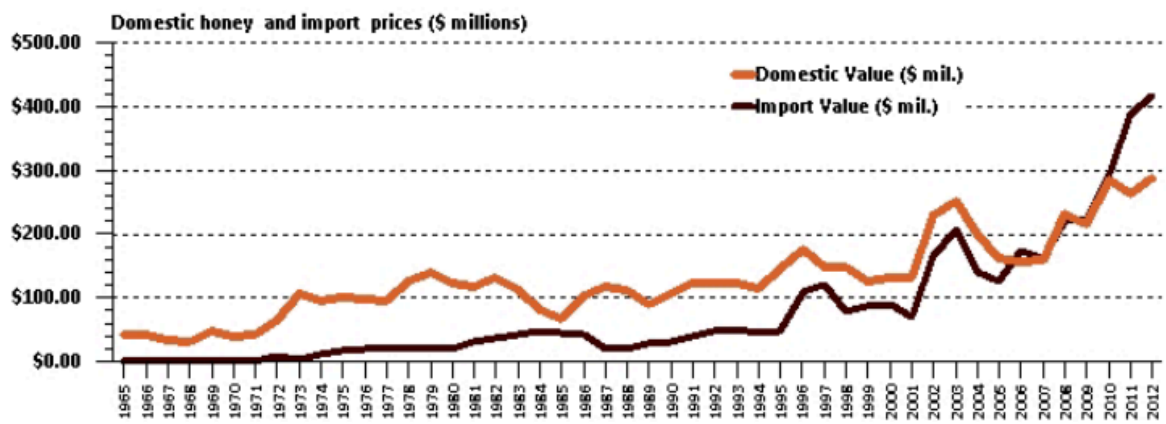


Figure 3.3: The price of domestic and imported honey 1995-2012 (Ward, 2014, p. 10)

At a national conference in January 2019, several beekeepers argued that honey packers stand to make greater profits off of cheap imported honey, which they can resell at U.S. market prices. This has made it challenging to lobby for changes to the R&P Act to support the marketing of domestic honey. It also makes some of these beekeepers feel that the NHB actually works against their own interest by promoting honey writ large, without educating consumers about the fact that the cheap honey they buy at the grocery store might not be honey at all. The NHB's marketing efforts have helped increase the price of honey over time, however, as evidenced in Figure 3.3 and through independent research (Ward and Boynton 2010). Yet when I talked to beekeepers, they explained that while the price of honey may be rising, the increases in prices do not keep up with the rising costs of producing bees—costs that I demonstrate in the sections that follow.

This section demonstrates several points. First, federal regulations are established in a way that ultimately prioritizes the concerns of honey importers and honey packers over those of beekeepers. The Board is composed of 2/3 importers and packers and 1/3 beekeepers, ensuring that beekeepers' interests are in the minority of the Board's decision-making processes. Additionally, loose regulation of imported honey has allowed cheaper, adulterated honey to flood the market, and beekeepers cannot keep up with these prices given their increased expenses in labor and inputs to manage their increasingly vulnerable bee colonies.

So, while the NHB's efforts have successfully contributed to an increased demand for honey over time (and a subsequent rise in prices), beekeepers argue that it has remained lower than the cost of production for beekeepers. This is why so many beekeepers feel driven to pollinate almonds, because the honey market prices have not kept up with their costs of production and they need additional sources of income to make up for their production costs. Yet despite the welcome income from almond pollination, producing bees for almonds is not easy, and has played a role in increased honey bee vulnerability. I detail this further in the following section.

The Challenge of Producing Bees for Almond Pollination

To understand why it is challenging to produce bees for the almond industry, it is helpful to consider this: the greatest number of bee colonies coming to California in February are from North Dakota, Idaho and other northern states, followed by Florida and Texas (Figure 3.4). Before almond pollination was a real option for beekeepers, beekeepers struggled to keep bees alive during long, cold winters. As a result, if beekeepers were not planning to pollinate almonds in the spring, then it was fairly common practice after a summer of honey production to either sell their bees to a beekeeper in the south, or to euthanize a portion or all of their colonies—an almost unthinkable prospect given the context of the current public sentiment to "save the bees."

Keeping bees alive through a long, cold winter is an input and labor-intensive affair. Northern beekeepers have to make sure that their bees do not starve or freeze through a winter that can last as long as four to six months. To stave off starvation, beekeepers have to choose between letting their bees consume their high-quality honey or harvesting most of that honey and leaving some

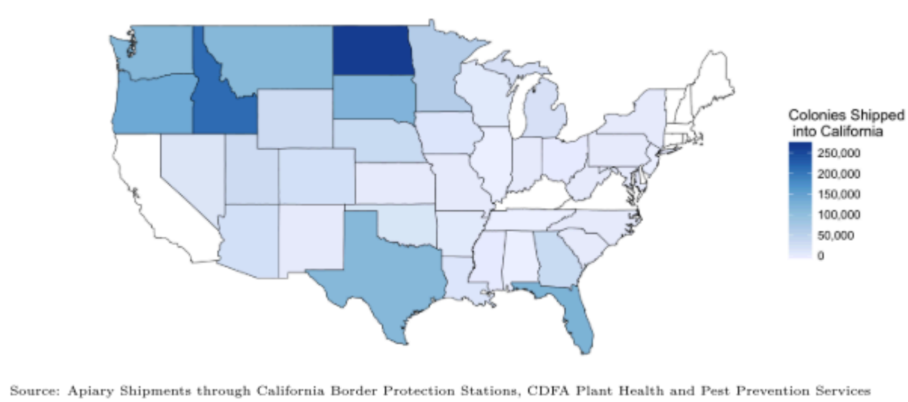


Figure 3.4: Honey bee colony shipments into California by state of origin (Goodrich, 2017, p. 146).

behind and supplementing the rest with sugar syrup, which can also be expensive. On top of that, beekeepers must provide shelter for the bees or they might freeze to death. Some beekeepers still keep bees in large, temperature-controlled potato cellars or warehouses, but these options are expensive, and tend to only work for highly capitalized operations. The storage space must be properly ventilated and temperature controlled, or the bees might overheat it and/or produce enough excess carbon dioxide that they suffocate.

Given this calculation and cost, if a northern beekeeping operation did not send its bees to California or a warmer state for overwintering, they might have euthanized their bees through various methods (Cheung 1973, 16:14), and then bought a fresh 'package' of bees in the spring from a bee breeder, which included a new queen and approximately 10,000 bees that the beekeeper could place in an empty hive. Note that these are not archaic practices; beekeepers in Canada, Alaska, and other northern states that do not participate in almond pollination may still euthanize their bees. In Alaska, for example, over half of the state's beekeepers euthanize their bees every winter (Hillman 2012).

As the almond industry boomed and became an economic opportunity for beekeepers, bees and the pollination services they provided became increasingly valuable. It no longer made sense to sell or euthanize bee colonies, because growers and beekeepers needed bees ready by February—not April or May, when a package of bees would have built up enough strength to pollinate an orchard. This meant that beekeepers had to transition their operational strategies from euthanizing or selling bees at the end of the year to keeping them alive over winter, ready for an early pollination in California. This brought a whole new host of challenges and management practices for beekeepers to master, which I detail in the following sections.

Figure 3.5: A package of bees about to be installed

Minimum frame counts incentivize intensified bee management

By 1983, Matt Thompson's family decided to transition from a sedentary operation to a migratory one, and their family sent their first batch of colonies to almond orchards. Matt helped build pallets for the colonies, which made them transportable. He added a forklift "mask" to their family's 1950 pickup truck so they could load the pallets of bees on a flatbed truck (four or six colonies to a pallet), and ship them to California. It was an exciting moment for Matt and his brothers. They were able to spend the winter somewhere warm, and the bees did so well in California that by the time they got back to Idaho, they were ready to start splitting[27] their

[27] Splitting a colony is when beekeepers divide one colony into two or three new colonies.

colonies and preparing them for honey production. However, Matt's family quickly realized that they would have to shift their management practices to have their colonies up to almond growers' standards:

> Growers wanted big hives, and they were inspecting even in those early years, because to them $20 was a huge amount of money to pay for a beehive. [Growers] were at least as picky then with the $20 rent as they are today with the $200 rent."

Matt's family operation started doing supplemental feeding in the fall, at first with their own honey syrup, and then with granulated sugar (2/3 sugar to 1/3 water) that they put in a vat and cooked until it made a syrup suspension. In the 1990s, they started making pollen substitute patties to feed their bees, a practice they continue at his operation. Now, Matt admits, they are feeding their bees year-round; their colonies all have feeders inside the colonies that hold a gallon and a half of syrup. Feeding their bees only stops for the period when they are in storage and when they are actually making honey—which does not include almond pollination, since they are not making honey in almonds. This shift to year-round feeding happens for a variety of reasons: a loss of available forage for bees, and an increase in colony density in areas where their operation pollinates or produces honey—both of which I discuss in Chapter Five.

One other central reason for feeding bees year-round, and particularly for feeding them right up until their short winter dormancy period, is out of an interest in getting high frame counts for almond growers. Growers want some measure of the average colony strength they are getting from a beekeeper, and the most common strength requirement is the "minimum average active frame count"—typically referred to as the average frame count (Goodrich 2017, 21). In a 2015 survey of almond growers, approximately 86 percent reported that their largest almond pollination contract had a minimum frame count requirement. Many growers hire an independent inspector to verify the average frame count through a representative inspection of the colonies (typically around 10-25% of the hives) (Goodrich 2017, 21). The industry defines an active frame as meeting one of the two criteria: bees cover at least 75% of both sides of a standard frame of comb within a hive, or there are at least four bees per square inch of comb (ibid., 18). An inspector measures colony strength by removing each frame and counting the number of active frames in the hive (ibid). At this time, the average frame count minimum is typically 8-10 frames per colony, with 10-12 as the ideal (ibid., 21 and 42).

Figure 3.6: A colony open for hive inspection

Though seemingly benign, many beekeepers interviewed cited high frame counts as an important driver in intensifying bee production. This is largely because, as mentioned earlier, honey bees typically hibernate over winter and then slowly build up their numbers by around March or April. In the 1950s and 60s, for comparison, California beekeepers in the

Central Valley typically supplied most of the almond pollination services. With no forage to feed on, frames of bees would dwindle over winter to around 4 to 5 active frames of bees—*half* the minimum required frame average now (Traynor 2017, 70; Cheung 1973, 16:14). California bee brood (larvae) would then build up in March, boosted by almond pollen if beekeepers had access to almond orchards during bloom.

The relationship between growers and Valley beekeepers was considered quite symbiotic during this period (Traynor 2017, 71), with beekeepers providing key pollination services for almond growers, and growers providing an early pollen source to help beekeepers build up their hives for honey production in the spring. Valley almond growers were paying between $1-$3 a colony (ibid.), which offered little incentive to southern California beekeepers to ship bees to the Valley for pollination services.

In the 1960s, the relationship between the almond industry and beekeeping industry changed dramatically. Research conducted by extension specialists and beekeepers demonstrated that stronger colonies distributed pollen more efficiently and resulted in stronger harvests (Traynor 2017). Almond growers slowly became willing to pay more for pollination services, and strong colonies went from $3 to $5 in the 60s, then $5 to $8 by the early 70s, rising again to $10 and $11 just a few years later (Cheung 1973, 16:23). These rising prices began to first attract beekeepers from Southern California, and then eventually Oregon and Washington as almond fees reached the same price as apple pollination fees in those states (Cheung 1973, 16:23; Traynor 2017, 71). As almond acreage increased to around 400,000 acres in the 1990s, pollination fees rose to $40/colony, attracting beekeepers from the Dakotas, Nebraska, and Texas (Traynor 2017; Cheung 1973).

Until around this time, bringing bees to almonds was still very beneficial not just for beekeepers, but for their bees. This was before Roundup Ready, the glyphosate-based herbicide, had hit the market in 1996, and also before growers started keeping the ground bare of all weeds to protect their trees from frost. One beekeeper stated, "The understory [of the almond orchards] used to be full of flowers and you'd come out of almonds with 14 capped frames of brood." (Interview, Apr. 5, 2017). What the beekeeper is saying here is that almond orchards used to be full of forage other than almond flowers (e.g. volunteer wildflowers in and around the orchards) and the pollen sources would be so prolific that beekeepers would have full frames of bee larvae because the colony would gather so much pollen, given all those floral resources.

Another beekeeper complained about the change in almonds as well. He said that somewhere around 2005-2007, growers adopted a "scorched earth" policy, and used RoundUp to kill all the weeds between the orchard rows of trees. From his perspective, "once the almond floors became clean [of flowering plants], the benefit of almonds changed" (Interview, Apr. 26, 2017). Their comments reflect the sentiment of the majority of beekeepers interviewed.

Many beekeepers I interviewed—some who still pollinate almonds and some who now do not—complained about the challenge of hitting those high frame count averages. Below, I quote a Texan beekeeper who used to pollinate almonds but now focuses only on honey production in Texas:

> California almonds turns your beekeeping operation on its head. Normally you'd manage your hives to have colonies reach peak in June 1st, even earlier in the south. Here you are trying to get a hive to 8 frames of brood and bees on Feb 10th? That's six months early—that's in the middle of winter on anybody's calendar. You're trying to make a hive do what is not natural to get it to that strength. (Interview, Feb. 28, 2017)

Many beekeepers described the process of getting bees to high frame counts by Feb 10th as "unnatural" or "unsustainable." Because of these high frame counts, beekeepers have to "push" their bees year-round; several beekeepers expressed concern that they are exhausting their bees through this process. Additionally, this type of production requires an increasing amount of inputs, which I discuss in the section that follows.

Making up for lost pollen and nectar through inputs

In order to get their bee colonies to these high frame counts for almond pollination, beekeepers began to feed their bees inputs year-round. Here, the Texan beekeeper discusses the use of inputs to get high frame counts:

> You have to push them with protein supplements—you have to push them when they don't want to be pushed. You have to make sure they have protein supplements, carb supplement, some guys use invert sugar…you just have to manage in totally different ways. (Interview, Feb. 28, 2017)

While honey (and honey substitutes) provide carbohydrates and a source of energy for bees, pollen is their only source of protein (Brodschneider and Crailsheim 2010, 282). High-quality pollen is essential for the growth and health of honey bee colonies and is believed to help bees resist or tolerate many of the stressors beekeepers face such as pesticides exposure and pathogens (Fleming, Schmehl, and Ellis 2015). Pollen is collected by foraging honey bees in pollen balls (See Figure 3.7).

Figure 3.7: Honey bee with pollen balls on hind legs. (Source: Wikimedia Commons, Ivar Leidus)

These balls are then brought back to the hive and passed along to worker bees, who pack the pollen balls into open comb cells and mix it with honey, regurgitated nectar, and salivary secretions that help ferment the pollen and turn it into a substance commonly referred to as bee bread, which has a lower pH and less starch then fresh pollen. Research suggests that lactic acid bacteria from the honey bee stomachs help with the fermentation process of the pollen and may add nutritive value (Brodschneider et al. 2016, 282) The composition of pollen varies depending on the floral composition in the landscape the pollen is collected (Donkersley et al. 2014). In addition to protein, the average composition of pollen consists of lipids, amino acids, sterols, vitamins and minerals (Brodschneider and Crailsheim 2010).

Beekeepers began to realize the importance of providing bee supplements to help their bees year-round, but particularly in the late summer and fall to help their bees have high frame counts for almonds. One Arizona beekeeper, Robert Spinner, stated that his operation never fed bees anything more than High Fructose Corn Syrup (HFC) until 2008, and the only reason they fed HFC was to stimulate brood production for almond pollination.

> The idea that every hive would be an 8-frame hive is ridiculous. If you set bees out years ago, you only had about 40% of your colonies in the best of times ready to go in February. It takes perfect conditions—*we're pushing these bees really hard to do this*. Now you have to feed them and syrup them all fall to get anything strong enough to go. They do not have vigor and it's really hard. (Interview, Apr. 26, 2017. Emphasis added.)

Spinner watched his operation change from a 50/50 ratio of income from pollination and honey production to 70/30 ratio in the 1990s, with pollination providing the majority income now, which has meant that he has to have his bees ready for almond pollination. After 2008, he started to follow other beekeeping models to feed his bees protein, transitioning from feeding 2lbs of protein patty supplements 3 times a year to a minimum of 10 pounds of supplements in the summer and fall. They would "shut down" their bees in December and let them go dormant for one month. Then in January they would crack open the hives again and start feeding another round of 5-7 lbs of protein patties again per colony to stimulate brood rearing and colony build-up for almonds: "[We were] feeding bees to build up a pollination force—if we didn't feed [them] hard, we couldn't do pollination. *Before that time, we never fed. Ever.*" (Interview, Apr. 26, 2017, emphasis added.)

Another beekeeper from the Dakotas, Pete Hendriks, started using pollen patties in 1995. Hendriks married into a beekeeping family and started working for his father-in-law in 1990. By 1993, they had moved their operation to pallets and forklifts and began going to California for almond pollination. Hendriks started feeding his bees pollen patties in part because of emerging research indicating that the supplements were helpful, but also because of his background in drag racing:

> I used to race cars as a hobby. My thing was: how can we get from point A to point B a little faster? I drew from that to think about my bees. What can we do to tweak this? How can we grow our bees better? (Interview, Sept. 28, 2017)

The first year Hendriks went to California, he was mixing pollen patties in the bathroom of his motel, in a Rubbermaid tub. They had cement trowels and ice cream scoops and would make pollen patties they could place inside of the hives: "I can crank [pollen patties] out like nobody's business" (interview, Sept. 21, 2017). His operation manages over 14k hives, and they start feeding bees in August, through winter, and into spring. When I asked if he would feed them protein through winter without almonds, he stated that they would probably feed their bees a lot less. Another beekeeper stated: "We manage for almonds. It wouldn't make sense to feed pollen and supplements if we didn't have almond contracts" (interview, Apr. 20, 2017).

Battling Mites—The challenge of killing a bug on a bug

Keeping bees alive year-round does not only entail feeding bees; it means that beekeepers have to battle pest and pathogens year-round as well. Mites have been a prime beekeeping concern since the mid-1980s and understanding the beekeeping industry during this period of intense almond expansion is impossible without understanding how *Varroa* mites have crippled the honey bee population. As mentioned in Chapter One, the threat of tracheal mites loomed over the industry for nearly 70 years before it finally struck in 1984, when the mites were detected in Texas and then quickly spread throughout the U.S., largely by the movement of migratory beekeepers. The mites were devastating for many beekeepers, but only for a few years.

Figure 3.8: Varroa mite on bee larvae (Credit: Wikipedia, Waugsberg)

Far worse was the introduction of the *Varroa destructor* mite, the current scourge of the U.S. beekeeping industry. The *Varroa* mite was first discovered in Sumatra on an Asian cavity nesting bee, *Apis cerana* in 1904, where it was considered an insignificant pest because it had likely coevolved with the parasite and adapted to keep the mite under control by adopting hygienic behavior (Navajas 2010, 375–76). It was not discovered on honey bees (*Apis meliffera*), however, until a reported finding in the Philippines in 1957 (ibid., 375). It then made its way around the world through several geographic routes, but eventually was discovered in the United States just a few years after the tracheal mite (ibid.). One account stated that they were first discovered in September 25th, 1987 by a beekeeper who supplied package bees out of Wisconsin, and those infested hives were immediately killed. It was too late, however. By October of that same year, however, they were discovered in 19 of Florida's 67 counties, and within two years were found in 19 states in the U.S. (Connor 2015).

Unlike the microscopic tracheal mite, *Varroa* mites are about the size of a light brown poppy seed and visible to the unaided eye (Doebler 2000). To describe its effect on honey bees, beekeepers often describe the mite as a giant vampiric crab on one's side, sucking blood and spreading viruses. The initial infestation occurs when female mites attach onto the abdomen of adult bees and begin feeding on the bees' fat body tissue (Ramsey et al. 2019)[28], and then enter the bees' brood cell to reproduce. Once bees have sealed the cell, the adult mite lays single eggs around every 30 hours. The nymphal mites feed on the developing bee pupae until the mites mature and leave with the newly emergent adult bee. The mites then immediately begin to spread to other bees in the colony (ibid). Because mites can easily jump from one bee to another, and

[28] Up until 2018, researchers and beekeepers thought mites were feeding on hemolymph, the equivalent of insect blood, hence the metaphor of the vampiric crab. New research indicates that mites are actually feeding on the fat body, the equivalent of the mammalian liver (Ramsey et al. 2019).

because bees commonly enter other bee colonies, mites can easily transfer to neighboring colonies as well (Peck, Smith, and Seeley 2016).

In my interviews with beekeepers, every beekeeper either placed *Varroa* as their number one or number two management problem (number two only if pesticides were at the top), typically followed by forage loss and the need to supplement constantly, discussed in Chapter Five. In the past, beekeepers described *Varroa* damage as far less virulent, meaning that they could have more mites on their bees before treatment became necessary (e.g. > 30 mites per sampled bees). Now even a small number of mites found in a mite sample (e.g. 1 to 10 mites per 300 sampled bees) can indicate impending colony collapse.

One state beekeeping specialist, James Tew*, described the mite's devastation for the beekeeping industry, which sums up how many commercial beekeepers view the mite as well:

> [*Varroa* mites are the] biggest catastrophe to befall apiculture since its establishment in this country in the 1600s…Honeybees have been through a terrible ordeal in having to learn to coexist with *Varroa* mites. In only a few years, the *Varroa* mite redesigned nearly 300 years of North American apiculture in ways akin to the dramatic way the boll weevil restructured the cotton-producing industry in the southeastern United States in the early 1920s. (Doebler 2000, 738)

At first, the statement seems highly provocative, bordering on hyperbolic. And yet, *Varroa* truly has reconfigured the industry, leading to—as Tew goes on to say—"the development of a new beekeeper." (Doebler 2000, 741). To address *Varroa* and keep their bees alive, beekeepers have had to change their approach to agrochemicals and pesticides, from something they avoided, to using pesticides in their hives. As one researcher described it: "*Varroa* destructor…has been responsible for transitioning beekeeping from one of the world's most chemical-averse agricultural industries to one of its most chemically-dependent" (Berry et al. 2013).

This transition happened gradually, as beekeepers grew desperate. One beekeeper, Sam Eaton, described how *Varroa* became an increasing challenge for their operation:

> When *Varroa* first came out, it was kind of like: "Here's the problem, and here's the answer". We prescribed a chemical strip with Amitraz; it was what they used in France. For the first few years it worked great. But eventually it went through the treadmill, and [a close beekeeping friend] began to notice resistance. Then we switched to a stronger miticide, which was nasty. We treated once a year after the honey was pulled. We put a round of strips in [of miticides] and it took out 99% of the mites. It was a "one and done" kind of thing. (Interview, Apr. 7, 2017)

What unfolded next for Eaton was a similar story for many beekeepers. As he noticed his bees developing resistance, he and many beekeeping friends started to do "home brews," where they would try using a banned chemical that often worked, called Taktic, mixed with other things like formic acid (a natural but often less effective treatment), and these combinations were fairly effective for a time. Eventually, even these chemical formulations stopped working. They had to start using multiple treatments each year, monitoring mites carefully and treating according to infestation, rather than just applying a blanket fall treatment. For Eaton, this started around 2000, when beekeeping became increasingly stressful:

> You resorted to off-label products. The mites would kill a whole hive of bees, so you got desperate. Beekeepers had to become 'independent scientists,' monitoring mite counts. Just when we thought we had it figured out, everything changed in 2006. The *Varroa* became more difficult; like they were on steroids. (Interview, Apr. 7, 2017)

Ellis points out that this is when neonicotinoids, a systemic pesticide, hit the market. He and several beekeepers pointed out this timing. However, it is also around the time when almond growers began applying insect growth regulators (IGRs) and adjuvants, both of which have noted sublethal developmental effects on honey bees (H. M. Thompson et al. 2005; C. A. Mullin et al. 2014; Fine, Cox-Foster, and Mullin 2016).

With the increased virulence of *Varroa*, not only were bees being hit with new agrichemicals outside the hive, they were being exposed to them *within* the hive as well. One beekeeper, Randy Oliver* writes about this moment and the major transformation in beekeeping management that followed:

> Beekeepers would never have considered intentionally introducing an insecticide directly into our hives; that is, until the arrival of the parasitic mites. At first the tracheal mite, and then *Varroa* [sic] devastated our operations; in desperation we abandoned our previous phobia of chemicals and soon ourselves became the major source of pesticide exposure to our bees...this sad fact initiated a new era of toxicity for the honeybee. (Oliver 2014)

Oliver documents this process in a blog post, tracing how beekeepers illegally used the chemical amitraz, a miticide, from the 1980s through 1995. Then beekeepers turned to synthetic pesticides that target mites: fluvalinate was the first (trade name Apistan or Mavrik), and then when the mites developed resistance to that miticide, they used coumaphos (CheckMite+ or CO-Ral), which mites became resistant to in 2004. However, fluvalinate is a pyrethroid and cuomaphos is an organophosphate, two of the most toxic agrochemicals to honey bees. Oliver notes how desperate beekeepers became as these treatments stopped working:

> At that point in time, the U.S. beekeeping industry was essentially thrown to the wolves, since there were no effective registered chemicals available to manage *Varroa*—forcing beekeepers wishing to save their colonies to experiment with "off-label" uses of agricultural pest control products. (*Ibid.*)

The salvation of the beekeeping industry were products containing amitraz at high doses (approximately 12% amitraz in the product), such as Taktic, which is not registered for beekeeper use by the EPA. However, many beekeepers I spoke with reported using this product, despite the fact that it is off-label, particularly when their other treatments do not seem to be working.

