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Introduction

THE MYSTERY OF DYING BEES

Darren Cox is allergic to bees. He used to be deathly allergic. A fourth-generation beekeeper, Darren has been working with bees since he was a teenager. One day when he was seventeen and working with his father in a bee yard, Darren was stung twice in the neck. He went into anaphylactic shock, a severe and potentially deadly allergic reaction that can narrow a person's airways and stop them from breathing. His dad drove him to the emergency room in his beekeeping truck, terrified his son wouldn't survive. Darren spent the next four days in the hospital.

When he finally recovered and was released, Darren's dad informed him that he had to keep helping with their beekeeping operation. He had purchased a few EpiPens to keep on hand when they were inspecting hives and explained that Darren would have to stab himself in the thigh with the EpiPen if he got stung and began to have a reaction. The epinephrine, a form of adrenaline in the EpiPen, would counter the allergic reaction and save his life.

And that was that. Darren went back to beekeeping.

Darren is telling me this story because I was stung between my eyes this morning while interviewing another beekeeper. My forehead throbs and is slowly swelling to what will later look like a botched Botox job, but I can't take Benadryl because it'll make me too sleepy to drive. Instead, I wear dark sunglasses and a hat to hide the swelling while I struggle to hide my shock at his story. He laughs and tells me that if

there's any group of people I should feel comfortable interviewing with a bee-stung face, it's beekeepers.

What eventually helped treat Darren's bee allergy was, paradoxically, the bees themselves. He used venom therapy, where a small dose of diluted bee venom is regularly injected over time to help build immunity, kind of like a vaccine. Still, I couldn't get over the fact that Darren was deathly allergic to bees, and his father made him work with them anyway. How desperate do you need to be to force your teenage son to keep working with an insect that almost killed him? And what kind of person makes a living off a creature that nearly took their life?

These were the kind of challenges, and the desperation, I saw beekeepers wrestle with during my years of research. However, most of the beekeepers I met were not deathly allergic to bees. Rather, they were struggling to stop their own bees from dying, year after year.



Beekeepers aren't alone in these losses. Around the world, alarm bells are ringing about a looming insect apocalypse.¹ Researchers debate the exact rate of these declines, but even conservative estimates suggest we're losing around 1 percent of land-dwelling insect populations each year—roughly 9 percent per decade.² The causes are complex and interwoven, and land-use changes, habitat loss, pesticide exposure, and climate change all play a part. Pollinators, with their sensitivity to environmental changes, are especially vulnerable to these threats.

It's easy to overlook the insect pollinators that surround us. During the day, bees and butterflies visit thousands of flowers. Beetles chew through leaves and petals to feed, passing pollen from one bloom to the next. Bumblebees perform buzz pollination by gripping onto flowers and vibrating their flight muscles to release pollen. Tiny midges, no larger than a pinhead, pollinate cacao—giving us chocolate—while a variety of bees, wasps, flies, and other insects pollinate coffee plants. Even mosquitoes play a role: Some species pollinate orchids, and all mosquitoes drink floral nectar and may transfer pollen as well.

As the sun sets, nocturnal pollinators emerge, drawn to pale, fragrant flowers that only bloom at night. Long-tongued moths seek out the

deep nectaries in honeysuckle, yucca, and orchids. They're joined by an ensemble of insects on the night shift: flies, beetles, short-tongued moths, and even some nocturnal bees and wasps. When winter comes, many of these insects enter diapause, a kind of insect hibernation, where they wait in suspended animation like dormant seeds until spring arrives and wakes them to pollinate once more.

Over millions of years, flowers and pollinators coevolved. Pollinators' unique traits—like their tongue length, flight patterns, and body shapes—influenced flowers' form and function. Flowers, in turn, shaped the pollinators. These interdependent relationships have fostered an incredible diversity of trees, shrubs, and flowers that sustain life on our planet. Today, around 90 percent of the world's flowering plants and 75 percent of the world's major food crops benefit from pollination services provided by insect and other animal pollinators.³ Their decline threatens the stability of our environment, our food systems, and the intricate web of life that depends on them.