Beekeepers were able to use this higher concentration of amitraz legally from the late 1980s until 1993 under the tradename Miticur Bee Mite Strips, which had 10% amitraz solution (EPA 1992).

However, after some beekeepers experienced losses after using the substance, they sued the producer (Hoechst-Roussel Agri-Vet Company). The company was never able to determine what caused the losses and voluntarily rescinded their label by 1994. Now the only amitraz product EPA currently allows is Apivar, which has only 3.33% of the product (U.S. EPA 2018), but is considered more expensive and less effective to many beekeepers I spoke with. Taktic is still on the market for livestock use (for tick treatment), so beekeepers obtain it through various means[29] and continue to make their own "home brews" of Taktic and other chemicals to treat the mites.

Many beekeepers expressed that they feel up against the wall because of mites, forced to use to an illegal product because they cannot find anything else that works as effectively. One large-scale beekeeper stated that he had tried buying all legal treatments for years until nothing else worked and the off-label treatment became the most reliable. Being a large-scale beekeeper these days means that you have to figure out how to keep bees alive: You can't do it with legal products; you have to be a bit of an outlaw. You're running this big operation, so you have to do stuff that's not legal just to survive" (Interview, Mar. 22, 2017).

Treating mites is a unique challenge for beekeepers who are not only providing commercial pollination services, but also making honey for human consumption. Beekeepers have to be careful that the chemicals their bees are exposed to do not taint honey, which they worry could kill the honey market for years (Randy Oliver 2007). A recent study of 200 honey samples from around the world showed that 75% of all the samples had traceable amounts of neonics (E. A. D. Mitchell et al. 2017). Miticides in honey have not seemed to be a big problem yet, however (García et al. 1996). One study in 2009 that aimed to trace miticides in Virginian honey did not detect coumaphos or fluvalinate residues above the "limit of qualification" (0.05 mg/kg) in any of the samples (Fell and Cobb 2009). However, beekeepers continue to be concerned about the chemicals they put into their hives and its effect on the quality of honey they produce.

Miticides can have toxic effects on bees too. One beekeeper describes using synthetic miticides as a type of chemotherapy, in which miticides need to be toxic enough to kill mites, but not so toxic as to be deadly to the bees on which the mites reside (Conrad 2013, 3). In his book on organic beekeeping, he writes about bees' exposure to miticides:

> Just as with people, the long-term health and vitality of the hive is likely to be compromised from such exposure, even if such detrimental effects are not readily and immediately evident. Because long-term tests have not yet been done, we may yet find that physiological and metabolic changes occur within honey bee populations over extended periods, and these detrimental effects may become obvious over several decades of exposure. (Conrad 2013, 5).

Indeed, research indicates that miticides are negatively affecting honey bees at sub-lethal levels. Drones exposed to fluvalinate during immature development had increased mortality, reduced body weights, and tended to have lower sperm counts (Rinderer et al. 1999), while drones exposed to coumaphos had lower sperm viability as well (Burley, Fell, and Saacke 2008). Queens can also have lower body weights (which may correlate with lower viability) if reared in

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[29] One beekeeper told me to go on Craigslist and search for Taktic (to use on horses) just to see how easy it is to obtain it.

elevated levels of fluvalinate (Haarmann et al. 2002). Another study tested the sublethal effects of fluvalinate and coumaphos, and those treated with coumaphos showed decreased brood survivorship and higher adult mortality (Berry et al. 2013). There is also evidence that acaricides can alter physiological functions, immune responses, and detoxification functions which can make them more susceptible to pesticides and pathogens (Locke et al. 2012). The two miticides, fluvalinate and coumaphos, can also toxically synergize and elevate their toxicity to honey bees (R. M. Johnson et al. 2013). A USDA also study showed that the two miticides that beekeepers regularly use, amitraz and fluvalinate, had a "pronounced effect" on honey bees' ability to resist parasite infection (Pettis et al. 2013a), meaning that the miticides that beekeepers are using to control their mites are making their bees more susceptible to other parasites such as *Nosema*.

What is clear is that while these chemicals are allowed by EPA and considered nontoxic to bees, research indicates that the very chemicals beekeepers rely on to keep parasitic mites off their bees might be toxic for the bees in their long term.

How pollinating almonds exacerbates *Varroa* mites

There is a lot of tension between beekeepers on why mites have become so problematic. As mentioned earlier, some beekeepers think that systemic pesticides like neonicotinoids increase mite virulence. Others strongly disagree and think that mite overload is a management issue, and that beekeepers need to be more systematic about their mite management practices:

> Mites are constant and predictable—a constant pressure. If you lose focus and aren't vigilant [you'll have losses]. Lots of people say that mites are their biggest problem, but…I monitor. A lot of guys don't monitor. That's the advantage of being on top of things. We mix things up, we try different things: we use new comb, genetic stock, feed programs. It's like Type 2 diabetes. If you don't pay attention, it'll take you down. If you don't know you have a problem, then shame on you. (Interview, Mar. 22, 2017)

Another beekeeper gets frustrated with beekeepers who blame pesticides for exacerbating bee losses but (he speculates or gathers from conversations) do not have careful mite management and monitoring systems. "Why are mites a problem? Let's grab a mirror maybe? Perhaps it has to do with your management practices." (Interview, Mar. 1, 2017).

However, other beekeepers point to pollinating for the almond industry as a potential exacerbating factor for mite's virulence, for several different reasons. The first is that in February, 75% of the nation's commercial colonies are all crammed into the Central Valley in very high density (Goodrich and Goodhue 2016), which facilitates the spread of pests and pathogens between colonies, such as *Varroa* mites. One study tested honey bees before, during, and after almond pollination for viruses and pathogens, and found that honey bees had much higher pathogen counts at the end of almond bloom than when they first went in (Cavigli et al. 2016).

The second reason is that beekeepers are paid so much for almond pollination that they constantly need to keep bees alive for almond bloom. This means they cannot take a Darwinian approach to allowing bees to evolve a mite resistance. To undertake this, beekeepers would stop treating their bees and allow their sick bees to die off and breed mite-resilient bees from the queens in the colonies that survive and are mite resistant. A study in Sweden tried this approach over six years, and noted that the survivor colonies were smaller and more inclined to swarm than the original colonies (Fries, Imdorf, and Rosenkranz 2006). This approach is problematic for two reasons. The first is that bees are so valuable and beekeepers could very possibly lose their entire operations through this method. Secondly, bees are highly mobile and untreated bees would infect other neighboring bees—a highly inconsiderate management approach.

A third reason almonds exacerbate the mite problem has to do with the gut pathogen *Nosema ceranae*. N. ceranea is a fungal spore that causes Nosemosis, a fungal infection in honey bees. The disease affects the productivity and survival of honey bee colonies, adult bee longevity, queen bees, brood rearing and pollen collection, as well as other bee behaviors (Z. Huang 2012) (Botias et al, 2013). When bees have mite infections, they often become more susceptible to *Nosema*. One stressor that exacerbates *Nosema* is fungicides, the primary pesticide used in almond orchards while honey bees are pollinating almonds. In a USDA study (Pettis et al. 2013a), honey bees fed pollen that contained the fungicide chlorothalonil were *three times* more likely to become infected when exposed to Nosema compared to control bees, and the fungicide pyraclostrobin had a significant effect as well. Another study shows that bees weakened by Nosema may have a more difficult time defending against *Varroa* mites (Bahreini and Currie 2015).

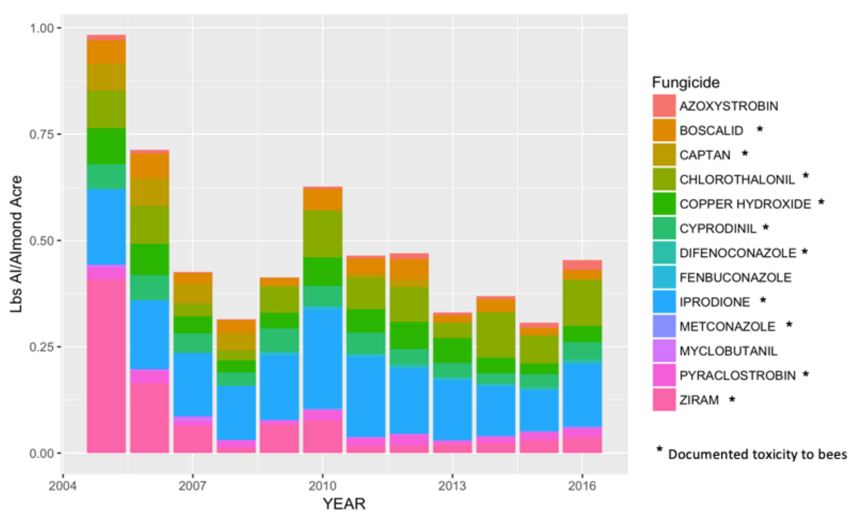

Figure 3.9: Top fungicides applied during almond bloom (Durant and Goodrich, in prep)

While the study did not investigate almond pollen, in a study I conducted of pesticide use in almond orchards chlorothalonil was one of the top applied fungicides to almonds during almond bloom (when bees are in almonds), and pyraclostrobin was in the top ten applied fungicides (Durant and Goodrich, in preparation) (see Figure 3.9). These findings all point to a connection between fungicides sprayed in almonds while bees are present, and honey bees' subsequent increased vulnerability to *Varroa*. In addition, beekeepers tend to treat Nosema with antibiotics; in fact, some prophylactically treat their bees with a powdering of antibiotics, typically

Fumagillin, seasonally throughout the year. Unfortunately, research indicates that these antibiotics also increase honey bee vulnerability to Nosema by altering their beneficial gut bacteria (Hong Li et al. 2017; W.-F. Huang et al. 2013), presenting beekeepers with an additional challenge to keeping their bees alive and healthy.

Lastly, a recent study on mites revealed that mites are feeding on bee fat bodies, equivalent to the mammalian liver (Ramsey et al. 2019). This has important implications, because bee fat body tissue helps bees detoxify pesticides (Landa et al. 1991) and research has demonstrated that Varroa-infested honey bees suffer more damage from pesticides that in other circumstances would have been biologically inert (Blanken, Van Langevelde, and Van Dooremalen 2015).

How almond pollination shaped honey bee queen production

Another key link between almond pollination and the virility of the *Varroa* mite is through the production of honey bee queens. Some beekeepers that I interviewed who do not pollinate for almonds pointed to almond pollination as a key reason that mites persist, in part because of how this has shaped the production of honey bee queens. One beekeeper, a queen breeder of Russian honey bee queens in the Midwest, argued that producers who pollinate for the almond industry demand a particular kind of bee for almond pollination, and this shapes the production of honey bees industry-wide:

> The California [beekeepers] out there [pollinating] almonds started selecting queens that produced more bees because that's what their customer [commercial beekeepers] wanted, because that's what *their* customers wanted, the almond growers. Growers want frames that are 10 frames [of active bees] or better**.** So, beekeepers were pushing queen breeders to select for bees that raise more bees. (Interview, Apr. 27, 2017)

In other words, because almond growers want high frame counts, beekeepers are prioritizing honey bee queens that produce a lot of bees by February, but only two subspecies of bees—the Italian and Carniolan bees—are capable of this. I discuss the implications this has for honey bee vulnerability in the following sections.

Bottlenecks that limited honey bee genetics

To understand why beekeepers have whittled down their bee stock to these two primary subspecies, it is helpful to trace several genetic bottlenecks that have limited the honey bee gene pool in the U.S. As mentioned in Chapter One, the 1922 Honey Bee Act limited the importation of foreign honey bee stocks to stave off the beekeeping industry's exposure to tracheal mites. While it successfully limited the spread of tracheal mite for nearly 70 years, it also simultaneously prevented the continued importation of other global bee stocks that could diversify the honey bee genetic pool and created a "genetic bottleneck" on the U.S. honey bee population (Cobey, Sheppard, and Tarpy 2016).

Another important bottleneck was the introduction of *Varroa* mites, which has not only contributed to crippling annual losses for beekeepers but has devastated the feral bee population a well (Cobey, Sheppard, and Tarpy 2016). Feral bees, honey bees that likely swarmed and then repopulated in the wild, have long flourished and helped play a significant role in pollinating crops (Doebler 2000, 739). In addition, they were a vital source of honey bee genetic diversity, given that some of these populations were ancestors of the eight diverse subspecies imported before the Honey Bee Act (Sheppard 2012). However, because they were not actively managed and treated for tracheal and *Varroa* mites, their populations were nearly decimated, and have not been able to serve as a genetic reserve for bee breeders.

Varroa mites not only decimated the feral population, they also played a role in consolidating the commercial queen breeding industry in the U.S. to just the Southwest and northern-central California[30] (see Figure 3.10). The California queen breeders have taken prominence as mites and Africanized bees have hobbled the strength of Southern operations. Many queen breeders in the South were decimated by tracheal mites in the mid-80s once *Varroa* mites were discovered in the U.S. Then Canada—whose honey producers were major purchaser of bee queens and packages to start their colonies back up after winter—closed the border to all queen bee and colony package imports in the late 1980s. This devastated the queen breeders and nearly destroyed the queen rearing industry in northern California. However, the mite losses ended up working in their favor, and the breeders were able to start supplying packages and queens to U.S. beekeepers whose operations had been toppled by tracheal and *Varroa* mites.

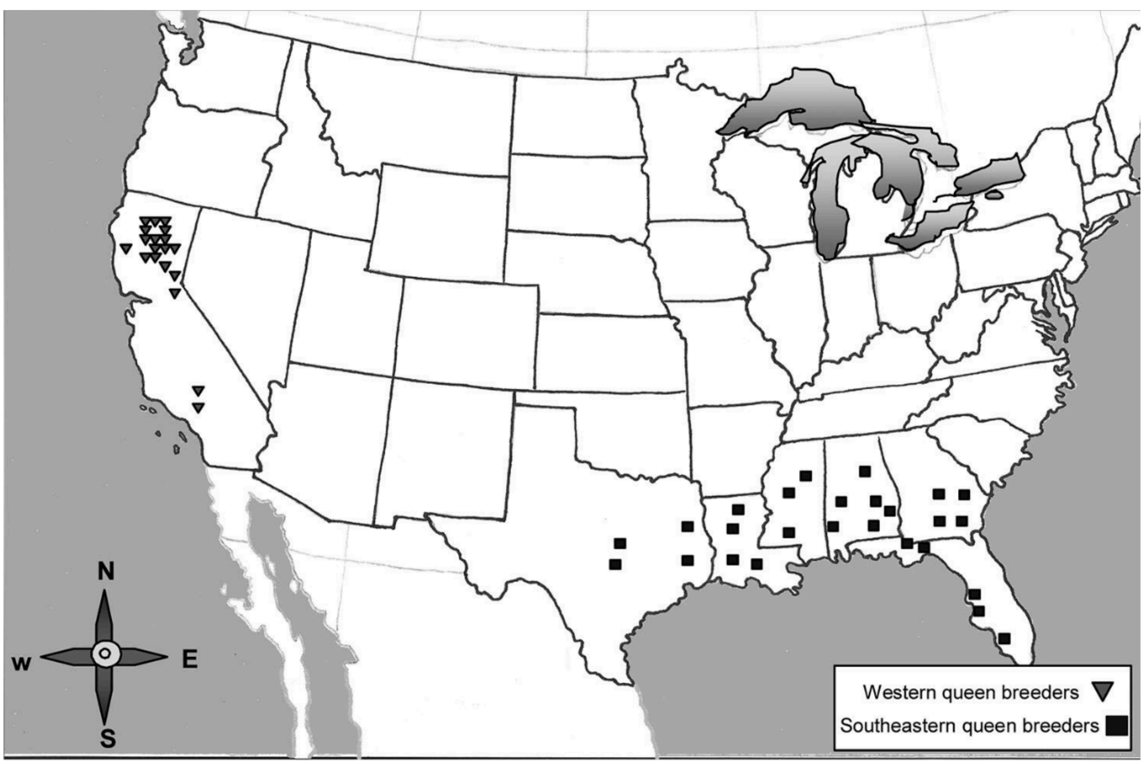

Figure 3.10: Locations of Western and Southeastern queen breeders (Delaney et al. 2009, p. 667)

In addition, Africanized bees are further encroaching near the southern border, threatening the viability of southern queen breeding operations. As a result, the northern California queen industry has become the primary source of commercial bee queens in the U.S., and now supplies the bulk of approximately one million honey bee queens that restock the 2.4 estimated colonies

[30] Specifically, Butte, Colusa, Glenn, Tehama, and Shasta counties.

nationwide (Cobey, Sheppard, and Tarpy 2016, 44). Southern state beekeepers are the next major queen-producing areas, with the majority of operations from Florida through Texas (Delaney et al. 2009).

This geographic consolidation limits genetic diversity in part because the queens are drawing from a limited pool of drones (male bees), and thus a limited pool of genetically diverse sperm. A honey bee queen has only one mating period, where she obtains her lifetime supply of sperm (Baer et al. 2016). During this mating flight, the virgin queen will typically fly to a "drone congregation area" where drones will mate with her mid-flight. She will typically be inseminated by 6 to 50 drones in mid-air (Delaney et al. 2009) over the course of one to four mating flights and end up storing up to 6 million sperm, giving her a fecundity of approximately 1.7 million eggs for a life span of up to eight years (Bozina 1961).

Because nearly all commercial queen breeders are consolidated in one to two regions, the managed and feral drones that provide genetic diversity are highly limited to the stock in that area. Lastly, not only are the queen breeders geographically consolidated, breeders draw from a relatively small sample of mated queen mothers for their propagation, approximately 500 queen mothers for over a million daughter queens (Schiff and Sheppard 1996; Delaney et al. 2009) providing yet another genetic bottleneck for honey bee diversity as well (Cobey, Sheppard, and Tarpy 2016).

Breeders are trying to address the Italian honey bees' genetic limitations by breeding queens that have hygienic traits. A hygienic colony is able to detect and remove ill or distressed bee larvae. Hygienic bees typically have less American foulbrood and chalkbrood, and also will have fewer *Varroa* mites (Spivak and Reuter 2008).

Figure 3.11: Pouring liquid nitrogen into cans to test for hygiene (USDA ARS 2001)

One way that researchers and queen breeders can test a colony for hygiene sensitivity is to test for how quickly a colony removes dead honey bee larvae (brood) (USDA ARS 2001). First, the beekeeper cuts both ends off a tall soup can into a tube, or uses a PVC pipe, and places a section of it into the wax of frame of brood. Then the beekeeper pours liquid nitrogen into the can (Figure 3.11). The brood within the can will be frozen, but the rest of the brood will be healthy and untouched. The beekeeper then places the brood back in the colony for 48 hours to allow the colony to clean out the dead cells. Finally, the breeder pulls the frames back out and observes how many dead brood within the frozen circle have been removed. If the colony removes over 95% of the freeze-killed brood within 24 hours over two repetitions, it is considered hygienic (Figure 3.12). The beekeeper would likely mark the hygienic queen and use it as a breeder to breed future lines of hygienic queens.

The breeders I interviewed were using hygienic queens that they had cultivated, often daughters of those originally cultivated by Minnesota Bee Lab, a subspecies referred to as the Minnesota Hygienics (Spivak and Reuter 2008). The challenge of maintaining this hygienic quality, however, is that breeders cannot control the mating flight, so if the queen mates with less than 50% of drones who are not from this stock, then the recessive trait will be lost in the next generation (ibid., 1085). Unfortunately, it is very hard for any breeder to control for this, given the unpredictability of the mating flight and the drones whose semen will populate the queen.

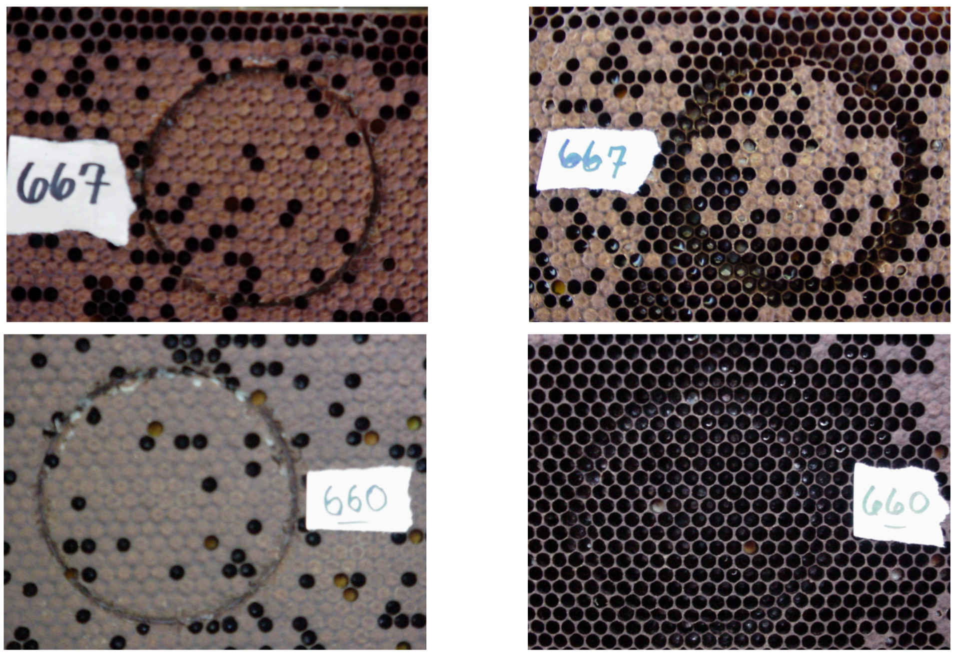

Figure 3.12: Before (left) and after (right) photos of dead brood removal. The non-hygienic stock is on the top, and hygienic stock on the bottom. (USDA ARS, 2001)

Almond pollination serves as an additional genetic bottleneck

Given honey bees' current vulnerability and the need for inherently more hygienic stock, USDA has been granting scientists permits to bring in new subspecies to diversify the honey bee population and support queen breeders. One strain that has gained popularity due to its resistance to *Varroa mites* are the "Russian bees" (*A.m. caucasica*). Imported in 1997 from far-eastern Russia by the USDA's Honey Bee Breeding, Genetics, and Physiology Laboratory in Louisiana (E. Rinderer et al. 2000), Russian bees are considered highly hygienic and much more resistant to *Varroa* than Italians.

Beekeepers describe Russian bees and Italian bees as having very different personalities. One Russian queen breeder in the Midwest described their differences:

> Consider the difference between a Doberman and dachshund. They're both dogs, both eat dog food, both poop dog poop—do dog things. But you don't let the Doberman hop in your lap. You don't put the dachshund out to guard your property. But you feed them the same and do everything the same. Russian and Italian bees are the same, but Russian bees

> respond [more] to the environment. If pollen and nectar are available, they'll raise brood. If pollen and nectar stop, they stop raising brood. (Interview, Apr. 27, 2017).

The breeder described an instance where he opened the colony up in early spring and saw a frame of eggs (brood), and then a "cold snap" weather event occurred. The Russian bees ate the eggs and the young larvae because, he explained, they are resource sensitive, and "judge the amount of available resources and compare it to the need". He explained: "Source and sink—if they can keep those in balance, then they'll do fine. But if the source is less than needed for the sink, they'll reduce the sink. Italians, however, lay eggs. That's just what they do." (Interview, Apr. 27, 2017).

This final point that the breeder makes about Italians—that they are known for laying eggs—is key to understanding how almond pollination shapes the production of vulnerable honey bee queens. Nearly every commercial beekeeper I interviewed that pollinates for the almond industry gets Italian queens because they are prolific breeders, which can help beekeepers get higher frame counts for almond pollination. While subspecies like Russian bees exist that would provide genetic diversity and resilience against *Varroa*, these bees simply do not build up their numbers in time for February almond pollination, even if stimulated with inputs:

> It's not a limited genetics problem, it's a genetic limits problem. The Russian genetics limit their use in pollination. One of the single biggest hindrances to having Russian bees integrated [into a commercial operation] is their lack of ability to produce huge brood nests by the first week of February. (Interview, Apr. 27, 2017)

I interviewed four different commercial bee breeders in Northern California and each breeder confirmed this perspective. Every almond pollinating beekeeper also expressed their inability to manage Russian bees: "I just can't get them pumped fast enough for pollination. I can't pump them up. In the summer they just won't do it. I can't take a Russian bee in December and make a big bee hive by first of February [for almond pollination]" (Interview, Mar. 24, 2017). This captures many beekeepers' sentiments: the Russian bees, despite the fact that they are more resistant to *Varroa* mites, are not attractive to beekeepers because they cannot be stimulated into high brood production over winter.

Instead of compromising on those high frame counts in February, beekeepers seem to have accepted higher winter losses each year. To make up for these losses, as one bee researcher noted, beekeepers are pushing their bees harder and harder, feeding them inputs, creating new colonies in the spring, and replacing their queens at least once a year, sometimes more often. The researcher referred to the new era of beekeeping as "feedlot beekeeping," stating: "it's all industrialized now" (interview, Feb. 9, 2019).

Bee researchers see how this industrialization effects honey bee queen bodies. Beekeepers consistently complained to be about honey bee queens; one phrase I heard several times was, "the queens are crap these days!" Researchers have noted that virgin queens are getting smaller, and more importantly, are developing smaller spermatheca (sperm repositories), which may limit their viability. This shrinkage can be due to a number of reasons, one of which is the buildup of pesticides in the wax that bees use to produce honey bee queens.

Pesticide-laden wax can build up through exposure to pesticides outside the hive, such as those used in agriculture, however, it can also accumulate from pesticides applied in the hive, such as miticides. Queen cells with a buildup of the miticide coumaphos, for example, can have sublethal effect on queen development, and can result in smaller queen size and the rejection of the queen by the colony (Collins et al. 2013). This indicates that not only are honey bee bodies being transformed by agrochemicals outside the colony, they are being transformed by the agrichemicals that beekeepers rely on to keep miticides at bay—all so that they can keep producing prolific colonies of bees each year for the almond bloom.

Conclusion

In this chapter, I traced how beekeepers transformed their beekeeping practices to pollinate for the almond industry, and how this has contributed to honey bee vulnerability. While this choice allows many commercial beekeepers to take full economic advantage of almond bloom, it also promotes the propagation of the honey bee subspecies that are most vulnerable to managed honey bees' primary pest, the *Varroa* mites, one of the primary reasons that beekeepers suffer from 30% colony losses each year (Kulhanek et al. 2017).

I demonstrated how this process of producing only two subspecies of bees to pollinate almonds, combined with stimulating bees nearly year-round, shipping them cross country, feeding them inputs, and exposing them to agrochemicals both outside and inside the hive (in the form of miticides) has played a central role in *deepening* honey bee vulnerability. At the same time, however, as beekeepers lose access to forage, they have come to rely on almond pollination as their primary source of income (Durant 2019). Beekeepers are unlikely to produce bees that are more resilient unless these bees would also be capable of February pollination. In this way, almond pollination has become a genetic bottleneck that limits the diversity of commercially produced bees.

Yet the vulnerabilities detailed in this paper also provide key sites of resistance to the industrial production of honey bees. As such, honey bees offer an important counterpoint to literature on the commodification of nature. Though honey bees are categorized by the federal government as livestock, they have characteristics that differentiate their production from the intensified management associated with concentrated animal feeding operations (CAFOs) that produce poultry, cattle, or pork production. On the one hand, beekeepers are feeding their bees inputs and antibiotics in ways reminiscent of other commercially produced livestock. They have simplified the bee subspecies to the two that produce the most bees prolifically and are easiest to manage—despite the fact that these two subspecies are also the most vulnerable.

Despite beekeepers' best efforts to produce a bee that would be the equivalent of the broiler chicken or the Angus steer, they manage an "unruly" nature that "not only resists human intentions but actively reshapes them" (Krishnan, Pastore, and Temple 2015, 5). Bees are highly mobile and social insects that cannot be fenced in or housed indoors year-round like other livestock. This makes it impossible to fully control which pests, diseases, and agrochemicals bees are exposed to, which drones the queen mates with, and how bees will respond to treatments. In addition, bees are insects, which makes it challenging to kill the tiny mite insects that plague them without causing sublethal or lethal damage to the bees as well.

This chapter demonstrates the enormous efforts beekeepers undertake to realign their management practices and reconfigure their bees to pollinate almonds, which has thus facilitated the growth of almond acreage in California. While this has provided an immense economic support to the beekeeping industry, it has also increased stress on honey bees and the beekeepers who struggle with the demands that producing bees for almond pollination entails.

This chapter also provides an important contrast to the almond industry, where we see how the commodification of different socio-natures can produce very different political economies as capital develops unevenly. With the almond industry, policies such as the almond marketing order helped strengthen the industry. Since the almond industry produces over 80% of the global almond stock, their growers stand to benefit from any generic marketing. Meanwhile for beekeepers, the marketing order may have weakened their industry by supporting the import of cheap honey, which has driven down the price of honey and helped make it nearly impossible for beekeepers to make a living from honey production. In addition, the almond industry has the benefit of a wide variety of root stocks and scions to draw from, while the beekeeping industry only cultivates primarily two subspecies commercially because those produce the bees the almond industry needs.

In short, we see how pollinating for the almond industry has also played a central role in limiting honey bee vulnerability. Despite the fact that most of the almond industry representatives I spoke to are not concerned about the future availability of honey bees limiting almond acreage growth, evidence points to enough vulnerability within honey bees—and an increasing loss of forage for post-almond honey production—that there may be cause for concern. This case provides yet another example of how environmental crises inevitably develop from capitalist production that threaten the forces of production that underpin capital development in the first place. What becomes clear is the ways in which vulnerable and "unruly" bees not only resist beekeeper industrialization as beekeepers become more deeply entwined with the almond industry but threaten to undermine the production of almonds as well.

Chapter Four: The Label is the Law—Productions of Ignorance about Bee-Toxic Agrochemicals

Figure 4.1: Photo of agrochemical sprayer spraying bee colonies. Photo taken by beekeeper, from car, as he drove into the orchard to check on his bees. Note that it is the middle of the day. The almond industry's Best Management Practices dictate that growers should only apply agrochemicals in the evening or at night. (Photo used with permission from beekeeper.)

Introduction

Beekeeper Aaron Bauer remembers the time he lost nearly half his bees just like it was yesterday, and it still gets him choked up (interview, Nov. 11, 2016). In a way, he partly blames himself. It was 2014, and his 500 colonies of bees had suffered the previous year from extreme drought and had been "living on feed and pollen supplement forever." He was excited to bring his colonies into almonds, because they normally build up well on "that good almond pollen."

As soon as he placed his colonies in the orchard, however, Bauer saw a sign stating: Do not Enter the Orchard: This has been sprayed with fungicide. He thought it strange, because he and his assistant had driven all the way to the orchard with the knowledge of the grower, who had agreed he could put the colonies in that day. He decided it must have been an older sign and left his bees there, since his contract stated he would be notified (he assumed by phone, as is standard) if the orchard sprayed anything bee toxic. Then, three weeks later, they were spraying again during the day. And then again, two weeks later.

"Meanwhile," he noted, "I've got a written contract that says I'll be notified if there's any spraying 36 hours in advance." Specifically, the contract stated they would call if they sprayed anything that was a "toxic insecticide."

On this second occasion, Aaron started inspecting his colonies, and as opened up some hives, he noticed he and the colonies were getting sprayed with agrochemicals from a nearby spray rig. "They [were] going by spraying everything," he said. "They see me, and they just keep spraying."

The week following the spray event, the bees were still doing ok. But then about a week later, the bees in the colony that had been first exposed with the first spray were emerging as adult bees—and dying shortly afterward. "Everything was sick and messed up…there were piles of bees coming out." He noted that the kill had a delayed effect by about three weeks, and it was the bee larvae being damaged, not the adult bees.

Aaron showed the damage to the pesticide control advisor (PCA) in charge of pesticide applications on the orchard; the PCA said that they looked fine. Not only did the PCA not see anything wrong, the he also said that they (he and the grower) can do whatever they want on their orchard as needed. In contrast to the PCA, Aaron's bee broker, who had connected Aaron with the grower, felt bad, but ultimately said, "looks like we had a light kill!" Aaron added as an aside, "I'd hate to see what a medium kill looks like!"

The following day after the PCA ordered the second spray, he also had Aaron's colonies graded for their frame strength to determine how much Aaron should get paid. Aaron was shocked that the PCA would grade the bees the day after they sprayed them with "poison." It did not seem fair. But Aaron did not actually say anything—he did not feel comfortable speaking out. Fortunately, his bees were still strong enough to make the grade and ensure that he got paid the proper amount.

Aaron finally called the Department of Pesticide Regulation (DPR) and had them test his bees for what had killed them. They gave him the results: his bees had been sprayed by two fungicides and one insecticide. Most likely the applicator had tank-mixed the various chemicals (i.e. mixed all the chemicals together in one spray tank), possibly adding in adjuvants and other additives. It is difficult to say what specifically killed the bees. The DPR official gave him the results, but also told him that because the pesticides were labeled "non-toxic" to bees, no one could do anything; no one could conduct a formal investigation, and no one could penalize the grower.

Aaron ultimately lost half of his hives, 250 out of 500 from this spray kill, the only major loss he has had in years. No one ever apologized, and the experience left him devastated, economically and emotionally. Aaron was not alone; in interviews, nearly every beekeeper interviewed described colony losses in 2014 as one of the worst years on record. One beekeeper lost three semi-loads of bees (containing 408 colonies each) that year (interview, Apr. 26, 2017), and numerous other beekeepers described losing a record number as well. Some were sprayed by growers, some by adjacent growers of other crops (like stone fruits) without bee colonies under contract.

Many experienced these delayed results as well, where their bees died three weeks after a spray event, and the brood was lost, killing a generation of bees right when beekeepers are trying to build their numbers for summer pollination. The trouble with brood losses is that they are harder to see, and sometimes, by the time the damage is visible, the beekeeper has already left the almond orchard and moved onto their next stop.

Since the advent of CCD in 2006/2007, pesticides, in addition to mites, have been one of the primary suspects blamed for annual colony losses. While neonicotinoids are the agrochemical discussed most by the press, they are simply part of a suite of agrochemicals whose damage is sublethal rather than toxic, which makes it far harder to trace their toxicity and effects on honey bees. And yet, as discussed in my introduction, it is not only the materiality of the agrochemical and the honey bee that poses a challenge to determining what causes honey bee vulnerability, it is also the process of knowledge production itself. As I discussed in the introduction, *how* we come to know *what* we know about honey bee vulnerability is a socially determined process, embedded in social contexts that produce the practices, norms, conventions, instruments, and discourses that produce what we understand as scientific knowledge (Jasanoff 2004, 3).

Suryanarayanan and Kleinman's body of research on pesticides and Colony Collapse Disorder traces the scientific and political practices that shape institutional knowledge about what factors shape honey bee declines (Suryanarayanan and Kleinman 2011; Kleinman and Suryanarayanan 2012, 2013; Suryanarayanan and Kleinman 2014; Kleinman and Suryanarayanan 2015; Suryanarayanan and Kleinman 2017). They trace how beekeepers' *in situ* experiences with neonicotinoids, a suite of systemic insecticides, have been excluded from processes to understand the causes of colony losses (Suryanarayanan and Kleinman 2013). They also highlight how EPA's current risk assessments produce ignorance because they do not require testing on short-term or chronic exposure to sub-lethal agrochemicals, or the effects of synergistic interactions between chemicals that honey bees might be exposed to in the field (Suryanarayanan and Kleinman 2011).

This chapter adds to their body of research on how beekeepers and regulators come to know (or not know) what factors are driving colony loss, through an investigation of the agrochemical regulatory apparatus that beekeepers navigate while pollinating almond orchards in California. In this chapter, I not only demonstrate how ignorance about bee-toxic agrochemicals is produced through the EPA's regulatory process (Proctor 2008; Smithson 1985), but also at California's state and county levels. State and county data collection processes are designed to only collect data on which *already labeled* bee-toxic agrochemicals are affecting honey bees, largely reinforcing what regulatory agencies, and thus growers, know about a particular pesticide. Thus, if an agrochemical suspected of colony damage is not currently labeled bee-toxic or is not classified as a pesticide, then investigators often cannot collect this data or test those honey bee samples. Subsequently, emergent data on which chemicals are bee-toxic goes uncollected.

Yet, it is not only state agencies that contribute to this production of ignorance—beekeepers contribute to it as well. Power asymmetries between migratory beekeepers and the growers whose orchards they pollinate, combined with beekeepers' apathy or frustration with pesticide regulation at all levels of governance, can disincentivize beekeepers from participating in the regulatory process. This *regulatory disengagement* means that beekeepers limit their reporting of agrochemical-related colony damage, and important data on which agrochemicals are toxic to honey bees goes undocumented. This case provides an example of how ignorance can be dialectically constituted by institutional processes and the stakeholders that regulatory processes are meant—in part—to protect. I term this cycle of ignorance produced by regulatory agencies and disengaged stakeholders an *ignorance loop*. Understanding how ignorance loops are created between regulatory agencies and stakeholders can help identify nodes of intervention to reengage stakeholders in producing knowledge about a particular phenomenon, such as which agrochemicals are toxic to honey bees.

In this chapter, I focus on the regulation of certain classes of agrochemicals: fungicides, insect growth regulators (IGRs), and adjuvants (chemicals added to pesticide formulations), which are not labeled as toxic to honey bees. Because they are not labeled, growers and their pesticide control advisors (PCAs) can apply them without notifying beekeepers. Similarly, growers do not have to pay a government fine if honey bee colonies are damaged as a result of an application, because they would not be violating any regulations. Beekeepers, however, have experienced colony damage and loss while pollinating almonds due to these agrochemicals, and data suggests that these agrochemicals are at the very least sublethally toxic to honey bees (Pettis et al. 2013b; DeGrandi-Hoffman et al. 2015; Sánchez-Bayo et al. 2016). This chapter aims to explain this gap between the EPA label and researchers and beekeepers' understandings of the toxicity of these agrochemicals, by tracing the epistemic processes of ignorance production from EPA offices in Washington D.C. to almond orchards in California, and the role these processes play in shaping honey bee declines.

I begin this chapter with an overview of literature on the production of ignorance and extend this theory through a discussion of ignorance production from the ground up. I introduce the term *regulatory disengagement* to describe how stakeholders disengage from regulatory processes, which results in the production of *ignorance loops* between stakeholders and regulatory agencies as ignorance perpetuates about pesticide use. I then provide some statistics on pesticide use in the almond industry during almond bloom, demonstrating how the label is informing how and when growers apply bee-toxic pesticides. This is followed by an overview of agrichemical regulation at the federal, state, and county levels in the United States, where ignorance is produced at various nodes of this governing apparatus. Finally, I demonstrate ways in which beekeepers disengage from reporting bee kills, what motivates this, and what they stand to lose from this regulatory disengagement and the ignorance loop it produces between their industry and EPA regulators.

An Agnotology of Bee Kills

Corporate and institutional productions of ignorance

Just as the production of knowledge is a social process, so too is the production of its counterpart: ignorance (Proctor 2008; Smithson 1985). The process of producing knowledge requires strategic decisions to attend to particular data at the expense of other data. The production of ignorance, therefore, is a "product of inattention" because we cannot study all things (Proctor 2008, 7).

Yet these strategic decisions are not apolitical processes with neutral consequences, and as such, ignorance should not be seen as "a simple omission or gap" (Proctor 2008, 9). Instead, we must attend to the ways that ignorance can be *actively produced*, maintained, manipulated, and engineered. Proctor termed the study of socially produced ignorance 'agnotology'—based on the Greek word for not knowing, *agnōsis—*as a way to describe how the tobacco industry obfuscated facts about tobacco's cancer risks by influencing public health researchers, courts, and governments for decades (Proctor 2008). Scholarship has continued to interrogate these processes through the nuanced concepts of "strategic ignorance" (McGoey 2012), "undone science" (Frickel et al. 2010), and "social production of ignorance" (Kleinman and Suryanarayanan 2013), to name several examples.

Even when ignorance is not produced with the intention to obscure risks from the public—such as the type of ignorance production I discuss in this chapter—it has distinct political economic drivers and consequences for the subjects of regulatory policy. Frickel et al. (2010) refer to this type of science as "undone science": research that social movement groups have identified as having an important social benefit but that has generally been left "unfunded, incomplete, or generally ignored" (ibid., 445). Analyses of "undone science" attend to the social inequities in technoscience by bringing attention to how "manifestations of power, access to resources, relations among organizations and procedures for rule making" creates winners *and* losers by repeatedly benefitting some groups more than others (ibid., 445).

Science can remain "undone" in part because agencies do not have the proper epistemic forms and framings to collect the data (Kleinman and Suryanarayanan 2012). Epistemic forms include "methods of data collection, approaches to testing, structures of experimental design, and standards of evidence" (Kleinman and Suryanarayanan 2013, 497). These epistemic forms do not emerge naturally; they are socially constituted, situated, and reinforced, depending on an institution's priorities. Beekeepers' knowledge is often produced via an "informal epistemic form" that allows them to respond to the dynamic and variable contexts of their beekeeping operations. This informality, however—one that relies on false-positive conclusions and leads beekeepers to a precautionary approach (ibid., 232)—has been incompatible with the type of knowledge production required by the EPA to determine whether these pesticides should be pulled off the market. Honey bee scientists' practices, by contrast, are "characterized by a causally driven, single-factorial epistemic form that emphasizes rapid, lethal effects of insecticides on honey bees, and a preference for false-negative (over false-positive) conclusions" (ibid., 233).

One way this occurs in pesticide labeling is as a result of the EPA's epistemic adherence to Good Laboratory Practice (GLP). GLP specifies how experiments should be "designed, performed, tracked, recorded, and reported, and by whom, in order for the results to be usable in federal rule making" (Kleinman and Suryanarayanan 2013, 506). This insistence on GLP as an epistemic form for recognizing appropriate knowledge means that only scientists can produce data that is considered "usable" by the EPA. This rules out, or at very least delegitimizes, the anecdotal and experiential evidence beekeepers offer to regulatory debates over the role neonicotinoids play in colony loss or damage. This is not simply a process of exclusion/inclusion that takes place with U.S. beekeepers; Maxim and van der Sluijs (2007) describe how the French Ministry of Agriculture negated the expertise of both beekeepers *and* researchers speaking out against Gaucho, a neonicotinoid, in an effort to renew the pesticide's authorization.

Kleinman and Suryanarayanan (2013) bring attention to three forms of "interrelated and overlapping varieties" of ignorance produced through the epistemic forms of the current system of agrochemical regulation in the U.S. (ibid., 498). Two of them are highly relevant here. The first form of ignorance is research that does not get conducted because the epistemic forms do not exist to address them. The second form of ignorance is a "false knowledge" (Kleinman and Suryanarayanan 2013; Haraway 1991) that results when these epistemic forms prevent certain questions from being asked. To reiterate: neither of these are necessarily intentional forms of ignorance production, but ignorance is produced as a by-product all the same.

At the same time, not having complete data on which agrochemicals actually kill bees does offer strategic benefits for institutions. Ignorance is often conceived of as a negative state that actors are incentivized to overcome, when in fact the cultivation of ignorance can be more advantageous to an institution (or multiple institutions) than cultivating knowledge (McGoey 2012). The concept of "strategic ignorance" brings attention to the way that corporations such as drug companies—and chemical companies, by extension—can harness ignorance as a resource. Specifically, the "mobilization of unknowns" can allow an institution, such as EPA or a chemical company, to deny liability in a disaster such as large-scale colony declines, and to "assert expert control in the face of both foreseeable and unpredictable outcomes" (McGoey 2012, 555). In other words, if the EPA does not require data on the chronic toxicity of pesticides, then both the EPA and chemical companies are not liable for colony loss from chronic exposure to these chemicals—demonstrating the advantage of keeping required tests as minimal as possible.

Productions of Ignorance on Agrochemicals from the ground up

What is central to the production of ignorance literature mentioned in the introduction, is that it has largely focused on one-sided productions of ignorance by one or multiple institutions (*e.g.* federal, state, and county agencies), which negatively affects stakeholders or practitioners (*e.g.* beekeepers). In other words, the production of ignorance here is one-sided and top-down, leaving the public as *de facto* recipients of ignorance production.

What is missing, however, is the way that ignorance can be produced from the bottom up (Fuchs, Hofkirchner, and Klauninger 2005), including through regulatory disengagement by public stakeholders. This refers to disengagement from supporting or implementing bureaucratic rules and regulations, including incident reporting procedures (such as a violent crime or an instance of pesticide drift), all of which can involve excessive paperwork, outmoded data collection processes, or punitive action for those who report. I use the term *regulatory disengagement* rather than civic disengagement (Cheng and Liu 2018) in part because the disengagement occurs with a regulatory process or framework and the agencies implementing it, but also because civic disengagement focuses on citizens, while regulatory engagement includes any stakeholder affected by a regulatory process, citizen or otherwise. The term does not mean that beekeepers are disengaged generally; many are very involved in civic politics but avoid regulatory processes because they do not see them as effective or they find them cumbersome.

Ignorance production through regulatory disengagement can occur for a number of reasons that parallel civic disengagement. Trust can erode between stakeholders and the government, as policymakers and state agencies fail to fulfill their commitments (Cheng and Liu 2018; Putnam

1995). For example, Maxim and van der Sluijs (2007) note how the French government's renewal of the neonicotinoid, Gaucho® —in the face of mounting evidence that the pesticide was toxic to bees—deepened mistrust between the government and beekeepers and their allies, who suspected the government of aligning with industry.

Disengagement can also occur as a result of social inequities or fear of retribution. Engaging with regulatory processes can result in punitive action—either against oneself, or against another entity (*e.g.* an employer)—both of which can entail creating risks for certain communities. Migrant farmworkers, for example, can risk losing their jobs or bringing attention to their undocumented status if they report injuries or illness from pesticides (Flocks 2012). Disengagement can also occur with migrant farmworkers because the health care personnel may not recognize or may downplay the symptoms the farmworkers are experiencing and so they decide not to report (Flocks 2012, 259).

This disengagement of stakeholders, and the subsequent ignorance produced, are key processes to attend to because stakeholders can play an important role in creating knowledge—or ignorance—about particular phenomena, such as the effects of agrochemicals on migrant farmworkers or honey bees. When beekeepers disengage from regulatory process and stop reporting these incidents, the consequences of this disengagement create a dialectic dynamic of ignorance, what I term an *ignorance loop*, where regulatory productions of ignorance about bee-toxic agrochemicals (in addition to other factors listed above) disincentivize beekeepers from reporting pesticide-related colony loss. This results in continued ignorance about which agrochemicals kill honey bees, which subsequently perpetuates beekeeper disengagement with local regulatory processes. Meanwhile, both beekeepers and state agencies lose valuable information about which agrochemicals are killing honey bees, as I demonstrate in the sections that follow.

Background on Pesticide Use in Almond Bloom

In an annual management survey taken in 2017, commercial beekeepers in the United States attributed over 28% of their colony losses to agrochemicals and pesticides (Kulhanek et al. 2017). Honey bees are highly sensitive to agrochemicals used in almond orchards (Fine, Cox-Foster, and Mullin 2016; Fisher II et al. 2018; Krupke et al. 2012) and beekeepers are thus vigilant about the agricultural products their bees are exposed to. This vigilance comes not only from a desire to keep honey bees alive to fulfill their almond pollination contracts, but also because the health of honey bees coming out of almonds can determine how well their bees can produce honey or fulfill pollination contracts for other crops—both of which provide the majority of an operation's revenue for the rest of the year (Bond, Plattner, and Hunt 2014). According to beekeepers, a big kill of numerous colonies, or widespread sublethal damage from agrochemicals that leads to delayed worker bee development or reduced adult bee longevity (Wu, Anelli, and Sheppard 2011), can set an operation back for the rest of the year.

One major question that came up when I heard, over and over again, about beekeepers' experiences with bee loss in almonds was: Why would almond growers apply bee-toxic chemicals when they invested so much money in bee pollination? The first answer to that is when bees are pollinating almonds, growers must balance the pest load of their crop (which might yield $4500/acre) with the investment they have made in honey bee pollination ($400/acre). Almond growers are able to produce high quality almonds only through the careful control of almond pathogens and pests (Teviotdale et al. 2002), and sometimes the need to address fungal issues outweighs the risk of harming bee colonies. The second and most important reason, however, is that growers and their PCAs do not know that they are applying bee-toxic agrochemicals because they are not labeled as such. It is important then, to understand what grower pesticide use looks like during almond bloom to triangulate beekeepers' experiences during bloom.

hus, to inform this chapter on beekeepers' experience with pesticides and pesticide governance during almond bloom, I conducted a pesticide use trend analysis with an agricultural economist[31] that looked at chemical applications by growers from January through the end of March, when beekeepers will either be near almonds or may be overwintering them in or near orchards (Durant and Goodrich, in preparation). The data came from each San Joaquin Valley counties' pesticide use reports from 1990-2016 (San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern), available on the Department of Pesticide Regulation's website. Growers must report the use of all restricted agrochemicals to their CAC, as I detail later in this chapter, through a pesticide use report (PUR) that the county submits to the CA Dept. of Pesticide Regulation. The aim of the study was to track the use of bee-toxic agrochemicals during almond bloom over time, from 1990-2016. I also, however, wanted to understand how the label affected growers' pesticide use while beekeepers had colonies in almonds. I detail my methods further in the Methods Appendix.