And yet we are losing them. For the past two decades, honey bee losses have shed light on the dire state of insect health. Beekeepers and their bees have faced a barrage of challenges, including parasitic mites, treatment-resistant diseases, pesticide exposure, and unprecedented natural disasters like floods and wildfires. These stresses have caused beekeepers to lose as much as half of their bee colonies each year—a gut punch for an industry already operating on thin margins. Over the past twelve years, I've watched beekeepers cycle through hope and despair as they've tweaked their practices again and again to keep their bees alive and their operations afloat.

I first learned about dying bees on an island in the Philippines. It was 2007, and I was a Fulbright Scholar researching the Philippine rice terraces in northern Luzon, the main island. A few weeks earlier, I'd been at my research site in the northern town of Banaue, surrounded by deep green mountains etched with two-thousand-year-old rice terraces typically cloaked in a tenacious damp fog. My home's walls were paper-thin and the cold seeped through, so I had to pile numerous threadbare

blankets on at night just to stay warm. My only friend in town, a Peace Corps volunteer, had left the region, and I was desperately homesick.

One evening, I pulled out a book a friend had loaned me, Sue Monk Kidd's *The Secret Life of Bees*. As I read about the novel's women beekeepers, the rich scent of honey, and the meditative hum of the hive, I knew what would ease my loneliness.

Bees.

Now, I'm not in the habit of seeking out insects when facing hardship, particularly the kind that sting. And yet something in me said: *Go hang out with bees and you'll feel better*. After doing some research, I discovered a small bee-focused farm and hotel, the Bohol Bee Farm, on the island of Bohol. I arranged to stay there for two weeks on a sort of mini internship to learn about beekeeping and shadow the owner, Vicky, a Filipina beekeeper who taught her craft to small farmers on the island.

For most people who are weird enough to get into beekeeping (especially if it's not a family business), there's often a first moment that hooks you. I remember mine clearly. Vicky invited me to look inside a colony, though I was wearing only a denim skirt, a short-sleeved shirt, and a straw hat.

"It's fine," she assured me. "They won't sting you." She leaned over and used her hive tool to pry the edges of the hive's lid, cracking the sticky barrier of propolis that bees use to protect and seal their hive. She gently pulled off the wooden lid and set it to the side of the colony, and the heady scent of warm wax and honey wafted out, along with the steady, low hum of the bees.

Years later, I'd have my own colony and learn to understand the pitch of a hive's hum, how opening the hive sparks a buzz of agitation that can settle quickly if the bees are not too disturbed. The hum comes from their rapid wing movements. Honey bees beat their wings around 230 times a second (13,800 times a minute), though the speed varies depending on the situation. Many experienced beekeepers can tell when a hive is happy, agitated, and even sick, based on the way their bees are buzzing. Back then, I found their contented hum soothing, like white noise or the ocean. *This*, I remember thinking, *is why I came here*.

During my stay at the Bee Farm, I learned that the bees I had fallen in love with were disappearing. At the beginning of 2007, media outlets

began reporting on a mysterious disorder affecting honey bees. The genesis of its arrival went something like this: In November 2006, Dave Hackenberg, a beekeeper with over forty years of experience, walked into his Florida bee yard to inspect his hives. Like many migratory beekeepers, he and his bees had spent the summer on the road, providing pollination services for crops like melons, apples, and blueberries. Hackenberg had just returned from Pennsylvania three weeks earlier with 400 hives in tow.

That afternoon, Hackenberg lit his smoker, a device that uses smoke to calm bees. He lifted the hive's lid to puff smoke onto the colony's frames and inspect them. After a few moments, he noticed that very few bees were leaving the hive. When he started pulling frames out to examine them, he saw something highly unusual—nearly the entire colony had vanished. The hive was completely empty, save the queen, the brood (eggs, larvae, and pupae), and some nurse bees. He quickly discovered that 360 of his previously healthy colonies had disappeared.

Researchers later termed this phenomenon Colony Collapse Disorder, or CCD, to describe the sudden and mysterious disappearance of tens of thousands of adult worker bees. The bees didn't die in or near the hive—they were never found at all. In their wake, they left hollowed-out colonies with typically just the queen, a few young bees, brood, honey stores, and pollen.⁴ Even stranger, the honey was often left untouched for weeks by other bees or common scavengers like wax moths and small hive beetles—something virtually unheard of, even in colonies dying from other causes.