The primary pathogen growers are concerned about during bloom is fungal growth, which can cause defoliation (Pickel et al. 2004). Fungicide use to control fungal pathogens tends to correlate with each year's rainfall (See Figure 4.2), as well as the geography of the almond orchard. Orchards in southern San Joaquin Valley such as Kern County, may need less fungicides during bloom—if any, due to low winter rainfall—while orchards in northern San Joaquin Valley counties may require more. Growers may also apply herbicides during this time, such as paraquat dichloride and glyphosate. Agrochemicals used earlier, in January, might be a dormant oil spray for red and brown mites and San Jose scale, and likely an insecticide such as an insect growth regulator (IGR), which will help control pests such as the peach twig borer and San Jose scale (Pickel et al. 2004). Some of the agrochemicals applied during dormancy (pre-bloom), bloom, and shortly after bloom can have sublethal toxicity for bees but may not be labeled as such[32], as I discuss in the sections that follow.

The results show that these labels play a key role in determining growers' use of agrochemicals. Below, I include two figures that demonstrate this. Figure 4.3 shows grower use of agrochemicals applied that have precautionary statements by the EPA (i.e. they are labeled as bee toxic). The two pink lines indicate the bloom period (occurring in between). A sharp decline in use of labeled toxic agrochemicals is clear during the bloom period. The agrochemicals are primarily used in January, and use spikes again slightly post bloom, after March 15th. In general, it seems clear that the majority of growers are observing the label during the bloom period. A

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[31] Dr. Brittney Goodrich, Assistant Professor and Extension Specialist at Auburn University.
[32] See Figure 4.5 for a comprehensive list of citations.

spike in labeled bee-toxic agrochemicals is apparent during 2014, however, which may correspond with the chemical applications beekeepers experienced during that year.

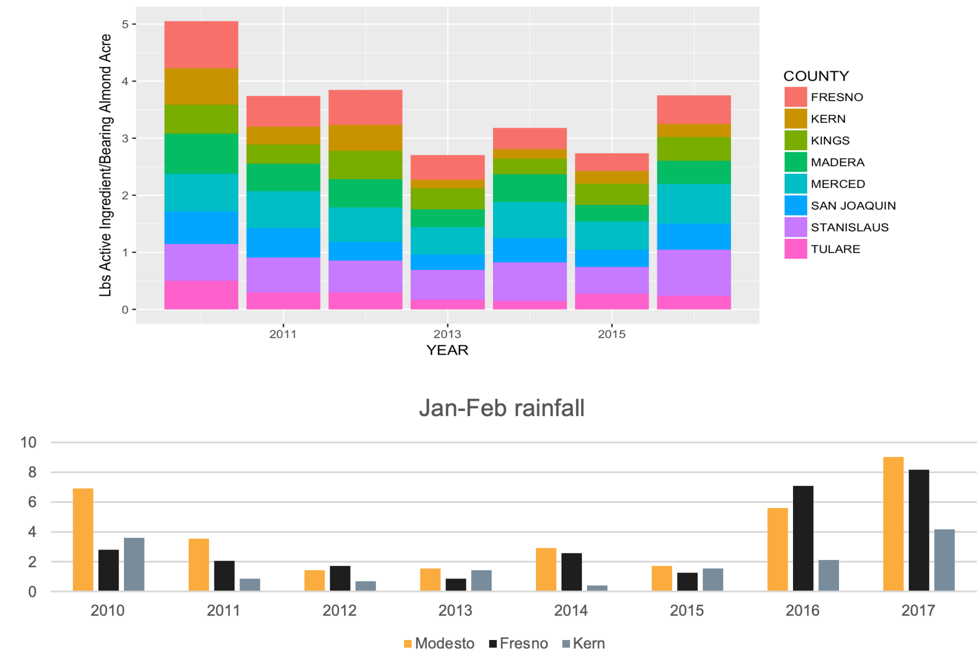

Figure 4.2: Use of fungicides vs. rainfall in major almond counties. Fungicide use tends to correlate with rainfall.

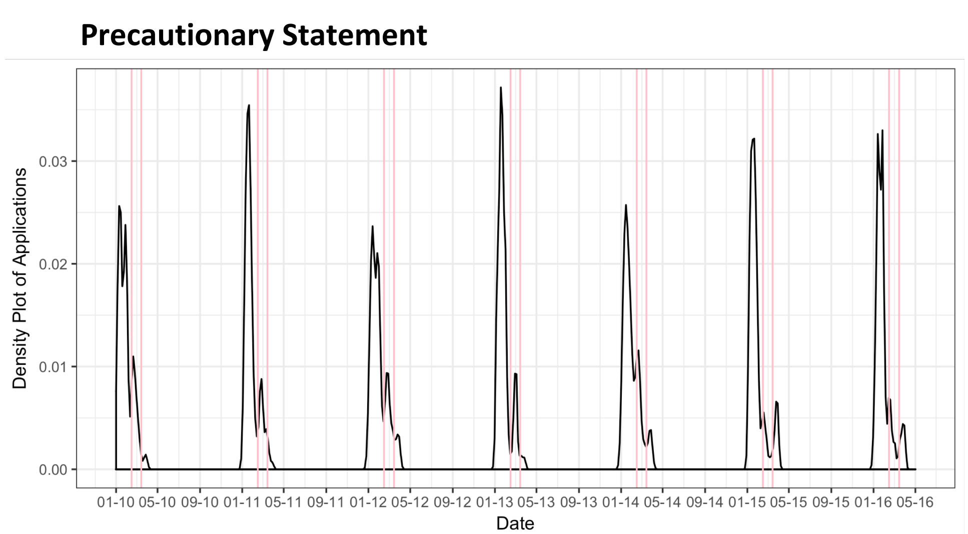

Figure 4.3: Labeled bee-toxic agrochemical use during almond bloom. The pink lines indicate the bloom period, Feb. 15-Mar. 15.

Figure 4.4 below, however, shows the use of agrochemicals that have demonstrated toxicity bees (in the peer-reviewed publications listed in Figure 4.5), but have no EPA precautionary statement (i.e. bee-toxicity warning label). This trend analysis thus demonstrated that the label is clearly informing growers' application behaviors, and that growers are applying a much lower amount of *labeled* bee-toxic chemicals during almond bloom, thus observing the legal requirements of the pesticide. However, they are also applying non-labeled bee-toxic agrochemicals during bloom, assuming that they are not bee-toxic and therefore safe to apply. And yet, as we see in Figure 4.5 ('Effect on Colony' column), these chemicals are largely toxic, through primarily to bee larvae.

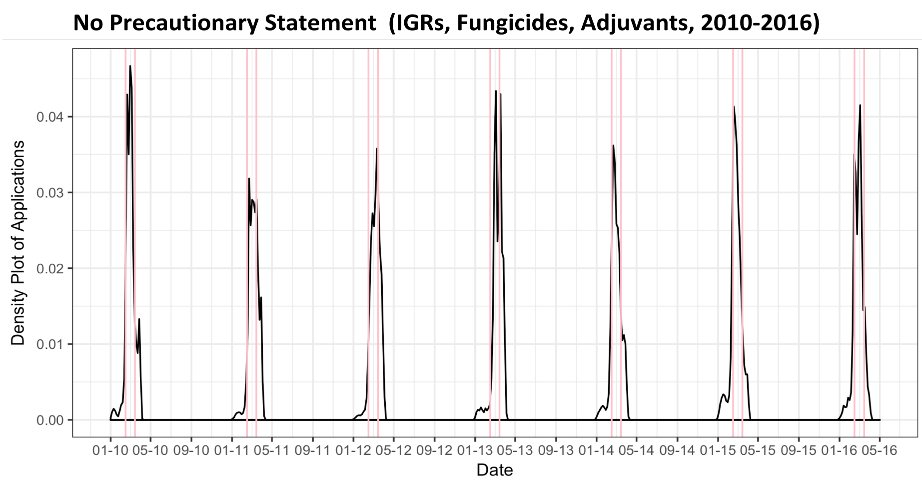

Figure 4.4: Bee-toxic agrochemical use during bloom with no precautionary statement. Bloom is the period between the two lines.

CHEMICAL NAME	TRADE NAME	FUNCTION	EFFECT ON COLONY	SOURCE
Diflubenzuron	Dimilin	IGR (insecticide)	Effects **honeybee larvae** in lab, but not in field	(Ciarlo et al. 2012; Fisher II et al. 2018)
Flubendiamide	Belt SC	Diamide insecticide	Possible effects **on honey bee larvae** development	(Hooven, Sagili, and Johansen n.d.)
Pyriproxyfen	Seize	IGR (insecticide)	Possible effects on **honey bee larvae**	(Fisher II et al. 2018)
Chlorothalonil	Equus, Initiate, Bravo	fungicide	Possible effects **on honey bee larvae** development	(C. a Mullin et al. 2010; Zhu et al. 2014)
Iprodione*	Nevado, Rovral	fungicide	Possible effects **on honey bee larvae** development	(Mussen, Lopez, and Peng 2004)
Difenoconazole	Quadris Top	fungicide	Potential effects on learning in honey bees	(Stone, Abramson, and Price 1997)
Paraquat Dichloride	Gramoxone	Herbicide	Causes honey bee losses and effects **honey bee larvae**	(Cousin et al. 2013; Fletcher and Barnett 2003)
Ziram	Ziram	Fungicide	Effects **honey bee larval** development in lab tests	(Mussen, Lopez, and Peng 2004)
Captan	Captan	fungicide	Effects h**oneybee brood** in lab but not enough evidence in field tests	(Mussen, Lopez, and Peng 2004; Everich et al. 2009)
Methoxyfenozide	Intrepid	IGR (insecticide)	Effects **honey bee larval** development	(Fisher II et al. 2018)

Figure 4.5: Bee-toxic (sublethal) agrochemicals applied during almond bloom, their effects on bees, and the research that supports these findings.

Finally, Figure 4.6 demonstrates a dramatic *decrease* in acutely toxic bee chemicals since the 1990s during almond bloom, such as organophosphates and pyrethroids, largely out of concerns about water pollution (Epstein et al. 2001). This is followed by a dramatic *increase* in agrochemicals such as insect growth regulators (IGRs) from 2004 to 2016, which are designed to kill developing insect larvae, such as honey bee brood, though bee brood are not the intended target.

These findings support beekeepers' experiences that growers are applying sublethally bee-toxic agrochemicals during almond bloom. However, they *also* support growers' and PCA's assertions that they are not doing anything wrong or illegal, but are indeed following the label, more or less, regarding agrochemical applications. This makes sense, given that growers have invested close to $400 per acre on pollination services, a $20,000 input investment for a 50-acre orchard.

The problem then, is largely with the regulation of agrochemicals, and the way that ignorance production about agrochemicals *is structured into* the regulatory and epistemological processes themselves. This is then exacerbated by some beekeepers' disconnection from engaging in these regulatory processes, out of a sense that they are not actually protected by them. In the following two sections on the EPA and county governance, I discuss these processes, and detail how ignorance is produced at the federal, state, and county levels.

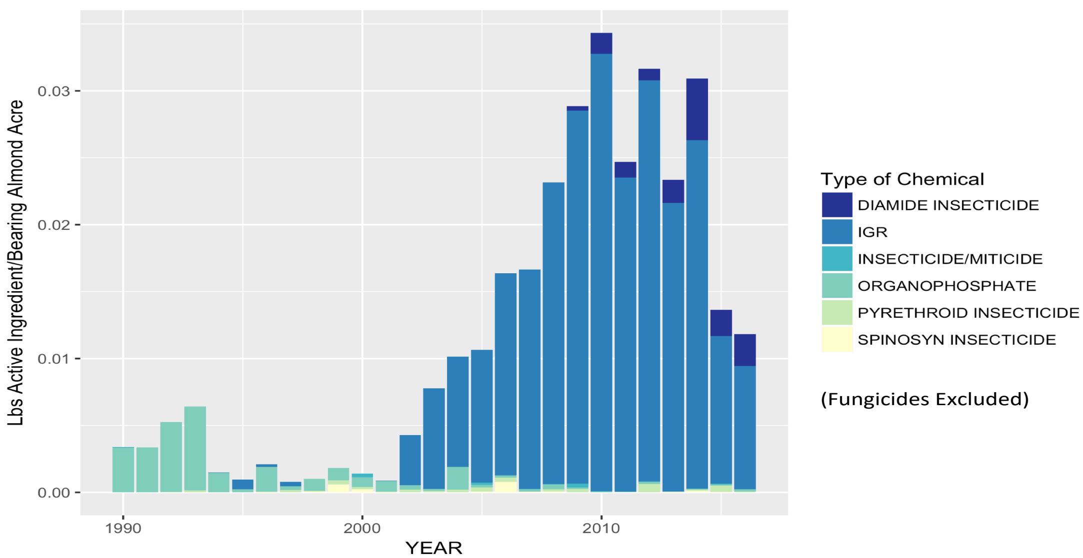

Figure 4.6: Agrochemicals used during almond bloom. Note that the greatest amount applied are insect growth regulators, some of which are bee-toxic, and diamide insecticides, also bee toxic (See Figure 5).

How federal regulation produces ignorance about bee-toxic chemicals

An overview of federal pesticide regulation in the United States

In the United States, pesticides can only be sold and applied if they have been registered through the US EPA (US EPA 2016). Pesticides are any class of substances intended to prevent, destroy, repel, or mitigate any pest (40 CFR §152.3), and include a host of agrochemicals that growers apply on their almond orchards such as fungicides, insecticides, and insect growth regulators

(IGRs). Chemical companies applying for pesticide registration follow a set of guidelines determined by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

FIFRA was first passed by Congress in 1947, and the US Department of Agriculture (USDA) was the agency responsible for implementing it. In the early 1950s FIFRA was more of a collaboration between the federal government and the chemical industry, to address increased pesticide use and production that developed during and after WWII (Wargo 1998). Pesticides were enthusiastically supported at the time, seen as strengthening the mechanization and efficiency of agriculture and solving public health problems like malarial mosquito infestations (Nownes 1991, 24:2). As a result, pesticide regulation was more concerned with providing uniform, reliable products for the farmers that used them, and any potential harm that could come to people or the environment was largely considered negligible (Thayer and Houlihan 2004; Wargo 1998, 71). FIFRA simply required pesticide manufacturers to label their products honestly, and include reliable instructions for use (Nownes 1991, 24:3). Control over pesticide levels in food was governed separately by the Federal Drug Administration (FDA), which was responsible for setting 'food tolerances', the legal limits for pesticide residues in food which were then calculated at levels to protect adults (Thayer and Houlihan 2004, 258; Wargo 1998).

The 1950s and 1960s saw a marked shift in public trust of agrochemicals. Emerging ecological research and public concern over links between pesticides and cancer prompted amendments to FIFRA, most notably inspired by public outcry in response to Rachel Carson's *Silent Spring* (1962), which detailed the toxic effects of DDT on human health and the environment (Thayer and Houlihan 2004, 257). It became increasingly clear that USDA and FDA were not able to fulfill their expanding regulatory obligations.

Partly in response to this, Nixon established EPA in 1970 and Congress moved pesticide regulation under its control through a 1972 FIFRA amendment, the Federal Environmental Pesticides Control Act (FEPCA). FEPCA redirected the federal government's pesticide regulation responsibility from accurate labeling to protecting the environment and human health (Wargo 1998). As a result, pesticide manufacturers were required to conduct a number of tests to prove that a pesticide did not pose "unreasonable adverse effects" on human health or the environment (ibid., 89). Congress deepened these requirements when they passed the Food Quality Protection Act (FQPA) in 1996, which attempted to address mounting concerns and scientific evidence that pesticides were in children's food (NRDC 1989; National Research Council 1993). The FQPA required a new suite of tests from companies attempting to register a pesticide (Thayer and Houlihan 2004).

How EPA labels pesticides bee-toxic

In 2005, EPA proposed to update and revise its data requirements for conventional pesticide products, including the requirement of an acute toxicity test on honey bees as part of its suite of required tests for any pesticides intended for outdoor or agricultural use, with honey bees acting as a stand-in for other non-target insects (US EPA 2005). Previously, honey bee testing had only been conditionally required in cases where the chemical would be applied when the target crop was in bloom (ibid., 12291). The amendment addressed the fact that honey bees can be exposed to chemicals on adjacent blooming flowers, if the chemical is applied when the target crop is not in bloom. Congress adopted the amendment in 2007.

FIFRA currently mandates a tiered system for assessing risks of a particular pesticide to non-target organisms, detailed in the Code of Federal regulations (40 CFR, part 158). Tier I tests serve as 'screens' for bee-toxicity (US EPA 2016). To register a pesticide for outdoor use, companies must provide a number of data points for non-target organisms, including a honey bee acute contact LD50 test. The LD50 acute contact test is designed to determine the dose of a pesticide—either the end product formulation or active ingredient—that will kill 50% of an experimental population of honey bees through a topical application of the test substance to the bees' thorax. After bees are exposed to the substance, mortality is recorded at 4 hours and then again at 24 and 48 hours, to a maximum of 96 hours. If the LD50 dose is less than 2 micrograms (μ) for the tested substance, then the pesticide will be labeled 'highly toxic' and have a "Bee Hazard" warning with a bee graphic on the label (Figure 4.7). If the product contains an ingredient with an acute LD50 greater than 2μ but less than 11 micrograms (μ), then it will be labeled "moderately toxic" and also have the bee graphic. If the acute LD50 dose is greater than 11μ, or bees will likely never encounter the substance (*e.g.* rat poison), then the label will likely not have a bee precautionary statement (US EPA 2016).

Depending on the results of the LD50 or existing data on the pesticide's ingredients that indicate bee toxicity, EPA may require a foliage test, which tests for less than 25% adult bee mortality when bees are exposed to the test substance on foliage. They may also request a partial field (Tier 2) or full-field test (Tier 3), which represent field-realistic conditions and are the most rigorous testing requirements (US EPA 2016, 9–10). Finally, FIFRA requires EPA to review registered pesticides every 15 years to make sure they continue to meet FIFRA standards (40 CFR part 155).

Figure 4.7: Bee hazard symbol on EPA-designated bee-toxic pesticides

Productions of Ignorance by the EPA

The data that EPA does *not* require from companies when approving a label for a pesticide highlights how ignorance is produced about which agrochemicals are bee toxic. First, chemical companies are currently not required to conduct an acute oral toxicity test, which is similar to the contact test, but the substance is ingested orally (US EPA 2016).

Second, FIFRA guidelines do not mandate screening of honey bee larvae (a 7-day test), which means that companies are only required to test *adult* honey bees for the LD50. The challenge with this is that honey bees bring nectar and pollen laced with agrochemicals back to the colony and feed these substances to honey bee larvae (Krupke et al. 2012). Because it takes several weeks for larvae to mature and hatch, beekeepers may not know for almost three weeks that their bees were hit by one of these agrochemicals while in almonds—so even EPA's 7-day larvae test would not be adequate to track larval damage. Third, FIFRA guidelines do not require the assessment of long-term continual exposure to pesticides (Sanchez-Bayo and Goka 2014), such as the constant consumption of pesticide-laden pollen stored in the colony (Stoner and Eitzer 2013). Fourth, EPA does not require testing of synergistic[33] effects of chemicals likely to be used at the same time; in other words, if a fungicide, insecticide, and adjuvant are mixed in a tank and then sprayed, chemical companies are not required to test the toxicity of this tank mix.

Finally, most FIFRA-required tests are on the active ingredient, not the end-use pesticide formulation, the combination of the active ingredient plus a number of 'inert' ingredients. Inert ingredients are subject to less-stringent regulatory testing (Caroline Cox and Surgan 2006). EPA admits the term inert is misleading because it implies that it is inactive or harmless (US EPA/OCSPP 2015; US EPA 1997). In actuality, many of these chemicals are active and may be more toxic or pose greater risk than the active ingredient (US EPA 2017a; Caroline Cox and Surgan 2006), or may increase the toxicity of pesticide formulations (Caroline Cox and Surgan 2006). Despite these factors, federal law does not require inert ingredients be identified by percentage or name on the label (US EPA/OCSPP 2015), thus falsifying the 'safety profile' of commercial pesticides (Hoq et al. 2018).

One class of these inert ingredients are adjuvants, spray tank additives that enhance the effectiveness of the pesticide formulation (US EPA/OCSPP 2015). Because pesticide adjuvant products "don't make pesticidal claims," they are not considered pesticide inert ingredients and are therefore not regulated by EPA (US EPA/OCSPP 2015). One class of adjuvants in particular, organosilicone surfactants, have demonstrated bee-toxicity (Ciarlo et al. 2012; Fine, Cox-Foster, and Mullin 2016; Chen, Fine, and Mullin 2018). However, since EPA does not regulate most adjuvants, chemical companies are not required to test for bee toxicity, and pesticides containing organosilicone surfactants will not be labeled bee toxic, despite evidence suggesting otherwise.

EPA has arguably enhanced its review process to protect honey bees. In 2012, EPA issued a Pollinator Risk Assessment Guidance for chemical registrants, a publication that came out of EPA's 2012 Scientific Advisory Panel (SAP) Meeting on Risk Assessment for Bees (US EPA 2016). In the document, EPA encourages chemical companies to voluntarily conduct an oral toxicity test when honey bees and other insects might be exposed to the product (US EPA 2016, 16). In fact, an increasing number of firms have conducted both acute contact and oral toxicity tests for new products in the past five years (interview with EPA representative, May 22, 2018).

For example, in a 2013 review conducted of nearly 322 pesticides—which represented over three quarters of all registered insecticides and fungicides for agricultural use—over 69% had data on oral toxicity (Sanchez-Bayo and Goka 2014, 3). An EPA official suggested one major reason this occurs is because European countries require these tests for all imported pesticides (EFSA 2013, 13), an outcome of intense political pressure applied by researchers, the public, and the European beekeeping community to change the EU's bee-related pesticide policies (Suryanarayanan and Kleinman 2014).

[33] From 1984-2007, EPA regulations (40 CFR § 158.75(b)) allowed EPA to request additional data and testing from a chemical company about potential synergistic effects, but in 2007 EPA deleted § 158.75(b), stating that it was unnecessary. In 2016, EPA petitioned Gina McCarthy, the EPA head at the time, to request that this ability be restored, but the request has not yet been granted (Housenger 2016).

In 2014, EPA issued guidance to chemical companies for how to evaluate potential risks to bees from pesticides—yet, it is important to note that this document outlines only *guidance* on risk assessments, not FIFRA *requirements*. EPA now also offers two online portals through which beekeepers can report a pesticide kill, through an email (beekill@epa.gov), or through the National Pesticide Information Center's reporting portal, a partnership with Oregon State University and EPA. Both sites allow beekeepers to bypass disciplinary actions that could occur for the beekeeper or their grower if they contacted the county.

Despite these advances, and because pesticide review only occurs every fifteen years, hundreds of chemicals are still in use that have not been tested for their effects at the larval stage or for oral toxicity, so the risks from these chemicals are still unknown (Sanchez-Bayo and Goka 2014; Caroline Cox and Surgan 2006). This is in addition to the other productions of ignorance about pesticides' toxicity for bees, including which chemicals are toxic when bees have chronic exposure (such as through consuming pesticide-laden pollen), or the toxicity of the entire class of adjuvants that may be toxic not only to bees, but also humans (C. A. Mullin et al. 2016). This gap in required testing has resulted in the "false knowledge" (Haraway 1988; Kleinman and Suryanarayanan 2013) that these agrochemicals are bee-safe. Thus, a wide variety of pesticides and adjuvants are approved for on-farm use that have sub-lethal and lethal toxicities for bees. In the next section, I show how these productions of ignorance are deepened in California through state and county regulation.

How California regulation produces ignorance about bee-toxic chemicals

In California, pesticide regulation is largely carried out through a partnership between the California Department of Pesticide Regulation (CDPR) and the County Agricultural Commissioners (CACs), guided by FIFRA, the California Code of Regulations (CCR), and the Food and Agricultural Code (FAC). Each year, growers must apply for permits from their CAC to use any restricted chemicals, pesticides that have a higher potential to cause harm to humans or the environment (CDPR 2018b), and only certified applicators can apply them (CDPR 2017b). This is the first in a two-step permit approval process; the first step specifies the location where the pesticide will be applied, while the second step identifies the date of the application and is called a Notice of Intent (NOI) (CDPR 2017b). Growers must file a NOI for bee-toxic agrochemicals with the county 48 hours in advance of the application (CDPR 2018a, 6). They then have four days to apply it or the permit expires and they must file again.

To benefit from the NOI process, beekeepers are legally required to register their colonies with the counties in which their hives are located (CDPR 2018b). In practice, many beekeepers *do not* do this, which will be discussed in the next section. For beekeepers who do, the NOI process proceeds like this: (1) If the grower notes a bee-toxic label on the agrochemical, s/he must tell the county when filing the NOI. (2) The county has 16 hours to give the applicator the phone number of any beekeepers registered with the county. This registration is sometimes entered in an online database, but several counties confirmed that they only have a large physical map with pins on it to denote known colony locations. (3) The applicator then must directly contact the beekeeper to inform them which chemical they will apply, and then (4) the beekeeper has 48 hours to respond.

In interviews, beekeepers shared that they might move or place a tarp over their colonies, or more commonly, negotiate the use of a different chemical or application timing that may be less problematic for their bees. Again, this *only* happens if beekeepers have registered their bees, if their colonies are visible to the grower and have contact information on them, or if they are contracted to pollinate the orchard where the agrochemicals will be applied. If they have not, then the beekeeper will not receive this call and the applicator will typically apply the chemicals without notifying those beekeepers. Finally, the grower is supposed to keep records of any restricted agrochemicals they apply. If the grower is applying the agrochemicals themselves, they must submit a final use report to the county by the 10th day of the following month (CDPR 2017a, chap. Ch. 4, p. 8). They must also keep these reports on file, so the county can check their reports in the event of an investigation. If the grower hires a commercial applicator, then the applicator must submit their use reports to the CDPR weekly (CDPR 2018a, chap. 10).

How County Ag Commissioners conduct a bee-kill investigation[34]

When a beekeeper observes colony damage or loss that they suspect is due to agrochemicals, they are encouraged to call the CAC office and initiate an investigation (CDPR 2018a, chap. 15). The goal of this investigation is not so much to find out what chemical killed or damaged the bees, but to determine if there was a 'misapplication' (i.e. a label violation) and possibly penalize the grower (p. 15). Because this is an official investigation, evidence is needed to support the beekeepers' case, and the best evidence is visible evidence, the type that occurs when an acutely toxic pesticide has been applied and a large number of dead bees pile up outside the hive. Colony damage from a sub-lethal application is much harder to trace (Meikle and Weiss 2017).

When the CAC gets the beekeepers' call, they will ask the beekeeper what actions they took inside their hive prior to the colony damage, such as whether they recently treated for parasitic mites, and which treatment they used. If the beekeeper admits to using a prohibited miticide[35], the investigator will often stop the investigation, because—as one county representative stated—the beekeeper might have killed the bees themselves with the prohibited miticide (interview, Apr. 2, 2018). If the beekeeper has since moved their operation's hives or has gone inside the colony and moved the frames, then sometimes the county will also stop the investigation because the beekeeper has tampered with the evidence.

If the investigator does decide to proceed after this initial phone screen, she will then go to the site of the reported bee kill to survey the damage, select samples, and gather forensic evidence. First, she will look for a substantial number of dead bees. The CDPR recommends the collection of ½ pound to a pound of dead bees, about the size of a full brown lunch bag of bees (CDPR 2006, chap. 47). If she cannot collect a proper sample, she may abandon the investigation. Next, the investigator will swab the colony box to collect chemical samples and sometimes collect a larval sample, which means they must cut out some of the larvae in the comb of the hive. The investigator will also study the pattern of the bee kill, to get a sense of what direction the agrochemical may have come from. For example, if all the bees on the north of the apiary site are

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[34] The data for this section is a summary of eight interviews with CAC representatives.

[35] Many of the beekeepers interviewed admitted to using a prohibited miticide, Taktic, because it has been one of the most effective treatments for parasitic mites—one of the current plagues of the beekeeping industry.

healthy but the bees on the south end of the apiary site show more damage, then the investigator will focus on growers to the south of the apiary.

Back at the office, the inspector contacts all growers within a quarter mile to one mile of the incident to ask about what agrochemicals have been applied within the last two weeks. They review the agrochemical labels to establish if they have a bee-toxic label. Some beekeepers find this problematic, however, because a grower or applicator can readily fabricate their pesticide use reports. As one bee broker stated: "[The] use reports… are only as good as the honesty of the guy that signs them…anybody can fudge a use report" (Mitric 2017). If the use reports support the claim that an *already labeled* bee-toxic chemical has been applied during this time, then the county will send the bee and swab samples to the Department of Pesticide Regulation's contracted laboratory to test for the presence of those chemicals.

If the samples test positive for a bee-toxic agrochemical, the CAC will determine what fine should apply and levy it against the grower, if it is possible to determine which grower applied the chemicals that killed the bees. However, this can be a challenge, because multiple growers could have applied the chemical within the two-week period. If a fine is levied, it does not go to the beekeeper; but to the CAC office. Beekeepers do not receive any compensation for their lost colonies from growers through this process. If a beekeeper wants to sue the grower for damages, he can use the investigation evidence to file a civil suit—though beekeepers and CAC representatives expressed that this rarely happens because of the litigation cost involved and the possibility of losing future contracts with almond growers.

"The Label is the Law": Productions of ignorance through state and county agencies

Both county representatives and beekeepers used the expression "the label is the law" repeatedly in interviews to summarize the county-level pesticide regulatory process, but each party has a different relationship to the phrase. For the county, the "label is the law" in the sense that FIFRA guidelines, Food and Agricultural code, and California regulatory guidelines legally determine their investigation and inhibit them from collecting field data on agrochemicals that are not currently officially identified as bee-toxic. Unless a labeled bee-toxic agrochemical has been applied, then the county cannot send the honey bee sample to the CDPR's testing facility to find out what chemicals killed the honey bees. One CAC talked about the conflict they face as law enforcers when they know that toxicological data exists suggesting certain chemicals are toxic to honey bees, but the labels do not reflect these data. He mentioned a bee symposium that the CDPR held in 2017 to share some of this research data:

> It's great to get info, but we can't enforce info and data. It's been "fungicides kill bees" as long as I can remember—and it's true; fungicides or an adjuvant did kill bees. But until it becomes a law or code or a label, that's not enforceable. The ag commissioner's office doesn't make the laws, they just enforce them. (Interview, Aug. 1, 2017.)

The only action the beekeeper can take in this situation is to call in the colony loss to the county, suggest what they think might have happened, and the county will note this report in their database. The beekeeper can also send a sample into a lab to determine which agrochemical killed their honey bees, but at around $400 to $700 per sample (Pesticide Research Institute

2018), it is both expensive and requires careful attention to packaging to maintain the sample's integrity.

To beekeepers, the expression "the label is the law" highlights the key role the label plays in protecting honey bees. Ultimately, it is *not* the NOI process that protects them, some beekeepers argue, because most large-scale beekeepers are rarely going to move hundreds of honey bee hives in the middle of almond bloom, even if they hear from a grower that a restricted chemical is going to be sprayed. Beekeepers face commercial production demands: they are hired to pollinate almond trees, and each day makes a difference to successfully pollinating the crop.

Secondly, it would be costly in labor terms to move their many hives, and third, where would they put them? The best thing that comes out of the NOI process—and this is an important benefit for beekeepers—is that they can potentially negotiate the terms of the application and keep track of which chemicals are being applied in case they experience colony damage. This underscores how the pesticide label ultimately protects honey bees from getting killed by agrochemicals, since almond growers typically mitigate their use of labeled bee-toxic agrochemicals during almond bloom (Durant and Goodrich, in preparation).

This points to the central role that EPA's labeling process plays in producing ignorance, and what is at stake by not requiring oral, larval, and chronic toxicity tests for agricultural pesticides that honey bees will most likely encounter. It deeply frustrates many beekeepers that EPA (guided by FIFRA) only requires the adult bee acute toxicity LD50 test from chemical registrants, when scientific data support beekeepers' experiences that pesticides are killing their bees at the larval stage and through chronic exposure, yet those chemicals may not subsequently be labeled bee-toxic until—perhaps—the review phase that occurs fifteen years after registration.

Beekeepers who track honey bee toxicology research, or who attend conferences where this information is disseminated, sometimes tell growers or applicators to not use the chemicals they suspect are killing their bees, and occasionally put this in their contracts. But some beekeepers expressed that they do not feel comfortable telling growers how to manage their orchards, and not all growers or applicators will care if there is no bee-toxic label to substantiate what the beekeeper has said. In short, some beekeepers' use of the phrase "the label is the law" carries a sense of defeat or apathy.

Beekeepers' Regulatory Disengagement

This section focuses on how beekeepers participate in the production of ignorance about which agrochemicals are toxic to honey bees, co-constituting what I term an *ignorance loop*, where data collection gaps in the EPA's registration process are iteratively reinforced by beekeepers' disengagement from reporting and investigatory processes. As a result, the knowledge beekeepers hold about the toxic effects of certain agrochemicals never makes it back to the EPA's database, so EPA scientists do not have that incident data to consider when reviewing the pesticide label later on, and then beekeepers must continue absorbing the damage they incur as a result of these chemicals' application. Below I look at some of the main reasons that beekeepers disengage from reporting bee kills.

Beekeepers fear they might lose contracts with growers

In March 2014, over fifty commercial beekeepers met in Los Banos, California with two representatives from the EPA's pesticide labeling division. The meeting's goal was for beekeepers to discuss the heavy colony losses they had experienced during almond pollination season that spring. During that meeting beekeepers were clearly frustrated with agrochemical regulation at federal, California, and county levels, and agrochemical labeling practices more specifically.

The EPA representatives asked beekeepers why they did not communicate directly with their almond growers to advocate for better agro-chemical spray protocols. One of the reasons several beekeepers cited was that they do not feel comfortable reporting or sharing a bee kill to the grower they pollinate for, or to an outside agency. Beekeepers cited that they will be "blacklisted" or lose their contracts if they report a grower whose agrochemicals killed their honey bees. One beekeeper stated in a follow-up interview: "Yeah, if you complain about pesticides too much, well, you're not coming back to this spot next year. As a general rule, if you complain too much, then you're outta here. Sorry. See you later. Don't come back" (interview, Aug. 4, 2015).

Another beekeeper expressed concern that some pressure to "blacklist" might come from the pesticide manufacturers themselves:

> The registrants [chemical companies] say if you would report more, get this on record, then you'll prove your point. But if we do that, farmers and applicators will see us as a problem. There is evidence that some registrants are sending talking heads to growers, saying, "if you don't want to have issues using our products and caring for your crops, you had better get rid of the beekeeper." (Interview, Sept. 28, 2017)

This is an important point to consider in the process of trying to understand how ignorance is produced about which agrochemicals kill honey bees: beekeepers perceive a power asymmetry that can deter them from reporting an agrochemical bee kill. The threat of losing current or potential contracts can play a powerful role in determining whether or not a beekeeper will report an agrochemical kill to the county. Suryanarayanan and Kleinman describe this power disparity: "The entire system of industrial agriculture focuses on advancing grower objectives. Thus, the relationship between growers and beekeepers is an asymmetrical one…migrant bees and nomadic beekeepers are serving grower clientele, not the other way around" (2017, p. 71).

This reluctance to report bee losses frustrates some beekeepers, particularly ones who work closely with the EPA on this issue. Two beekeepers in this position discuss this conundrum here:

> Beekeeper 1: Every time you talk to the EPA they say nobody is saying anything, nobody is reporting. It's all anecdotal, so then it doesn't mean anything.
>
> Beekeeper 2: It stems back from beekeepers thinking: 'If I report a problem then I'm going to get blacklisted or piss off my almond grower'—but they fail to look at the bigger picture, which is that if you don't start talking about these things, they aren't going to go away. They're only going to get worse. (Interview, Mar. 3, 2017.)

This demonstrates how some beekeepers who have remained engaged in regulatory processes recognize what they stand to lose from other beekeepers' regulatory disengagement.

The county does not collect emergent data on un-labeled pesticides

Another major factor determining whether beekeepers will report a loss is what type of loss it is. If the damage or loss was acute and caused by a labeled bee toxin (typically a pyrethroid or an organophosphate), then the loss is typically very obvious: thousands of dead honey bees pile up just outside the hive. It is easy for an investigator to collect honey bees for this type of loss. However, if the loss was caused by a fungicide, IGR, or adjuvant (chemicals thought to be responsible for most of the losses beekeepers have experienced recently), then the damage will likely occur to the honey bee larvae inside the colony and not the adult bees, and because it is the larvae that will be affected it might take weeks for the damage to become obvious. By that time, the beekeeper will likely be out of the almond orchard where the incident occurred, and possibly out of the state. The following interview excerpt illustrates beekeepers' frustration with the county's focus on acute, highly visible bee kills:

> Beekeeper 1: When [the county investigators] come out, they only want to look at what is right in front of the hive. If it's not at a level where the death is so fast inside of the hive that [the honey bees in the hive] get the bulldozers out and push the bees out, it drastically reduces the amount of dead bees you see in front of the hive.
>
> Interviewer: So [the county] really wants a very specific kind of kill.
>
> Beekeeper 1: The mechanism for reporting a bee kill is not even beginning to scratch the surface.
>
> Beekeeper 2: They want an organophosphate, an old-school pesticide kill.
>
> Interviewer: Quick and obvious.
>
> Beekeeper 3: If it's not quick and obvious, it doesn't exist. (Mar. 3, 2017)

Many beekeepers know that the county will not investigate colony loss if the suspected agrochemical is not labeled bee-toxic. From their perspective, what is the point of reporting a bee kill if the county will not investigate it anyway?

Beekeepers do not report losses because they did not register their colonies with the county

One way that beekeepers contribute to the production of ignorance is by remaining invisible to the county during almond bloom, which means they do not sign up for the county's NOI process (the notice of intent to spray bee-toxic agrochemicals), nor register their colony's locations with the county. As mentioned earlier, beekeepers are required by California state law to register their colonies with the county in which they are contracted to pollinate and identify their colonies either at the entrance of the apiary or on the colony box itself (CDPR 2018a, chap. 13).

Beekeepers can then opt in to the NOI process where they will be notified if they are within one mile of a labeled bee-toxic pesticide application.

If a beekeeper calls the county to report a bee kill and has *not* registered their colonies with the CAC's office then the CAC representatives may feel a sense of frustration that the beekeeper did not follow the law and report their colonies. One county representative stated: "It is kind of like: You're not following the rules, but you want everyone else to. Which is common for beekeepers, I might add" (interview, Aug. 1, 2018). In another interview with a CAC representative from a different county, the representative mentioned over fifteen times in one hour that beekeepers do not register their colonies (interview, Apr. 2, 2018).

In fact, CACs reported that 50-80% of the beekeepers in their counties do not register their colonies with the county. They can determine this through a basic calculation, which is to double the approximate almond acreage—that is around how many colonies should be registered since each acre of almonds requires two colonies of bees. It surprised many CACs that beekeepers do not register, because it only costs ten dollars (13 FAC 4 § 29044), and then the registered beekeeper will receive notices about bee-toxic pesticide applications. From the CAC perspective, their problem is that existing state legislation does not give them authority to penalize beekeepers, and the fine is low enough that it is not a real deterrent, typically around $50.

One county representative put the blame for colony losses on the beekeeper: "Very few [pesticide] applicators and farmers are causing bee kills. The fault is on the beekeeper for being sneaky" and not registering with the county in the first place (interview, Mar. 12, 2018). Another CAC expressed this frustration about the challenge of getting beekeepers to register their colonies:

> It's a bit of a wild west out here—all the bee regulations in the code don't have any teeth that the county commissioner can stand on. The way they're written up is very clear. But there's no definition of penalties for beekeeper. There is no code for that, no written law. (Interview, Aug. 1, 2018.)

Some beekeepers, however, cited the registration and NOI processes as their reason for not wanting to register. One beekeeper stated: "the entire edifice is old, antiquated…the entire schmaltzy process is outdated!" (interview, Mar. 30th, 2018). Fresno County, for example, requires beekeepers to fill out a written application in which they list their township, section, and range location coordinates, and then include a "satellite map" (this request is in bold type)—and then send it via US Mail with a $10 check (Fresno CAC 2017).

Some beekeepers felt that the CAC registration process has a technological lag that does not favor mobile, office-less beekeepers. Most of the large beekeepers are operating out of hotels, driving around in trucks all day, using their smart phones to conduct business. Having a system that requires them to send information on each individual apiary site—they could have dozens—via postal mail (instead of email), adds another level of bureaucratic paperwork that most beekeepers dislike in the first place. As a result, the beekeeper may not report a bee kill to the county because they may get a citation for not registering as part of the investigation.

By not registering their bees, beekeepers frustrate both growers and the county. The grower may have followed the NOI procedures and contacted nearby 'visible' beekeepers (who have contact information written on their colonies) before applying a bee-toxic agrochemical. However, they may still damage the bees of beekeepers who did not register. As a result, every CAC interviewed confirmed that they may choose to *not* do an investigation since the beekeeper did not comply with the law in the first place. If an investigation is not pursued, then data about which agrochemicals are bee-toxic during almond bloom does not get recorded in the databases that eventually make it back to the EPA—thus contributing to further ignorance about which pesticides are killing bees.

Conclusion

This chapter focused on productions of ignorance about which agrochemicals are toxic to honey bees through the processes of regulating pesticides. I argued that mechanisms of ignorance production are embedded into multiple scales of the regulatory process (federal, state, and local) and then reinforced by beekeepers disengaging from the regulatory process out of frustration, apathy, or possibly because they are not following regulations and want to remain invisible to the county. This reinforces ignorance at the EPA office and creates an "ignorance loop" between federal agencies and bee stakeholders about which chemicals are killing bees. As a result of this disengagement, emergent data gets lost.

This case provides an example of the social inequities produced by undone science (Frickel et al. 2010). It demonstrates how the production of ignorance can be structured into regulatory policies, an unintentional biproduct that supports corporate interests nonetheless. It is clear that these gaps in required data for pesticide registration will hobble the beekeeping industry until addressed. Beekeepers—who play an integral role in US agricultural—will likely continue to experience the colony losses and sub-lethal damage that makes their bees vulnerable to pests and disease for the rest of the year. In addition, trust between beekeepers and the regulatory system that is ostensibly designed to protect them continues to break down.

As noted earlier, a strong alliance with chemical companies' interests is baked into FIFRA's vestigial roots, though the FEPCA and FQPA amendments helped cleave some of these ties. However, changes in the Trump administration have pointed to EPA's support for industry over the public (Dillon et al. 2018), such as EPA's reversal on its decision to ban the organophosphate pesticide chlorpyrifos (US EPA 2017b), despite voluminous data supporting its acute toxicity for farmworkers and developmental damage in children exposed to the chemical (e.g. US EPA 2015). Decisions like these—so overtly in favor of the chemical industry—break down beekeepers' trust in the EPA and lead to regulatory disengagement. As one beekeeper stated at the 2014 EPA meeting in Los Banos: "You need to change EPA to CPA, because you guys are trying to protect the chemical companies, not the environment" (interview, Mar. 24, 2014).

However, EPA representatives in the pesticide labeling division share a different side of the story and expressed frustration about how FIFRA regulations limit their ability to respond to honey bee losses and request the data beekeepers want them to collect. In an interview, two representatives shared an anecdote that demonstrated how hard it is to make changes to agrochemical labels because of existing statutes (interview, Apr. 17, 2014). Between 2004 and

2008, U.S. poison control centers received 10,000 to 14,000 calls *per year* about children getting poisoned from eating the rodenticide d-CON, produced by Reckitt Benckiser (McClure 2010).

According to the EPA representatives, more than 95% of the time that there are issues with a label, companies will agree to labeling changes (interview, Apr. 17, 2014). However, in this case, Reckitt Benckiser refused to comply with the voluntary change, arguing that restricting the rat poison will likely lead to "potentially significant public health consequences" (McClure 2010). Instead, the company sued EPA and forced them to go through the required process determined by existing statues. After a protracted legal battle, it took EPA from 2008 until March 31, 2013—over five years—to halt the production of d-CON rodenticide, a chemical poisoning *children* (US EPA 2013).

This anecdote provides helpful context when trying to understand challenges beekeepers face changing labeling processes in support of honey bees. EPA's labeling system, guided by FIFRA law, reflects an increasingly "anti-regulatory posture" that still relies heavily on cost-benefit analysis and quantitative risk assessments (Ashford 2006, 353), as well as a 'sound science' approach that excludes beekeepers' lay expertise (Suryanarayanan and Kleinman 2011). These existing mandates largely make sublethal pesticides innocent until proven guilty, effectively making humans, honey bees, and the environment writ large a testing ground for sublethal pesticide toxicity.

This stance highlights FIFRA's earliest iteration as a collaboration between growers and the federal government to provide reliable chemicals to the agricultural industry. This relationship ultimately protects chemical companies and growers who are "collectively aligned with the agrochemical industry" (Suryanarayanan and Kleinman 2017, chap. 54). This is not to say that it is easy to get an agrochemical registered—it is tedious and expensive—but the EPA does not operate under a precautionary system like that of Europe for example, which would lead to a more conservative approach to pesticide regulation (ibid., 99).

Turning to county regulation by CACs, interviewed representatives expressed frequently that they are also bound by regulatory policies guiding their investigatory processes. When asked why they do not run samples on honey bees that may have been exposed to chemicals *not* labeled bee-toxic, but clearly killing honey bees, CACs expressed that CDPR and FIFRA policies do not allow them to (though CDPR has made exceptions on occasion[36]). They pointed out that agrochemical screens are expensive, so to screen for a wide variety of agrochemicals—rather than select the few that they suspect—is a costly use of state funds. As such, there may be budget limitations which enforce the status quo of current investigatory procedures.

While beekeepers have incentives for regulatory disengagement from reporting bee kills, it also comes at a price. One former beekeeper who has worked for decades to help guide EPA and CDPR policies explained that many beekeepers do not understand that bee kill data needs to be recorded by EPA to inform the label re-evaluations they conduct every fifteen years. In fact, one pesticide testing center, the Pesticide Research Institute, is working with several bee advocacy

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[36] On one occasion, a CAC sent a sample for her own investigation on behalf of a beekeeper. The lab found that it was a lack of water that had killed the bees. The CAC said that beekeepers often do not put out enough water for their bees and that this can also cause colony losses (interview, Mar. 12, 2018).

organizations to support beekeepers' testing of pesticides. On their website, it states: "Remember: If US EPA doesn't know about your poisoning incident, it didn't happen, and nothing will change to prevent incidents like it in the future."

This appears to be true. If CDPR and EPA do not know about colony loss or damage from suspected pesticides, then this information will not be considered during the 15-year review process and the pesticide will continue to not have a bee-toxic precautionary label. This demonstrates how stakeholders ultimately bear the burden of creating ignorance loops between their community and regulatory agencies.

Lastly, this case points to a larger problematic: the way that monolithic federal agencies use reductionist policies and scientific processes to regulate complex, living systems. As mobile, uncontrollable insects, honey bees defy simplistic regulatory practices and require complex, technologically nimble approaches. Beekeepers, as the managers of highly complex organisms subjected to agrochemicals in invisible and hard to trace ways, are particularly vulnerable to this type of regulatory process.

Chapter Five: Honey bee Vulnerability and Exclusions from Floral Resources

Figure 5.1: Honey colonies in North Dakota

Introduction[37]

Seth Roberts remembers beekeeping with his grandfather 25 to 30 years ago, when making honey in Minnesota was easy. They would sometimes have as many as five or six boxes of honey, called honey supers, stacked on top of the main colony box. He had to back up his old Chevy pickup and stand on the tail gate just to take the top off and get into the hive. "Every one of those boxes would be chock full. Now you put two to three supers on in a year, and even with your strongest hive in the best area you get three boxes of honey" (interview, Feb. 16, 2016). Another commercial beekeeper who grew up in a beekeeping family in Idaho used to get 150lbs per hive as a kid, and then it went down to 60. Now, he says, "It's shocking if you can make more than 30lbs a colony" (interview, Mar. 23, 2017).

This situation reflects the plight of many commercial beekeepers in the United States. Despite the fact that honey bee colony numbers have stayed fairly consistent since the early 2000s, honey production has declined from 171 million pounds to around 156 million in 2015 (USDA-NASS 2017a). In interviews, many beekeepers attributed the decline in production to diminishing bee forage, i.e. bee-friendly flowers, particularly in the Midwestern Corn Belt where over 45% of the nation's honey is produced each year (USDA 2018). This has placed a lot of stress on commercial beekeepers, many of whom have shifted their operation focus from honey production to commercial almond pollination as a result (H. Lee et al. 2017). While this decision

[37] Portions of this paper were published in an article in *Journal of Rural Studies* (Durant 2019).

has helped keep beekeeping operations in business, it presents challenges for both beekeepers and their honey bees.

Understanding some of the factors that shape forage change can give important context to researchers investigating honey bee declines, and honey bee vulnerability more broadly. As mentioned in the introduction, between 1947 and 2005, the United States experienced a 59% decline in honey bee colonies, from 5.9 million to 2.4 million honey producing colonies (VanEngelsdorp et al. 2008, 2). In Chapters One and Three, I detailed one of the drivers behind colony losses: diminished demand for honey and a flood of cheap honey imports made it difficult to make a living as a commercial beekeeper solely off commercial production. Beekeepers have subsequently turned to commercial agriculture for income, which, as I show in Chapter Two, comes with its own host of factors that contribute to honey bee vulnerability, such as exacerbating the virility of Varroa mites (DeGrandi-Hoffman et al. 2014), and less access to diverse, high quality pollen (Di Pasquale et al. 2016, 2013).

A more recent consideration in research on bee health is the effect of habitat and forage loss on wild and managed bee populations. Ecologists brought attention to the effect of habitat loss on native pollinators before honey bee losses became widely documented in 2006 with the advent of Colony Collapse Disorder (CCD) (Kremen et al., 2002; Potts et al., 2010). Yet research on how diminished access to forage may impact beekeepers and honey bees has only recently become a point of focus: for example, how land use change in the Northern Great Plains has significantly reduced access to honey forage for beekeepers (Otto et al., 2018; Otto et al., 2016) and how the decline of this forage might affect honey bee health (Hellerstein et al. 2017).

This final chapter thus contributes to research on forage change and its effects on managed honey bees in the United States, by investigating the mechanisms that shape beekeepers' access to forage. I argue that as beekeepers lose access to forage through various economic, legislative, land management, and social processes, both honey bees *and* beekeepers become increasingly vulnerable. When beekeepers lose access to forage lands, they increasingly have land-use conflicts with landowners, environmentalists, policy makers, and even other beekeepers in their efforts to re-secure access. These conflicts have created a growing source of stress in the beekeeping industry, and as a result, many beekeepers use manufactured pollen substitutes to make up for the lost nutrition and increasingly turn to commercial pollination for income. Evidence suggests that both practices can have negative impacts on honey bee health (e.g. Cavigli et al. 2016; Fleming, Schmehl, and Ellis 2015).

Commercial beekeeping in the United States requires beekeepers to seasonally relocate their colonies so that bees have constant access to blooming forage. Such broad tracts of land are rarely owned by the beekeeper. Thus, each forage site requires the negotiation and maintenance of new social relationships (personal, economic, juridical, and political) that will either "constrain or enable" access to forage (Ribot and Peluso 2003). In addition, honey bees travel through landscapes without attention to property rights or landscape borders. This means that the survival of beekeeping—and managed honey bees—depends largely on beekeepers' ability to maintain access to property they do not own, to produce stinging insects whose foraging habits are unpredictable and uncontrollable. This is a surprisingly tenuous economic arrangement for an industry whose pollination services add a significant contribution to United States agriculture.

This chapter also extends theories of access (Ribot and Peluso 2003) and its converse, exclusion (Hall, Hirsch, and Li 2011). An access and exclusions framing of changing forage availability pays attention to the web of social relations between beekeepers and landowners—as well as state, non-governmental organizations (NGOs), and corporate entities—to explain how beekeepers have gained, maintained, and lost access to forage, and the subsequent effects these processes have had on honey bee health and beekeeper precarity. This analysis adds to theories of access and exclusion by demonstrating how the migratory nature of the commercial beekeeper creates a unique set of barriers to access within the context of the United States' large-scale industrial agricultural system, making it increasingly difficult to produce bees.

I begin with a review of scholarship on theories of access (Ribot and Peluso 2003) and, in more detail, its converse, exclusion (Hall, Hirsch, and Li 2011). I then summarize commercial beekeepers' annual management tasks and the role that forage plays in commercial honey bee management, to help contextualize what is at stake for beekeepers as they lose access to diverse, non-toxic forage for their honey bees. I also discuss the mobility of the honey bee and the challenge this can pose for maintaining access to forage sites. A discussion of three cases follows, in which beekeepers have been excluded from forage sites in the Midwest—a key region for honey production. I highlight the powers and processes that shape these exclusions, and discuss the consequences of these exclusions from forage, particularly how beekeepers have turned to manufactured pollen and nectar inputs and commercial pollination for income. Finally, I highlight beekeepers' efforts to regain access to forage lands and discuss the implications of these findings in the conclusion.

A Theory of Access to and Exclusion from Floral Resources

Political ecology scholarship has a rich history of investigating conflicts around access to land-based resources, bringing attention to the mechanisms that drive environmental change such as declining bee populations (Watts and Peet 2004; Peet, Robbins, and Watts 2011; Robbins 2012). Ribot and Peluso define access as "the *ability* to benefit from things" (2003, 153), extending beyond property's definition as "the right to benefit from things." By focusing on the *ability* to access land resources rather than the *right*, analysts have a broader set of tools to understand and contextualize conflicts over land resources that occur between landowners and land managers and resource users who have historically had access to land without legal property rights.

Conflicts over access to natural resources are intimately bound up with power and authority (Sikor and Lund 2009), and investigations into property dynamics allow insights into state formation and governance as well (ibid., 3). Drawing from Ribot and Peluso's definition of access, Hall et al. (2011) bring attention to the role that state formation and governance play, as well as other powers, in resource exclusions. Their 'Powers of Exclusion' framework positions exclusion as the converse of Ribot and Peluso's definition of access (ibid.*,* 7). Where access analyses highlight the mechanisms that constitute "the means, processes, and relations by which actors are enabled to gain, control, and maintain access to resources" (Ribot and Peluso 2003, 159–60), exclusion analyses highlight the actors, social dynamics, and political economic mechanisms actively *preventing* smallholders from the resources they need to sustain their livelihoods (Hall, Hirsch, and Li 2011, 8). Though the framework has largely been used to discuss conflicts in Southeast Asia (Filer, McDonnell, and Allen 2017; Howson 2017; Friis and Nielsen 2016), I engage it here to contextualize land use conflicts that beekeepers face—and likely other mobile producers, such as pastoralists, gatherers, and foragers who do not own the land or resources needed for production.

The authors detail four powers of exclusion at work in Southeast Asia: regulation, force, the market, and legitimation (Hall, Hirsch, and Li 2011, 15–19). *Regulation* is often—but not exclusively—associated with state and legal mechanisms that shape who gets access to land and how it can be used. *Force* excludes through direct violence or the threat of it and is carried out through state and non-state actors. The *market* can exclude by limiting access to land through price mechanisms that incentivize land management practices that have excluding consequences. Finally, *legitimation* discursively establishes the normative grounds through which these processes become socially acceptable and entrenched. The authors also mention several other powers of exclusion not detailed at length in their book, two of which I highlight here: *new knowledge and technologies* such as agrochemicals that can contaminate floral resources (ibid., 197), and *environmental changes* that reduce access to resources such as the reduction of bee forage due to drought (Thomson, 2016) and climate change (Le Conte and Navajas 2008). Exclusion can be understood as localized processes that result from interactions between these larger-scale powers.

Hall et al. (2011) detail seven localized processes that drive exclusions in rural settings. Though their study site is Southeast Asia, most of the processes are surprisingly relevant in the case of beekeepers and land access in a North American, industrial agriculture context. The processes of *licensed exclusion* (ibid., 27), through which governments grant formal legal titles to land, and *self-exclusion* (ibid., 71), through which small holders exclude themselves from resources, are less relevant to the cases in this chapter. The next five, however, are quite relevant. *Ambient exclusions*, where communities are excluded from landscapes in support of conservation initiatives (ibid., 60), can occur when government entities and NGOs exclude beekeepers from public lands or conservation sites to maintain habitat and forage for native pollinators. *Volatile exclusions* (ibid., 87), where communities lose access to land converted to monoculture production for boom crops, result when farmers in the U.S. Midwest convert range and prairie landscapes that beekeepers use for honey production to participate in a corn and soy boom.

Post-Agrarian exclusions, where land is converted to non-agrarian uses (ibid., 118), unfold as suburban and urban development displace agriculture and rangeland forage that beekeepers rely on for honey production (Naug 2009). *Intimate exclusions,* when neighbors and kin exclude one another from land access (Hall, Hirsch, and Li 2011, 145), can take place when one beekeeping operation expands and seeks more forage sites and intentionally or inadvertently pushes other beekeepers off of their previous sites. Finally, *counter-exclusions* can occur when communities resist dispossession and assert control over land they once had access to (ibid.,170), such as beekeepers and bee advocates working through social and political networks to limit the use of bee-toxic agrichemicals on site.

To these seven processes of exclusion, I add an eighth: *Toxic exclusions*. Toxic exclusions occur when resources that producers rely on are contaminated, such as when nectar and pollen are polluted by pesticides. What is unique about toxic exclusions is that the resource is often still technically accessible (e.g., bees can still gather contaminated pollen unless acutely poisoned) but accessing the resource would be harmful for the resource user or their livestock (bees, sheep, cattle, etc.). Toxic exclusions often result from a nexus of powers such as new technologies like pesticides that growers apply to their crops, which are often legitimated through scientific research and regulation; for example, the EPA's registration process that only requires chemical companies to test a pesticides' acute toxicity on honey bees (Kleinman and Suryanarayanan 2012). As market forces create crop booms and regulatory bodies subsidize or support them, agricultural landscapes simplify and often require new tools for pest management like toxic agrochemicals. I detail a toxic exclusion beekeepers face in Part Three.

It is important to note that though exclusion is often framed negatively, exclusion is the inevitable outcome of land relations and thus has a double edge (Hall, Hirsch, and Li 2011, 7): in order for someone to have access to a finite resource, access must be denied to someone else. These dilemmas make policy solutions to access conflicts particularly challenging. Drawing from access theory and the Exclusion Framework can help contextualize how land use changes have affected beekeepers and other mobile producers in varied global contexts and how these changes are driven by and bound up in processes of governance, market forces, discursive legitimation, environmental change, and the introduction of new production technologies.

Returning to the case of bees, in Chapter Three and Four, I discussed some of the critical social science theory on bee declines, particularly the way that social processes shape regulation, science, and land management practices in ways that can hinder or protect honey bees. As mentioned, these processes emerge, in part, because the system of industrial agriculture prioritizes growers' objectives over beekeepers' (Suryanarayanan and Kleinman 2017, 71). To reiterate, this has led to asymmetrical relationships between beekeepers and growers where: "migrant bees and nomadic beekeepers are serving grower clientele, not the other way around. And beekeepers are the ones who largely have had to adjust in response to growers' changing practices of cropping and pest management (ibid.).

These power asymmetries between beekeepers and land managers not only shape honey bees' exposure to pesticides, but also beekeepers' access to non-toxic forage sites and apiary locations more broadly. Though some urban communities have welcomed managed bees (L. J. Moore and Kosut 2013), other beekeepers struggle to keep honey bee colonies in population-dense urban environments, where neighbors are wary about being stung by bee swarms (Edwards and Dixon 2016). Commercial beekeepers and honey producers also face conflicts over access to public lands, due to conservation efforts that position beekeeping as antithetical to public forest management (C. Phillips 2014; Watson 2017). These limitations to access are particularly challenging for beekeepers, many of whom feel an intimate connection to their honey bees (Maderson and Wynne-Jones 2016; C. Phillips 2014; L. J. Moore and Kosut 2013), and yet also rely on them for their livelihood.

What emerges from this scholarship is evidence that supports Kosek's (2010) claim that the changing relationship between humans and bees has contributed to honey bee vulnerability, as I detailed in Chapter Three. And yet what I aim to show in this chapter, is that it also demonstrates how changing relationships between *humans and the land* contributes to honey bee declines as well. As cities increasingly urbanize, diverse agroecosystems simplify, and monoculture agriculture proliferates, floral resources will diminish and conflicts will continue to increase between land managers and migratory beekeepers. I detail these processes in the sections that follow.

Beekeeper Mobility and the Maintenance of Access to Forage

The challenge of maintaining access to forage

Maintaining access to forage sites is one of the primary activities of most beekeeping operations. Ribot and Peluso define *maintenance of access* as a process that requires "expending resources or powers" to keep access to that resource open (2003, 159). Honey bees need access to food year-round, particularly from early spring through late fall, when they have hopefully amassed enough honey and pollen stores to last the colony through winter. Beekeepers may need to move their colonies every few weeks to months depending on which plants are blooming, which requires them to navigate a new set of social relations, local ecologies, and multi-scaled bureaucracies at each location. Each forage site is likely on someone else's land. Beekeepers are typically paid to keep their bees on site if they are providing crop pollination services, but otherwise beekeepers maintain their access primarily through a gift economy including jars of honey and boxes of fruit—though sometimes they also pay monetary rent. Besides finding sites with floral abundance for honey production, maintaining access also means assuring landowners' neighbors that the millions of bees housed next door will not negatively impact their daily lives.

After almond pollination, most beekeepers will move on to the next pollination contract or work on increasing colony numbers through 'splits,' where beekeepers take one full colony and split it into two or three, adding a new queen to each new colony. Some beekeepers skip further

Figure 5.2: Beekeepers doing a hive inspection in N.D.

pollination services after almonds and take their bees straight to honey forage after doing their spring splits. For honey production, beekeepers must have an intimate knowledge of regional geography, to know where and when different pollinator-friendly species bloom. They must pay attention to water availability and rainfall because honey bees need a water source and a lack of rainfall can affect the length of floral bloom. Beekeepers must also attend to shipping logistics. Trucking 2,000 colonies of bees requires over four semi-trucks (each semi can haul 450 colonies) and shipping bees comes with its own set of concerns: labor costs, weather issues (keeping bees cool or warm during shipping), state border inspections, and the occasional dreaded truck tip-over that can kill millions of bees (Egel 2017).

These geographic and logistical processes dovetail with a key component of maintaining forage access: the negotiation of social relations (Ribot and Peluso 2003, 172). A beekeeper must manage relationships with the landowners, property managers, and federal land managers who have forage sites, as well as the management practices (such as agrochemical applications) on those sites. Finally, beekeepers must protect themselves against 'rogue' beekeepers whose activities undermine the community: beekeepers who crowd forage sites by placing colonies too close to established beekeepers' sites, or those who actually steal other beekeepers' colonies during almond pollination, for example, to take advantage of the income from almond bloom (Rocha 2017). Other rogue activities might include poor beekeeping management that results in pathogen and disease transmission among other nearby colonies, or colony 'robbing' where a hungry colony invades other nearby colonies for food, potentially weakening the invaded colony. Poor management can also result in honey bee swarming behavior, which can frustrate locals and weaken their perception of beekeepers as well (Edwards and Dixon 2016).

How honey bee mobility challenges forage access

Honey bees typically fly between a half a mile to three miles for forage but can fly up to five and a half miles from their colony site to forage (Hagler et al. 2011; Pahl et al. 2011). They do not observe property lines or arrangements, of course, which makes it quite difficult to exclude them—or any pollinator—from any given landscape and the floral resources embedded within. Because bees are invisible from a distance and cannot be branded or marked like other livestock, it is difficult to know if a beekeeper's bees are 'trespassing' on land they do not technically have access to, or if a forage area is overstocked.

Honey bees can also paradoxically challenge beekeepers' access to forage in several ways. They can be exposed to toxic chemicals on an orchard, or pests and pathogens in nearby colonies (such as *Varroa* mites) and can bring these chemicals, pests, and pathogens back and decimate a colony. Perhaps most problematic though, is the nuisance that honey bees can pose for landowners. A grower or farmer might apply agrochemicals and kill off a substantial portion of a beekeeper's colonies (often bees located on a neighboring farm). This could lead to bad press, a lawsuit, or restrictive regulations on pesticides that limit landowners' on-farm management practices. This obstacle, or at least the specter of it, plays a major role in the sense of a power asymmetry between beekeepers and landowners, since complaining about agrochemical use might get a beekeeper kicked off a forage site or blacklisted by other growers or land managers in the community.

Three Cases of Exclusion from Forage in the Midwest

As a result of these various processes, beekeepers frequently face exclusion from forage sites. A focus on the way that access is structured by power relations (Ribot and Peluso 2003) is essential to understanding the social world of beekeepers and the exclusions they face from forage sites. Because beekeepers are often migratory, and therefore transient, they regularly find themselves in asymmetrical power dynamics with the growers, landowners, and land managers whose land they rely on for forage (Suryanarayanan and Kleinman 2017, 71). This makes it difficult for them to advocate for their needs or situate themselves within a particular community, and quite easy for them to be excluded from land that they once had access to:

Figure 5.3: Prairie Pothole Region (Source: USGS public domain)

> We're bee guys, so we're just nearly human. We're the hookers of agriculture. We show up wearing a veil, we come at night, we take their money, and we're gone." (Interview, Aug. 7, 2015)

This beekeeper went on to detail an encounter he had in the Midwest when he tried to speak out at a local town hall. A local banker told him he was "just a six-monther" (meaning, he only lived in the town for six months a year)—even though he has been coming to the same town for over forty years. This transience, even when it recurs annually for decades, makes beekeepers vulnerable to exclusion from floral resources.

The following three cases of exclusion are geographically focused on the Prairie Pothole Region (PPR) in the United States Midwest. The PPR has a unique geography of prairie grasslands and depressional wetlands (i.e., potholes), embedded within an expanding agricultural landscape. As a result of this unique geography, the PPR is home to migratory birds and waterfowl (Johnson et al., 2005), monarch butterflies, amphibians, and other migratory birds.

These lands have also been an ideal site for honey production for generations. Currently, nearly forty percent of the nation's commercially managed colonies are brought to this region each spring and summer (Otto et al. 2016). The PPR's abundance of bee resources is diminishing, however, as federal agricultural and energy policies, pesticide practices, and conservation efforts result in three distinct beekeeper exclusions that I detail below.

Figure 5.4: Prairie Pothole Region (Source: USGS public domain)

Volatile Exclusion from forage due to a crop and soy boom

The first exclusion is a *volatile* exclusion, where beekeepers have lost access to millions of acres of forage lands as the result of a corn and soy boom in the Midwest. One of the reasons the PPR has remained a keystone of beekeeper livelihoods is the Conservation Reserve Program (CRP), a voluntary program administered through the Farm Service Agency (FSA) under the USDA. Established in the 1985 Farm Bill, the CRP pays an annual rental fee to farmers to set marginal or unused farm land aside for conservation for ten to fifteen years, and to plant species that will help reduce erosion, provide habitat for wildlife, and improve water quality; ecosystem services with values that exceed the land rental costs (Johnson et al., 2016). As of early 2018, around 25.6 million acres of land were under CRP nationwide with a designated funding of $2 billion annually (Stubbs 2014, 1).

CRP lands are attractive to beekeepers in large part because enrolled landowners are restricted from haying and grazing on the land, which allows beneficial flowering plants, such as various clover species, to bloom and provide floral resources throughout the spring and summer. This abundance of pasture and rangelands—in addition to cultivated crops such as alfalfa, sunflower, and canola—has played a key factor in North and South Dakota's strong honey production (Otto et al., 2016). In 2017, North and South Dakota were the top two honey-producing states in the country, producing nearly 58 million pounds of honey, around one-third of the United States' total production (USDA-NASS 2017a).

Though the CRP has helped maintain an abundance of forage sites for commercial beekeepers, agricultural and energy policies threaten their future use. One of the greatest factors that recently diminished CRP acreage was weakened support in the 2014 Farm Bill, which reduced the CRP

Figure 5.5: Corn and wheat fields (another major crop) in North Dakota

enrollment cap from 32 million acres to 24 million acres by 2018—a 25% reduction in acreage available to beekeepers for honey production (Stubbs 2014). These reductions occurred alongside another more complex challenge to the program: a corn and soy crop boom that has incentivized farmers to move marginal and conservation reserve lands into corn and soy production.

Crop booms take place when land managers rapidly convert large areas of land to mono-cropped or nearly mono-cropped production—often supported by rising crop prices, state support, and new growing techniques (Hall, Hirsch, and Li 2011, 87–88), and the resulting land use transformations last at least a year or more (ibid., 88). Two key US federal policies helped support this boom: the 2005 Bush-era Energy Policy Act, which authorized the renewable fuel standard (RFS), and the 2007 Energy Independence Act (EISA), which expanded and extended the RFS (Bracmort 2018). The RFS requires a percentage of corn-based ethanol and biofuels to be mixed with petroleum-based transportation fuel. This amount must increase annually, from 4 billion gallons in 2006 to 36 billion gallons in 2022 (ibid., 2). The legitimation given to support the ethanol mandate was to reduce greenhouse gas emissions and strengthen the US renewable fuel sector.

Shortly following the enactment of these policies, corn prices rose from around $2 a bushel for corn in 2006 to $7 in 2013 (USDA-NASS 2015). Soy prices also spiked from around $5 a bushel in 2006 to $15 a bushel in 2013 (USDA-NASS 2015). These high commodity prices made federal CRP rental payments less competitive for farmers from 2008 through 2014; many farmers terminated their CRP contracts or did not re-enroll in CRP once their contract expired (Stubbs 2014). Around 2013, the corn and soy boom began to diminish and the commodity price has since dropped to an average of $3.50 a bushel for corn and $9 for soy (USDA-NASS 2017b), making CRP rental payments more competitive again. However, since CRP acreage has been enrolled to its maximum acreage, farmers can no longer participate in the program unless the acreage is expanded in the 2018 Farm Bill. One researcher reflected on the implications of diminished CRP lands for bee health:

> What we are doing is swapping bee forage lands for food deserts. We are taking high quality forage lands out of our system and putting in its place crops that have no nutritional value for honey bees. (Interview, May 21, 2018)

Crop insurance programs also incentivize farmers to convert land into cultivated crops, including marginal lands such as wetlands and rangelands that beekeepers rely on for honey production (Claassen et al. 2011). The 2014 Farm Bill increased funding in crop insurance through the Price Loss Coverage (PLC) and Agricultural Risk Coverage (ARC) programs. Farmers who enroll in these programs receive payments if the revenue from their commodity crops drops below a price point benchmark. As a result, approximately 1.9 million acres of wetlands and 5.3 million acres of 'highly erodible' lands were converted from 2008-2012 (Craig Cox and Rundquist 2013), further reducing forage lands for commercial beekeepers:

> The problem is that…the federal government comes up with rules that drive changes that were unintended. I believe that agriculture needs federal crop insurance, but it has also driven some landowners into making poor short-term decisions [like] taking that grassland and converting it into corn row production, because they know that the federal crop insurance provides county level yield prices. (Interview, Aug. 30, 2017)

While CRP acreage has diminished throughout the US, some of the most drastic losses have occurred in the PPR next to prime beekeeping forage sites (Hellerstein et al., 2017; Otto et al., 2018). As long as federal funds continue to provide commodity insurance and financial support to farmers who engage in risky land use practices like farming marginal lands, beekeepers will continue to see shrinking access to the pasturelands they require for forage and honey production each year (Otto et al., 2018). This case demonstrates how market and regulatory powers helped fuel a crop boom that has contributed to beekeepers' exclusion from bee forage lands. The next two exclusionary processes have developed as a direct result of the processes discussed in this case, demonstrating how exclusionary processes can have cascading, domino-like effects that result in additional exclusions.

Toxic Exclusion from forage due to pesticide use

When farmers convert prairie lands to corn and soy production, they do not simply diminish forage for beekeepers, they also replace it with a suite of bee-toxic agrochemicals. In this case, we see how *volatile exclusions* from a corn and soy boom result in secondary *toxic exclusion*s. Farmers adopt new pesticides to treat boom crops, which contaminates beekeepers' primary resources: nectar and pollen. This has motivated some beekeepers to avoid the region entirely during periods of agrochemical application and subsequently lose access to the forage being sprayed as well as the nectar flow from other blooming flowers in the region.

Bee-toxic agrochemicals on pollen and nectar sources are one of the most long-standing and pernicious forms of exclusion beekeepers have faced. While honey bees are not technically excluded from foraging on treated nectar and pollen, consuming bee-toxic chemicals can lead to the sub-lethal poisoning of a colony that a beekeeper might see with a fungicide or systemic insecticide, or the acute poisoning and subsequent death of affected worker bees—such as the result of getting hit with an organophosphate pesticide.

While an extensive body of literature documents the harmful effects of insecticides on pollinators, a particular class of agrochemicals have been increasingly used in corn and soybean plantings that are sublethally toxic for honey bees: the suite of systemic insecticides called neonicotinoids. Neonicotinoids have become one of the most widely used insecticides worldwide since their introduction in the early 1990s (Stokstad 2007); they translocate throughout the target plant and become toxic to herbivorous insects (and potentially other organisms) that feed on the plant (Simon-Delso et al. 2015). They became popular in large part because of their lower toxicity for fish and other vertebrate species compared to organophosphate and carbamate insecticides, as well as their varied modes of application, ranging from seed coatings to foliar sprays (Goulson 2013, 978).

Neonic-coated seeds are most often planted in the Midwest and are applied to 80-100% of all corn and 34-44% of all soybean hectares in the form of foliar sprays and seed applications (Douglas and Tooker 2015, 5088). Since corn and soy acreage total over 171.4 million acres (89.6 and 81.8 million acres for soy and corn respectively), this means that between 95 and 121 million acres of corn and soy are treated with neonicotinoid insecticides (USDA-NASS 2018b).

Seed applications are particularly tricky for beekeepers: manufacturers coat corn and soy seeds with neonic pesticides and talc, and when these seeds are planted, the neonic-laced talc can become airborne and land on pollen and nectar sources that honey bees and other pollinators access for honey production and pollen (Krupke and Long 2015). Research indicates that this aerial dust can cause direct mortality in honey bees (Marzaro et al. 2011). Neonicotinoids can have sub-acute effects as well: they impair honey bees' ability to navigate back to the colony (Henry et al. 2012), depress their immune capacity to resist pests and disease (Brandt et al. 2016), and increase "queenlessness" (loss of the colony queen) over time (Tsvetkov et al. 2017).

Some beekeepers who typically go to the Midwest for honey production have had to adjust their migration schedules to avoid seed planting season because they are concerned about acute exposure to neonicotinoids. As a result of the combination of agrochemicals and forage loss, one beekeeper describes the PPR as "the least worst place" to produce honey (interview, Aug., 8, 2017). Another beekeeping operation detailed how neonicotinoids affect their bees:

> Queens in colonies with neonicotinoids don't lay eggs as effectively. The field force is getting affected. They have homing issues and the colonies dwindle over time. Overall the whole hive goes down. It reminds me of how the nobility would gradually poison each other over time in medieval studies. (Interview, Aug. 10, 2017)

This operation now refers to the region as the 'poisonous prairies'. Another beekeeper stated, "It's death to bring bees [to North Dakota] earlier than the 15th of May" (interview, Aug. 11, 2017), before corn plantings typically end. However, some beekeepers do not have the option of staying out of the Midwest until the seed plantings are finished:

> A lot of beekeepers don't [go to the Midwest during seed planting season]. But then some guys…that's what they do—they don't have any other choice. And those guys will often have bee kills. (Interview, Sept. 28, 2017)

Agrochemicals are also a source of tension between beekeepers and landowners, as speaking out (publicly or in-person) against bee-toxic chemical use can result in a beekeepers' exclusion from a forage site. This asymmetry is even more acute when beekeepers are not being paid for a pollination contract but are on a land owner's property to make honey. The concern for maintaining good relationships with landowners informs how beekeepers talk about pesticides to the public. One firm described an interaction with a journalist when asked about how pesticide use affects honey bees:

> [We] had to say [to the journalist] numerous times, 'Look, we care about our farmers and respect them and don't have any problem with what they do. [We] had to say it several times, because if the word gets out that you have any kind of issue [with agrochemicals] you can say goodbye to your forage sites and your relationship with that landowner. (Interview, Aug. 10, 2017)

Neonicotinoids' toxicity is also a source of contention between beekeepers. Some beekeepers have not experienced losses due to corn seed planting, and express frustration with those who lobby to ban neonicotinoids because they fear that farmers will return to older, acutely toxic chemicals like organophosphates on their row crops:

> 20 to 35 years ago methyl parathion [an organophosphate] was a real issue. They'd spray it and it would kill meadow larks and baby deer and you'd see mountains of dead bees. Beekeepers are really afraid of returning to those days. (Interview, Aug. 10, 2017)

> What would you rather have, neonicotinoids—on which the jury is still out—or the older pesticides that were deadly? The worst thing ever, or better than what came before? (Interview, Mar. 1, 2017)

Other beekeepers, however, feel that this line of thinking supports the interests of agrochemical companies over beekeepers' needs. One beekeeper described a beekeeping convention where Bayer Chemical advised beekeepers to keep their bees in winter holding yards until corn growers have planted their seeds:

> The problem is that this planting can range anywhere from April through June. This is prime buildup for bees—they need to access dandelion, apple trees, etc. They need to build up the colonies during the prime time [Bayer is] telling [beekeepers] to stay away. A lot of beekeepers do stay away till after they plant corn. A hobby beekeeper doesn't have this option, however. A monarch butterfly or a rusty patch bumblebee doesn't have this option. It's an exercise in absurdity except that there's money to be made. (Interview, Apr. 7, 2017)

This case demonstrates how one exclusionary process, lost access to forage due to a crop and soy boom, can result in a secondary exclusionary process: the poisoning of the floral resources that remain. Here we see the exclusionary powers of environmental change and new technologies intersect with regulatory and market powers that supported the boom in the first place to create an additional exclusion for honey-producing beekeepers.

Ambient Exclusion from forage due to conservation practices

As forage lands diminish, contestations over remaining forage have emerged between native bee advocates and beekeepers. This case highlights competing claims over these CRP lands, specifically, over which seeds should be included in the seed mixes that vegetate these sites. It demonstrates how conservation agencies legitimate honey bee exclusion through honey bees' classification as a "non-native" or "invasive" bee species and ecological research demonstrating forage competition between the different species.

Figure 5.6: Bee visiting fiddleneck (Lacy Phacelia), a native annual forb

Despite the challenges described in the first two cases, beekeepers and other pollinator advocates have had some success in addressing the increased dearth of forage in the Midwest. In 2014, the Obama administration submitted a federal memorandum requiring the establishment of a pollinator task force to increase and improve pollinator habitat (The White House 2014). They also allocated millions of dollars in technical and financial assistance to ranchers to help plant pollinator forage through the USDA National Resources Conservation Service (NRCS) and the Environmental Quality and Incentives Program (EQIP) (USDA 2014).

At first glance, it would appear that conservation organizations and beekeepers might have a strong alliance and would work jointly towards creating pollinator habitat. In many situations this is the case, yet some beekeepers feel that certain native-pollinator organizations have co-opted public concern and funding around honey bee declines and are now using it to support native bees and exclude beekeepers from forage they have had access to in the past. A number of beekeepers expressed concern that the NRCS—which has been tasked with overseeing the selection of seeds for the seed mixes—is closely tied to native pollinator advocacy organizations. They fear that pro-native pollinator priorities will dominate pastureland restoration, such as planting only native seeds on CRP and EQIP lands.

Beekeepers are frustrated by the emphasis on native bees and nativity in seed mixes for CRP land in particular, when CRP plots have historically been working lands that fluctuate in and out of production:

> It's a huge debate. We're tired of fighting. We're fighting native bee folks because they're anti-managed species. They're anti non-native. I really think that what it comes down to is this: they're just making a living. They found a way to make a living off an

> issue. [Native bee advocates] get people all riled up about native issues and keeping things pure and pristine as it was three-hundred years ago. (Interview, Sept. 28, 2017)

Beekeepers worry that this focus on ecological nativity will limit which seeds are included in the CRP seed mixes, particularly if sweet clover seeds are left out of the mixes. Sweet clover is one of the most beneficial flowers for honey production (Tilley et al. 2008). However, because it is an introduced species that can spread rapidly, it is also viewed as a weedy invasive plant that competes with desirable native species (ibid.,1-4).

On the other side of the debate, ecologists express concern that public interest centers largely on an industrialized agricultural insect, and that policy must also support native pollinators, whose populations are also declining (Koh et al. 2016; Kopec and Burd 2017). This pushback against honey bees centers on three primary arguments. The first is that research indicates that honey bees compete for forage with native bees (González-Varo and Vilà 2017; Geldmann and González-Varo 2018), particularly during times of drought (Thomson 2016) or in areas with sensitive or endangered bee species (Henry and Rodet 2018).

A second reason is concern over pest and pathogen transfer (Fürst et al. 2014). Commercial honey bees are exposed to many pathogens during their time pollinating orchards, particularly while in almonds (Cavigli et al. 2016). When honey bees come into contact with other native pollinators—while foraging on public lands, for example—these diseases may be passed between species (Fürst et al. 2014). The third argument is that agriculture has become highly dependent on one species of pollinator to the exclusion of native pollinators. This overreliance on a single species makes farmers more vulnerable as honey bee health becomes increasingly tenuous (Kremen, Williams, and Thorp 2002).

Given native pollinators' tenuous status and potential competition for resources between native pollinators and honey bees, native bee advocates and researchers have a strong impetus to push a conservation agenda that favors native pollinator species moving forward—even if that means that managed honey bees must be excluded from forage sites they have historically had access to for honey production (Geldmann and González-Varo 2018).

Yet not all ecologists believe nativity should be prioritized in CRP seed mixes. One government research ecologist in the PPR stated: "to say that honey bees are not natural is to say that humans and livestock production are not natural" (interview, Mar. 3, 2018). This ecologist pointed out that the PPR has a long history of animal and human presence and thus CRP lands might not be ideal sites for native prairie restoration:

> The CRP lands are still working landscapes—meaning that they can produce hay, they are a version of fallow land, they are still productive, and they are owned by farmers, rather than seen as public lands that have been reserved to restrict human presence/footprint. So, since these are lands are owned by farmers and used by industry at will, it makes sense for the beekeeping industry to also have access to those lands. (ibid.)

The conflict between beekeepers and native bee advocates highlights a complex access conflict over forage between competing state, public, and ecological interests. On the one side, honey bee's economic contribution to agriculture is easier to quantify, which can legitimatize conserving land for honey bees. On other hand, native bees provide essential ecological functions and pollination services that can provide insurance against honey bee losses (Winfree et al. 2007; Garibaldi et al. 2013)—but their populations are low in intensified farming systems (Kremen, Williams, and Thorp 2002). These cases demonstrate the double-edged nature of exclusion (Hall, Hirsch, and Li 2011): both honey bees and wild pollinators require access to these floral resources and provide important pollination services, but advocating for access for one pollinator community may end up excluding the other from a key site for forage.

Consequences of Forage Change

Transition to commercial pollination and manufactured inputs

Lost access to forage has socio-ecological consequences for beekeepers and their honey bees, due in part to a greater reliance on commercial pollination, as well as increased competition for forage sites between beekeepers that lead to intimate exclusions. Many of the beekeepers interviewed used to earn around ten to twenty percent of their income from commercial pollination twenty years ago. Now, those beekeepers get at least forty-five percent, sometimes more, of their annual income from pollination contracts, because they cannot make enough money from honey production to keep their operations afloat:

> I can't keep the bees alive in Michigan. Before I switched up my bee plan and came out here and tried almond pollination—it was just my grandpa and I and we were only raising honey. We were having, on average, a 75% loss rate every winter. *75% of our bees would not survive the winter.* And the 25% on average that survived were so weak and beat up that you couldn't make splits out of them…the honey crop isn't what it used to be. I can remember growing up as a kid, some of the hive averages we used to get—those days are gone. (Interview, Mar. 16, 2017)

While almond pollination has helped many beekeepers economically, they also acknowledge the detrimental effects that commercial pollination can have on honey bee health. In addition to the stresses mentioned in Chapter Three, beekeepers suffer from overcrowding while in almonds. Two million colonies from around the country condensed into the Central Valley for six weeks of bloom leads to high pathogen transfer between honey bee colonies (Cavigli et al. 2016). In addition, honey bees exposed to pesticides during commercial pollination are more susceptible to pests and parasites (Pettis et al. 2012; Seeley and Smith 2015) and this exposure can have both acute and sub-lethal effects on the colony, making it harder for the colony to survive. In addition, migratory management can cause oxidative stress and lead to a significant decrease in the lifespan of migratory bees (Simone-Finstrom et al. 2016). However, the reliable income from almond pollination and the lost income from honey production mean that many beekeepers feel they need almond pollination to fund their operations each year, despite the risk it poses to their bees.

As beekeepers face diminishing forage and dependency on commercial pollination, they also increasingly rely on inputs. To make up for the dearth of diverse pollen and nectar sources, beekeepers feed their bees manufactured pollen patties, which may not be as nutritious as actual floral pollen (Z. Huang 2012; Gregory 2006). Operations also feed sucrose syrup to honey bees to supplement for nectar. At one operation that ran around 3,000 colonies, I saw a large metal tanker truck full of sugar syrup to feed their honey bees after almond bloom. This, the beekeepers informed me, is the norm. Not only are these supplements expensive for beekeepers—feed inputs alone can take up about 15-20% of the outgoings in an operation—the lack of diverse and non-toxic pollen is also problematic for honey bee health (Di Pasquale et al. 2016).

Intimate Exclusions between beekeepers

As forage lands diminish, beekeepers of varied operation sizes have described moments of *intimate exclusion* (Hall, Hirsch, and Li 2011, 145), where other beekeepers have taken over a forage site they have had for years. One beekeeper in North Dakota noted that the colony crowding in his region started happening around 2010. This beekeeper, who has been in the region for decades, ended up losing a forage site to another beekeeper that was new to town:

> Most landowners are pretty loyal—but not always. I thought I had a good relationship with one guy. We had five locations [on the landowner's property] and then all of a sudden [the landowner] booted us off and he didn't even want to talk about it. It really bothered us because we would've liked to resolve the problem since we've been going there for ten years. (Interview, Sept. 28, 2017)

Reduced and competitive access to forage can also result in overstocking, where too many colonies are placed in one forage site. According to beekeepers, this can lead to lower honey yields for all the beekeepers trying to produce honey on those locations. Beekeepers in North Dakota from 1976-1978, for example, averaged around 116lbs per colony (USDA-ESCS 1978). Today, the honey average is close to 76lbs (USDA 2018), though most commercial operators that I interviewed put their colony average closer to 30-50lbs. A mid-sized operation blamed the almond industry's expansion for the overstocking trend in North Dakota:

> Almond pollination was the second gold rush. Around the 2000s, people started coming to North Dakota with nowhere to go in the summer after the [almond] bloom. They'd leave semis full of bees on farmer lands and farmers would call and complain about it…A lot of those guys are just looking for a place to put their bees during the summer and care less about making honey. (Interview, Aug. 10, 2017)

Another beekeeper described how he had mentored a fledgling beekeeper for a year, and then the following year the mentored beekeeper—who had learned the other beekeepers' forage locations—placed colonies in adjacent sites across the road without asking (interview, Apr. 6, 2017). As a researcher, I had several beekeepers refuse to take me to forage sites or tell me where they were located because they were afraid other beekeepers might find out. This air of competition over disappearing forage has led to a building sense of distrust and secrecy over the scraps of land that remain.

Counter-Exclusions: Efforts to regain access to forage lands

The consequences of access loss are not all dire for beekeepers. Exclusions from land are iterative, socially determined processes. This presents many challenges for beekeepers, which most of this chapter has attended to. However, it also creates some unique opportunities for beekeepers to direct their efforts to *counter exclusions*, where they regain access or create new spaces of access for honey bees. Though there are numerous examples, I focus on a few that are relevant to the cases in this chapter.

The first *counter-exclusion* centers on limiting honey bees' agrochemical exposure. Some beekeepers feel that agrochemicals are the greatest threat to their honey bees and have directed their efforts towards changing grower practices and pesticide policy. Beekeepers have worked with the industries they pollinate for, such as the almond industry, to help educate growers on honey bee best management practices that farmers and growers can practice while on site (CDPR 2018a). Some have also successfully made changes through litigation, such as a recent case between beekeepers and the EPA that requires EPA to change their label review policy on neonicotinoids and other agrochemicals (Ellis v. Housenger 2017).

Yet until the EPA implements these changes, growers will continue to apply bee-toxic pesticides, as evidenced by the data in Chapter Four. To address this, various stakeholders met to address the issue in 2014. Beekeepers, extension specialists, members of the Almond Board and industry, and the CA DPR jointly crafted and publicized a set of best management practices (Bee BMPs) to address the rising use of sublethal and unlabeled bee-toxic pesticides during almond bloom due to the knowledge gap in the EPA's labeling system (California Almond Board 2014). The BMPs have four core precautions, which are to (1) Maintain communication between all parties on the specifics of pesticide application, specifically between beekeepers and/or bee brokers, the pesticide control applicators (PCAs), farm managers, land owners, and applicators (California Almond Board 2014, 4). (2) Only spray fungicides in the late afternoon or evening. (3) Avoid tank-mixing products during bloom because some agrochemicals might have synergistic toxicities for honey bees. (4) Avoid applying all insecticides during bloom. Many of the growers I spoke with mentioned these BMPs in our interviews and their attempts to follow the guidelines. However, at the time this dissertation was published, the pesticide use reports only extended to 2016 and it was difficult to quantify if the BMPs have affected grower application practices.

However, beekeepers are very aware that they are dependent on industrial agriculture for their annual income, so not all beekeepers put their efforts into addressing pesticide use. A number of beekeepers acknowledged that while agrochemical use can indeed be problematic for honey bees, they would rather solve that problem with landowners directly. As a result, the second *counter-exclusion* consists of beekeepers' efforts to create access to new forage sites through policy changes such as personally lobbying congressional offices to increase CRP allocations, or through establishing collaborative relationships with landowners and managers to plant bee forage sites. By focusing on creating new forage, beekeepers bypass broader conflicts over on-site agrochemical use. Creating new forage enrolls the landowner in a cooperative project, rather than a prohibitive one. Getting a grower to 'buy in' to planting forage can also create an incentive to talk about issues like forage and agrochemical use:

> When you have bees or forage on the property, you rarely lose bees to pesticides, because we have conversations with the grower or landowner before a spray event would normally happen. (Interview, Mar. 2, 2017)

These small-scale negotiations do not address the large-scale mechanisms that drive beekeeper exclusions. Yet because some of the exclusionary processes that beekeepers face occur as the result of land management practices (such as pesticide application), beekeepers often appeal to their relationship with land managers to sway them towards bee-friendly management practices, to perhaps offset some of the other stressors honey bees face on agricultural lands:

> Forage is the one thing that we can control and impact that can begin to address the death of a thousand paper cuts [that pollinators are currently experiencing]. If you have highly nutritious forage and habitat and it's healthy and available, it puts the bees and other pollinators in a better position to handle all the other stressors, all the other paper cuts, that they get throughout the year. (Interview, Aug. 30, 2017)

These counter-exclusions demonstrate how beekeepers' relationships with landowners make their access both tenuous *and* negotiable. Though they may not always be successful, they at least have the opportunity to inspire pollinator-friendly land management practices, thus procuring or maintaining the access they need to keep their honey bees, and their commercial operations, alive for another season.

Conclusion

Pollinator crises—for both honey and native bees—do not happen in an apolitical vacuum. A political ecology framing that focuses on the powers and processes that shape beekeepers' exclusion from forage makes three things very clear. The first is that the survival of commercial beekeeping depends largely on beekeepers' ability to negotiate a constantly shifting and economically precarious terrain of social relations to maintain access to forage. The second is that the vulnerability of managed honey bees and the precarity of commercial beekeepers are interconnected. The third is that addressing honey bee vulnerability requires a more complex approach than simply figuring out which chemicals are killing bees or which miticide will best mitigate damage caused by *Varroa* mites. Critical social science research on the entwined political, economic, social, and environmental forces that shape the context in which beekeepers manage bees can bring new insight into factors driving bee losses.

As discussed, beekeepers lose access to floral resources through a variety of exclusionary powers and processes: Case one highlighted a volatile exclusion from a crop boom, driven by regulatory and market powers which reduced allocated acreage for conservation land, and incentivized farmers to transition CRP land into corn and soy production. Regulatory policies such as crop insurance programs, while valuable, have the unintended side effect of encouraging farmers to farm marginal lands that beekeepers once accessed for honey production. Case two explored a toxic exclusion resulting from the crop boom, as new pesticide technologies result in environmental changes: the pollution of floral resources with neonicotinoid dust. Beekeepers then avoid the Midwest during seed planting season and miss out on prime honey production forage. Case three focused on the ambient exclusion of honey bees, spurred by conservation efforts to support native pollinators.

These exclusions are legitimated by research indicating competition between honey bees and native bees, and by positioning honey bees as ‘invasive’ or ‘livestock’. As a result of disappearing access, many beekeepers have experienced intimate exclusions when neighboring beekeepers take over their forage sites. Beekeepers may subsequently turn to manufactured pollen supplements and commercial pollination as a result—both of which can contribute to honey bee vulnerability (Gregory 2006; Cavigli et al. 2016).

This analysis demonstrates that Hall et al.’s Exclusions Framework (2011) applies not only to land conflicts in Southeast Asia, but to a North American context as well. Beekeepers are subject to exclusionary forces in part because they do not own the land they need for production in the United States. Thus, they are constantly vulnerable to land management decisions made by land owners and land managers on public lands.

Recalling Chapter One, however, another reason beekeepers’ access to land may be so tenuous could be in part because their physical presence and pollination services—like that of all pollinators—is largely invisible and can be difficult to quantify or fully appreciate (C. Phillips 2014; D. Mitchell 1996). This invisibility can give a sense that land is ‘empty’ and that activities on that land will have little consequence, which can lead to practices that are detrimental to bees and other pollinators. Hall, Hirsch, and Li note that “large-scale agricultural schemes…depend on a concept of empty land…just waiting for productive investment. But such land is hard to find” (2011, 204). In this chapter, I have aimed to show that even the vast swaths of privately-owned agricultural lands, such as the corn and soy fields in the Midwest, are *not* empty—or at least not yet. There are beekeepers, honey bees, and numerous other pollinators on or near these lands, accessing floral resources and pollinating the bloom that remains.

Chapter Six: Conclusion

Figure 6.1: Bee colonies in the foothills after almond pollination (April 5, 2017).

In 2015, Mike Escobar sold his operation of over 20,000 colonies and got out of the commercial beekeeping business. Mike started beekeeping back in in his early teens, when he, his dad, and his brother acquired some hives to pollinate their garden in Massachusetts. When his dad had an injury at work, he and his brother worked with a commercial beekeeper to make ends meet at home. In the fall of 1977, when Mike was a sophomore in high school and his brother had just graduated, their dad passed away. The two brothers had around 200 hives at this point, and they decided to build their operation into a livelihood that could support their family. Over the following decade, they built their 200 colonies out to around five thousand hives.

Then came the tracheal mites in 1984, *Varroa* mites in 1987, and low honey prices in the 1990s. By the mid-1990s, his brother got out of the business, because it "just wasn't fun anymore." Mike decided to stick with it and geared the operation towards commercial pollination; they focused on New Jersey blueberries, Maine apples and blueberries, and cranberries in Massachusetts, then traveled down to Florida for the citrus honey flow.

In the winter of 1992, Mike brought around 2000 hives to almonds for $35 a colony. The honey prices were horrible that year, around 53 cents a pound, and Mike was looking for economic alternatives. It was too hard to ship to California to make it worthwhile then—the logistics, the regulation, the fire ant checks at the border were not yet worth the effort. He didn't come again until 2004, when he sent about 2000 hives to help a friend fulfill an almond pollination contract after a substantial winter loss. In 2005, with the citrus greening sprays, he was one of many beekeepers discussed in the introduction who were driven out of Florida and into almonds to make up for the lost income from citrus honey. Once Mike committed to almond pollination, he figured out how to manage the logistics, and built his operation from around 6,000 to 20,000 colonies over the course of ten years.

Managing for almonds was hard. Bees naturally want to grow in the springtime, Mike shared, and then in the fall, you're usually supposed to get them ready for winter. But they needed large amounts of bees in February for almonds, so instead of winding their operations down in the fall and letting the colony naturally dwindle, they were building their colonies up instead. Mike shared his experience, as it became increasingly stressful:

> Have you ever heard the expression about how you cook a frog? That if you put them in the cold water and keep turning up the heat they die, but if you put them in cold water, they jump out? That's the best way to describe how your operation grows into something you're not happy with all of a sudden. Beekeepers don't go into beekeeping to get rich. You do it because it suits you. Somehow it wasn't fun anymore.
>
> Why do you work? You work to have a life you like. And at some point, it gets out of hand. When I talk to some of these other beekeepers [pollinating almonds], they tell me, we're whooped too. It's the gerbil spinning the wheel—it's not at all good…not for the beekeepers and not for the bees. Hauling them all over the country—there's something not right about it. What we are doing to make bee hives in the middle of winter is not natural. Can we do it? Yes. The harder question is why are we doing it? And should we continue? (Interview, Mar. 22, 2018)

One of the hardest things for Mike was feeling like the almond growers he pushed his bees for didn't really appreciate the hard work he put into them. His experience with growers on the east coast was "night and day" different: "I knew all the farmers. I started with dad or grandpa, then eventually worked with the grandkids. The people were connected with their properties in a really genuine way." But some of the growers he worked with in almonds (mostly in Kern County) were large, corporate farms. "There was no talking to them. They're corporations. I don't care what the Supreme Court has said, but corporations are not people" (ibid.)

Somewhat ironically, Mike sold his bees to a large almond growing corporation in 2015. I asked him what it was like when he went to the annual beekeeping conference the following year. He said his beekeeping friends were all jealous. According to him, three people were smiling at one conference, and the rest all looked "glum." Those three beekeepers who were smiling, he said, were the ones who had sold their operations the previous year as well.

Escobar's story captures the melancholy and exhaustion intrinsic to many of the beekeepers I interviewed. Many of them were tired: tired of pushing their bees so hard, tired of getting sprayed by pesticides, tired of fighting growers about their pesticide practices, tired of justifying their high pollination fees to almond growers. Just tired, much like—one could argue—their bees.

In this dissertation, I have aimed to show, in part, how exhausting it is for beekeepers to produce bees for almonds, as well as the impact the almond and beekeeping industry social relation is having on honey bee health. To better understand the dynamic between beekeepers and almond growers, particularly its historical underpinnings, this dissertation engaged with several key questions: What role did beekeepers have in the expansion of the almond industry in California, and how has pollinating for the almond industry reconfigured bee production and bee bodies in turn?

To tell this story, I analyzed the two histories of each industry, sometimes separately and sometimes together throughout their interdependent dynamic since the early 1900s. What we see is two very different industries developing unevenly, and yet dialectically producing each other through time and space until this present moment, when the industries—and the fate and state of the commodities they produce—cannot be considered separately from one other. This will surely change eventually. However, I argue that when trying to understand *this current moment* of current honey bee vulnerability, we must look to the almond industry, and the regulatory processes that support its activities, for clues and insights about bee health.

On the one hand, this dissertation offers a political ecology of how almond growers and beekeepers transformed the California landscape such that almond acreage, at present, resides on over $1/10^{th}$ of California's irrigated land. I offer an additional facet to the history of almond expansion, one that troubles how the almond industry narrates its expansion both in its marketing and in interviews. What I show is that the almond industry has been reliant on paid bee pollination since the early 1900s and was only able to expand in part because of the work of commercial beekeepers as they changed their management practices to produce almond-pollinating bees. Thus, almond expansion occurred in part because of the labor of beekeepers and bees. At the same time, in Chapters Three and Four, I also show that while *being in* almond orchards during bloom can cause sublethal (and sometimes acute) damage for honey bee colonies, *producing bees for* the almond industry also plays a pivotal role in honey bee vulnerability.

In this final section of the dissertation, I synthesize the main findings of my research, and highlight contributions to debates on the commodification of nature/socionatures, the barriers that land and animals pose to capital penetration, and theories of the production of knowledge and ignorance. I then highlight the implications of this research for policy makers and practitioners, and detail possibilities for future research.

Main Findings

1. Producing bees as pollination laborers for California agriculture leads to their increased vulnerability

In Chapter Two, I discuss how the almond industry has limited its need for human labor, primarily through advances in mechanization. However, almond production still largely requires the year-round labor of beekeepers to produce bees for pollination in order to produce a prolific almond crop each year. To have the large 'field force' of bees that growers demand, beekeepers have had to industrialize their production through year-round inputs and have selected the most prolific subspecies of bee for almond pollination (Italian bees, *A. m. ligustica*). This subspecies of honey bees are also more vulnerable to *Varroa* mites than other subspecies, a pest that currently challenges the industry and underpins the 20-30% average annual losses beekeepers struggle with each year (Kulhanek et al. 2017).

These production practices emerged as beekeepers transitioned from producing bees for honey to producing bees for their labor for the almond industry. When beekeepers are producing honey, their bees are creating a food product. As such, beekeepers must be careful about the agrochemicals their bees are exposed to and must also make sure their bees are feeding on actual floral resources to produce as opposed to sugar syrup. Producing bees for pollination labor, however, means that bees are brought into orchards and farms where they will likely be exposed to more agrochemicals. However, it is not just about exposure to agrochemicals. It is also that bees are being produced for their labor and their ability to produce more bees, which can lead to an intensification and genetic simplification of bee production in ways that leave them more susceptible to pests and disease.

Producing bees for industrial level pollination services has disrupted honey bee reproduction: changing their reproductive cycles, their lifespan, their genetic diversity, and their diets. They are forced to produce year-round without winter hibernation, a process that exhausts queen productivity and makes bees more vulnerable to pests and disease. In this way, a contradiction arises as beekeepers shift their operations from honey production to prioritize bee production for industrial agriculture. This process contributes to honey bee vulnerability.

2. Mobile natures provide a particularly challenging barrier to industrial production

In Chapters Three through Five, I showed how honey bees' mobility can act as a barrier to industrial production for both beekeepers and growers. First, because queen bees primarily mate in the air with nearby drones, control of the genetic lines expressed is difficult. One alternative is instrumental insemination, but this is currently too expensive for many commercial breeders to attempt at scale.

Second, honey bee mobility plays a role in exposing bees to agrochemicals applied both in and outside the orchards that beekeepers were contracted to pollinate. This can kill or damage a colony, which can mean that a beekeeper will lose the ability to accumulate capital through that colony in the future. Third, bees' need for mobility requires beekeepers to also be mobile and rely on land for production that they rarely ever own. Bees can become a nuisance to other landowners, which can limit beekeepers' ability to find honey locations, and they can also compete with native insects in ways that have encouraged native bee advocates to advocate for forage seed mixes that are not beneficial to honey bees, effectively excluding honey bees and their beekeepers from those forage lands.

These chapters thus add to debates that demonstrate how mobile natures provide a unique barrier to industrialized commodification such as wild fish (e.g. Longo and Clark 2012) compared to sedentary or confineable natures like broiler chickens (e.g. Boyd and Watts 1997; Boyd 2001), through the unique case of pollinating insects.

3. First-world mobile producers who do not own the land they require for production have power asymmetries with land owners

This dissertation also aimed to trace the challenges that migratory beekeepers face as commercial-scale mobile producers who do not own the land required to produce bees and honey. This dynamic was highlighted particularly in Chapters Four and Five.

In Chapter Five, I highlighted the challenges beekeepers face as they attempt to gain and maintain access (Ribot and Peluso 2003) to land for bee and honey production. Because beekeepers are producing stinging insects, this can pose a challenge to finding land for production. However, the greatest challenge beekeepers face comes from an increasingly chemically-dependent, monoculture agricultural system that is inherently inhospitable to bees.

Beekeepers have long maintained their livelihoods through carefully maintained social relations with farmers and landowners, and yet beekeepers' needs and property owners' opportunities for profit (actual or perceived) are increasingly coming into conflict. This highlights the subsequent need for regulations that provide incentives to stop or slow transitioning land solely into industrial, monoculture crop production like we see in the Midwest with corn, soy, and wheat; and California with almonds.

In Chapter Four, I showed how beekeepers lack the regulatory oversight they need to be protected from agrochemicals that are bee toxic, as well as to report and investigate agrochemicals that are causing colony damage, even if they are not labeled bee toxic. These regulatory dynamics emerge out of a system historically designed to protect non-target insects from acute damage, without enough attention to sublethal toxicities. Additionally, California regulators are unable to data on unlabeled bee-toxic agrochemicals, so ignorance about which agrochemicals are bee toxic is continually reproduced.

I argue that these dynamics result, in part, because beekeepers are migratory. This makes it harder for state and county regulators to trace and protect them, because their systems are primarily designed to manage industries operating on the land under county and state jurisdiction. This analysis adds to theories of access and exclusion (Ribot and Peluso 2003; Hall, Hirsch, and Li 2011), and shows how mobile producers face access issues in the global North that somewhat parallel mobile producers in the global South, where access and exclusions theory have been more commonly applied.

4. The expansion of California's almond industry has only been possible with the labor of migratory beekeepers and their bees

As I show in Chapters One and Two, the almond industry has been able to expand since the early 1900s, in part, because of a series of socioecological events that challenged the beekeeping industry: low honey prices after the war and again in the 1990s, disappearing forage as monoculture agriculture expanded, virile mites that require high labor expenses to manage, and new pesticides that act sublethally or synergistically on bee colonies in ways that policy makers have yet to adequately regulate. Beekeepers thus became increasingly reliant on the almond industry's high pollination fee to make up for their inability to produce honey, as well as the high cost of inputs and labor required to keep bees alive.

Meanwhile, the almond industry continued to expand, in large part through its marketing efforts and advances in breeding and almond culture, as detailed in Chapter Two. The Almond Board sells almonds in more than 90 countries around the globe (Almond Board 2017a, 7) in part by marketing the agrarian imaginary of California, a vision of a beautiful agricultural landscape that makes invisible the hard work of beekeepers and the bee kills that result from pesticides applied during almond bloom.

This elision is deeply rooted in the history of California agriculture over the past century. As Don Mitchell argues: "the history of the making of the California landscape has shown that there is an important disconnection between representations of a landscape and its material reality" and that this severing is "*essential* and *necessary* to the functioning of the political economy" (D. Mitchell 1996, 199).

Yet not only does the disconnect happen in almond marketing, almond growers and representatives interviewed also ignored beekeepers' central role in the expansion of their acreage. Though the industry has recently started mentioning bees into their marketing, interviewed industry representatives and growers did not acknowledge how beekeepers had reconfigured their management practices to produce honey bees and the role these efforts have played in almond expansion. Instead, their labor—and the crisis they face of annual colony losses—remain largely invisible, like much of the migratory labor that has constructed California's agricultural landscape.

Implications for Practitioners

This research is helpful for both beekeepers and almond growers who want to protect managed honey bees. It is also highly relevant to policy makers and regulators interested in protecting bee health and the long-term sustainability of pollinator-dependent or reliant agriculture. Chapters Three, Four, and Five offer the most relevant findings to practitioners, which I summarize briefly below.

Chapter Three traces efforts beekeepers have made to produce bees for almonds, which can help give background to the escalating prices they charge growers for almond pollination. In this chapter, I bring attention to the risk beekeepers take in relying heavily on a limited subspecies of bee to pollinate almonds. Beekeepers and growers might consider the negative effects that demanding high colony frame counts in February has on honey bee health. One step growers could take is to consider reducing the minimum average frame count required for a colony to count as an active colony—e.g., reducing it from 8-10 frames down to 6-8, so that beekeepers will not be required to work their colonies so hard over winter, which may increase colony vulnerability. In addition, it may allow beekeepers to incorporate more genetic variety into their commercially bred queens. For example, with lower frame count requirements, beekeepers might be able to consider incorporating Russian subspecies—which are more resistant to *Varroa*, but less productive—into their operations.

Chapter Four highlights where pesticide regulation falls short in protecting honey bees. It provides further evidence that current EPA guidelines are not stringent or comprehensive enough to protect bees during almond bloom, which would need to be addressed through changing EPA and FIFRA guidelines. In addition, county investigators need to be able to investigate and collect data on emergent agrochemicals that beekeepers suspect might be killing their bees, and this data must be communicated to EPA headquarters to inform labeling requirements. Additionally, EPA could consider re-evaluating pesticide labels not every fifteen years as mandated by FIFRA, but more frequently for agrochemicals where incident reports indicate a higher toxicity than shown through the testing required for registration.

At the county level, county agricultural commissioners could transition to online, map-based registration systems that better represent beekeepers' mobile needs, to better track colony locations. And finally, beekeepers should consider registering their colonies in the counties they are in and remain engaged in reporting bee-toxic pesticide applications to the EPA through the various means available to them—even if it is not through the county office.

Finally, Chapter Five highlights one of the most important and problematic trends beekeepers face: lost access to the forage needed for honey production. These forage spaces not only allow beekeepers to produce honey, beekeepers argue that they also provide a sort of "detox" for honey bees as spaces with little to no agrochemicals and a diversity of pollen and nectar sources—unlike the pesticide-laden monoculture pollen and nectar bees are exposed to in conventional agriculture. Policy makers and agricultural industries can draw from the findings in this dissertation when considering the value of and requirements for CRP programs, or forage plantings in and around orchards and row crops (or nonconventional spaces such as along roads and highways) and how to protect and encourage these spaces for both wild and managed bees.

Directions for future research

This dissertation focused on the development of the almond industry and commercial beekeeping industry in San Joaquin Valley. I chose the San Joaquin Valley in part because the bulk of the Central Valley's orchards are there, but also because the northern Central Valley—i.e. counties north of San Joaquin County—have a very different political economic dynamic between commercial beekeepers and almond growers. As I discuss in Chapter Three, the northern Central Valley is home to the bulk of the queen breeders in the U.S., and many of those queen breeders have colonies that pollinate almonds as well, but also live there year-round. From my interviews with queen breeders in the industry, breeders shared that the region had some different regulations around agrochemical spraying and the importation of out-of-state managed colonies into the area as well. As such, it would be helpful to conduct a comparative analysis of the different political economies of three different Central Valley sub-regions, specifically a more pointed analysis of Kern County, versus Northern San Joaquin Valley, versus the queen breeding region, to see how the almond-beekeeping industry dynamics shift according to their social dynamics, specifically when growers have their orchards pollinated by a local community of sedentary beekeepers versus out-of-state or out-of-county migratory beekeepers.

Another important regional factor to look at would be how the geography of each region affects grower practices. Geographic nuances, particularly around water, were factors in growers' annual management practices, such as when and how often agrochemical sprays were applied. This would likely play a role in determining what types of practices growers could adopt to protect bees during almond bloom. Future research could thus look more closely and comparatively at how these regional nuances affect growers' abilities to adopt bee-friendly practices on their orchards. Size of operation would be an important factor to attend to as well.

On a similar topic, water has also played a fundamental role in the development of the almond industry and will continue to shape its future, as I discuss in Chapter Two. More attention needs to be given to how key players' (such as Wonderful Farms) efforts and ability to access water has underpinned almond expansion. More attention also needs to be played to how key almond growers are able to take advantage of California's fractured and conflicting water regulatory system (Hanak et al. 2012; Worster 1985; Hundley 2001) to obtain access to water rights.

Another area of research would build on the pesticide use data in Chapter Four and would require geographical information system technology (GIS) to attend to the geography of pesticide use during almond bloom. During my interviews with beekeepers, they expressed that one of the key sources of bee-toxic pesticide sprays were not from almond growers, but from adjacent growers of other crops (namely stone fruits and vineyards) that applied agrochemicals during almond bloom and the month following. Their bees would then be exposed by visiting those bee-attractive blossoms, even if the crop does not require hired colonies for bloom. Our research (Durant and Goodrich, in preparation) was able to track almond grower agrochemical use (and honey bee exposure) during almond bloom through pesticide use reports (PURs), because we knew that bees were in almonds during those periods. However, GIS analysis could look at the PURs of other suspected crops (particularly stone fruits), and by using the locational data in the PUR, could highlight pesticide use on other crops closely surrounding almond orchards during bloom. This information would be helpful to share with the almond and beekeeping industries and could inform efforts by the almond and beekeeping industries to influence best management practices with neighboring crops.

Further building off Chapter Four's findings, continued research on the production of ignorance around bee regulation would help better frame the EPA's regulatory approach to bee-toxic pesticides. One question, for example, is how much of the EPAs approach towards bee-toxic pesticide regulation has been a strategic production of ignorance (McGoey 2012) versus a structural or incidental ignorance? This research would require further interviews with beekeepers, as well as interviews with former and current EPA employees, and most importantly internal document analysis through documents obtained through the Freedom of Information Act, with a particular focus on pesticide registrations of peer-review researched (but not labeled) bee-toxic agrochemicals.

Another key area of research would look more pointedly at the epistemological dynamics that support uneven development between the almond and beekeeping industries. Specifically, how have beekeepers' and growers' access to knowledge and technological transfer underpinned their development? Beekeepers come to California each year from different states and only have one beekeeping extension specialist in all of California. Almond growers, however, are consolidated in California and have access to numerous extension specialists throughout the state in different reasons, who are constantly working on research and tech transfer to support the industry. More research could trace how this evolved over time, and how access to knowledge (or lack of it) has shaped the two industries' development.

Finally—and perhaps most optimistically—it would be helpful to look at new resource management approaches emerging between beekeepers and growers around floral resources (nectar and pollen). My findings indicate that only recently, since the introduction of the almond industry's Best Management Practices in 2014, has the almond industry begun to implement and press for substantive changes in almond orchard management to protect bees during almond bloom.

My research on almond bloom thus brings attention to an important question: how do we define the resources of floral nectar and pollen, and what new forms of resource management are emerging, or could emerge, in response to honey bee vulnerability? In Chapter Five, I showed how the beekeeping community requires access to floral resources. While the resources they draw from are not commodified (as in, growers are not producing almond pollen or nectar for exchange), they are located within commodified plants that beekeepers want access to. At the same time, bees are mobile, and can access nectar and pollen on plants that beekeepers have not been contracted to pollinate as well. This 'excludability'—i.e. the challenge of keeping away outsiders as defined by Ostrom (1999)—is what helps define floral resources as common resources.

Future research could thus investigate emergent resource practices between growers, beekeepers, and also native bee advocates on agricultural or public lands, as farmers and growers increasingly realize their reliance on bee pollination, and bees' and beekeepers' need for access to diverse and healthy forage. One case could be to examine the Best Management Practices outlined and communicated by the Almond Board, to study the development of these BMPs in detail (discussed in Chapter Four), and their uptake among almond growers. Another case would be the negotiation of CRP lands in the Midwest detailed in Chapter Five, and how beekeepers, ecologists, public land managers, and farmers are addressing and negotiating the need for bee forage and habitat for native bees and honey producers in the Midwest.

These new resource practices have largely occurred as a result of the extreme losses beekeepers have faced since 2006, and their subsequent attempts to bring attention to their losses through any means possible: the media, the EPA and other state and federal regulatory agencies, and the almond industry as well. While growers may feel that beekeepers are just complaining, because "that is what they do" (interview, Oct. 5, 2018), this relentless "complaining", combined with litigation, appears to be the only way that regulations have changed in beekeepers' favor (Ellis v. Housenger 2017). This confirms Mitchell's assessment in his conclusion that:

> The actual California landscape has been allowed to go on in obscurity except when farmworkers have demanded that it be seen and taken seriously for what it is: a place of ruthless, relentless exploitation (and indeed a place of beauty), a place quintessentially modern both in its architecture…and in its experiments with social control" (1996, 201).

While the almond industry's 2014 Best Management Practices offer a strong step in the right direction, Mitchell's point makes clear that the only way regulatory agencies and industrial growers and farmers are going to realize the central importance that managed pollinators play in our current agricultural system—and subsequently act on it—is if beekeepers and bee advocates continue to 'complain', to litigate, and otherwise make visible the labor of the beekeepers and bees who have helped construct California's agricultural landscape for the past 150 years.

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Appendix: Methods

Interviewees	#	Approx. hours
Beekeepers	41	150
Almond growers and industry representatives	23	45
State and federal regulators	12	20
Researchers and extension specialists	11	17
TOTAL	**87**	**232**

The qualitative interview data for this dissertation came from 87 in-depth, semi-formal interviews (totaling over 232 hours) with 41 commercial beekeepers whose operations ranged from 300 to 90,000 colonies, 23 almond growers and representatives from the industry, 11 researchers that support the beekeeping community; and 12 government officials who work in county, state, and federal offices. Interview data was primarily collected from 2015-2017, but my engagement with the beekeeping and grower communities started in 2013 and continues through the present, with participant observation at numerous conferences, beekeeper meetings, daylong workshops, and many informal conversations and community gatherings.

Commercial beekeepers (i.e. beekeepers who primarily make their income from beekeeping) were chosen to represent a range of operation sizes. A 300-colony operation is considered commercial (Kulhanek et al. 2017), and the average beekeeping operation interviewed ranged from 1,000-3,000 colonies. There were about four outliers, whose operations ranged from 14,000 to 90,000 (the largest in the industry), and one almond pollinator who managed 20 colonies as a sideliner[38]. Questions asked about beekeepers' annual management practices and how they have changed over the past two decades (or since they started commercial beekeeping), and their perspectives on what played a role in those changes. I also asked about the role that the almond industry has played in these processes, as well as general questions about their professional relationship with their grower, how they handle conflicts that arise, and about their knowledge support networks for growing advice, such as conferences, extension specialists, and pesticide crop advisors (PCAs). Interviews ranged from 90 minutes to three or more hours.

I selected **almond growers and industry representatives** in San Joaquin Valley from the three highest producing counties in the Valley: Stanislaus, Fresno, and Kern. These counties also capture the geographical breadth of the eight counties in the San Joaquin Valley, with Stanislaus in the north, Fresno in the center, and Kern in the south. Growers were stratified to represent different operational sizes, ranging from growers managing close to 100 acres, to one of the largest growers in the world, Wonderful Farms, who manage over 20,000 acres of almonds. Larger operations tended to focus solely on almond or mixed agricultural production for income, while other growers may grow almonds on an inherited plot of acreage, with the help of a farm management company. In those cases, I tried to speak to the on-site farm manager when possible as well. Questions asked about growers' annual management practices and how these have changed from the mid-eighties and what factors played a role in almond expansion and increased production. Similar to my interviews with beekeepers, I also asked about the role that beekeepers and bees have played in these processes, as well as general questions about their professional

[38] A sideliner is a beekeeper who keeps bees, but it is not their primary income.

relationship with their beekeeper, how they handle conflicts that arise, and about their knowledge support networks for growing advice, such as conferences, extension specialists, and pesticide crop advisors (PCAs). These interviews averaged around 60-90 minutes.

Researchers selected for interviews were chosen with guidance from the beekeeping and grower communities, as well as the result of a literature review of relevant ecological research on honey bee issues—which also informed sections of this paper—and through networking at beekeeping conferences. The **government officials** consisted of representatives in the Environmental Protection Agency's (EPA) pesticide labeling division, and government employees at the Agricultural Commissioner's Office in each of the eight counties in California's San Joaquin Valley.

This dissertation research started in 2012 with a central question: How has pollinating for the almond industry affected commercial bee production, and how might it contribute to honey bee vulnerability? Having been a beekeeper for several years and followed the "crisis" of honey bee declines since 2007, I knew that the almond industry had become the central employer for most commercial beekeepers in the United States. I started attending beekeeping conferences in the fall of 2013, namely the California State Beekeepers Association, to observe and understand how beekeepers framed their challenges.

It was at that first meeting in South Lake Tahoe that I began to really understand the complexity of the plight of bees. One beekeeper in the Midwest spoke about the forage loss they were facing that was affecting honey production, and I realized that many beekeepers were pollinating for the almond industry only reluctantly because they were struggling to make a living off of honey anymore. And yet, I sensed reluctance and frustration from within the community about what seemed like a forced reliance on almond pollination for an income. Because of my innate shyness, and because the beekeeping community seemed to be suffering from interview fatigue from journalists trying to understand what was killing bees, it took a while to start getting interviews to explore these dynamics further. I was fortunate enough to get interviews with some of the central leaders in the community who, once rapport was established, connected me to other beekeepers as well.

The beekeeping community has two national beekeeping organizations, though many beekeepers attend or belong to both. The American Beekeeping Federation (ABF) is the oldest of the two and represents all members of the beekeeping industry—not just commercial beekeepers, but hobbyists, honey packers, and other members of the industry. The other, the American Honey Producers Association (AHPA) is for beekeepers who identify as honey producers only and is a smaller organization. The two organizations meet at the same time each year in different locations, forcing beekeepers to choose one conference or the other. Every third year, they hold their meetings together.

I mention these two organizations because I started to find that each had a particular culture, and that I would need to interview beekeepers from both. For example, beekeepers from AHPA tended to emphasize pesticides as the main problem killing beekeepers and had members who were more actively speaking out against pesticides and litigating the state or federal agencies, particularly on the topic of neonicotinoids. Beekeepers from ABF, I noticed, tended to focus more on mites as an issue, with pesticides as a secondary and constant cause. While these are broad generalities, I wanted to make sure that I captured the sentiments, values, and observations of each, to make sure my research reflected the diversity of the community.

The commercial beekeeping community is relatively small. Estimates range from 1200 to 1600 in the United States, though there is no reputable number since the USDA only does a census on honey producers and not on commercial pollinators or migratory beekeepers. According to some beekeepers, it is possible that the number of migratory commercial beekeepers is actually closer to a three to five hundred. I interviewed beekeepers until I began to experience saturation. With some beekeepers, those that might be described as leaders in the community with long histories with the industry, we had conversations time and time again, countless hours that I did not include in my semi-formal interview hour count. I primarily did my interviews in trucks with beekeepers as they drove to check on their colonies. I observed colony inspections, went to local gatherings and bee meetings, such as the Delta Bee Club meeting, the most attended bee club meeting in the Central Valley. Once beekeepers left California after pollination, I had to conduct some interviews by phone as well.

As I interviewed beekeepers and began to understand the central role the Midwest played in shaping their decision to pollinate almonds, I realized I needed to go visit North Dakota, the prime honey producing state in the U.S. as I detail in Chapter Five. I made a two-week trip out there and packed it with interviews and observations with researchers and beekeepers so I could better understand the land use changes driving beekeepers into the almond industry. This trip, and the follow-up interviews conducted afterward, informed much of the qualitative data for Chapter Five.

A pivotal meeting for me was in the spring of 2014, when I attended the EPA meeting in with over 50 beekeepers after an almond pollination season rife with bee kills—I detail this briefly in Chapter Four. Beekeepers expressed immense frustration with the labeling of bee-toxic pesticides and blamed this shortfall on their bee losses that year. This led to two investigations. The first was to understand how pesticides were labeled and regulated in the U.S. and California, which provides the bulk of Chapter Four. The second investigation, mentioned in Part Two of Ch. Four, required statistical analysis skills and coding I do not yet possess, so I partnered with an agricultural economist, Dr. Brittney Goodrich, who did her PhD research on the beekeeping and almond industries as well while at UC Davis. Working with two U.C. Berkeley undergraduate students, Evan Yoshimoto and Kelly Chang, and informed by numerous researchers and beekeepers, we compiled a list of bee-toxic agrochemicals (both EPA labeled, and those indicated by at least one published study) used during bloom. We then analyzed them looking at various factors, particularly application trends over time, and then what growers' practices were while beekeepers were in almonds. The results of this study are being written up as a paper and has been invited for submission to *California Agriculture*.

I spent the bulk of 2018 interviewing almond growers. My questions for growers were primarily: What factors drove almond expansion? How did their management practices changed from the mid-80s to 2016? What are their management and pesticide practices during almond bloom? And finally, I was curious about what their primary concerns were as an industry, and were they worried about getting bees for future pollination? I met growers at the annual Almond Board conference (ABC), and also through beekeepers, bee brokers, and local grower meetings as well. Chapter Two is the result of my conversations with industry representatives and growers about the factors that drove almond expansion and how practices have changed from the 1980s to 2016. Because I was concerned that interviews would not adequately tell me about grower pesticide practices, I relied mostly on the Pesticide Use Reports—required by the County Agricultural Commissioner's office (CACs) to answer the questions I had about their practices.

Finally, Chapter One was the result of pure curiosity about the early relationship between growers and beekeepers. I consulted numerous historical documents, almond and bee culture manuals, and agricultural histories written by people in the industries, but also by agricultural extension specialists and historians.

Any errors in this dissertation are entirely my own.