Hackenberg's experience was not an isolated event. By January 2007, CCD had wiped out more than a third of US honey bee colonies, and Europe also experienced record losses.⁵ Blame for the disease ran the gamut, from plausible explanations to wild speculation. Some news outlets even stoked fears that cell phone radiation might disrupt bees' navigation, which scientists quickly debunked.

Back in 2007, CCD intrigued me as it did many others. The media posted alarming headlines such as "Vanishing Honey Bees Mystify Scientists" and "Honey Bees Vanish, Leaving Keepers in Peril."⁶ Slowly, it morphed into an ecological whodunit, an entomological game of Clue.

Newspapers announced suspected culprits as if they'd been indicted for crimes, from viruses to pesticides to mites. I was riveted as I read the news on Vicky's computer, with its achingly slow internet connection, and desperately wanted to join the teams trying to discover the cause.

In 2012, I started my PhD at the University of California, Berkeley. As a social scientist, I wanted to understand the social and environmental drivers of bee declines, like pesticide practices and regulation, land-use change and policies, and shifts in bee management over time. Rather than thinking about bee health as affected by one pesticide or virus, I had a feeling that there was a larger story, as there often is with environmental issues.

That's when I learned about the California almond industry.

Each year, right around Valentine's Day, almond trees blush pink and white 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 as billions of bees descend on over a million acres of almond trees. Beekeepers from around the United States haul their colonies into orchards on flatbed trucks and semis, an estimated 2.7 million colonies in 2024.⁷

At the height of pollination in February, when the different varieties' blooms briefly overlap, you can stand in the middle of an orchard and smell the heady fragrance and hear the hum of bees zipping through the branches as they cross-pollinate the trees. By the end of bloom, it looks like winter 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 bees once visited the flowers.

California's almond growers produce over 80 percent of the world's almonds, and nearly all of those trees are planted in the Central Valley. The industry has accomplished this through relentless expansion since the mid-1980s, growing from just over 400,000 planted acres of trees in 1985 to 1.5 million acres in 2024—an area roughly the size of the



FIGURE 0-1. A blooming almond orchard in Glenn County, California (photo by Kathy Coatney/Image Source Limited; courtesy of Alamy).

state of Delaware.⁸ This expansion has been fueled in large part by the high prices growers can get for their specialty crop. In 2023, almonds were California's top valued agricultural export, with \$4.4 billion in foreign sales.⁹

But this booming industry has an ecological Achilles' heel. Almonds rely on insect pollination, and most varieties require two colonies of managed honey bees per acre. As almond acreage has expanded throughout the state, so has the demand for bees. Today, beekeepers truck nearly 99 percent of the nation's honey-producing colonies to the Central Valley each February, an astounding concentration of hives in a single region.¹⁰ For commercial beekeepers—those who make a living from their bees—almond pollination fees have become a more reliable and higher-paying income stream than honey production, which is why so many now place the almond industry at the center of everything they do.

When I first started learning about the relationship between the almond and beekeeping industries, I wanted to understand how it evolved—how beekeepers adapted their operations to pollinate almonds, and how growers' practices affected bees during bloom. I think, secretly, part of me hoped to make a *Clue*-like pronouncement in my

doctoral thesis: *It was the almond grower, with the pesticides, in the almond orchard!* But as I dug deeper, the story became more complicated. I found myself asking: What are the tradeoffs beekeepers make to stay afloat? How did our food system come to rely so heavily on a species this fragile? And what does it mean—ecologically and ethically—to keep asking so much of our bees?

These questions zigzagged me across the country, tracing a path not unlike the migratory routes of beekeepers themselves. I began in the almond orchards and then followed the trail to queen bee breeders in Northern California. I eventually traveled to the Midwest, where more than 50 percent of US honey is produced each summer, then talked to regulators at the US Environmental Protection Agency. Ultimately, I landed in Washington, DC, where I spent a year at the US Department of Agriculture on a fellowship with the American Association for the Advancement of Science, working on climate, pesticide, and pollinator issues.

What became clear from my immersion in the beekeeping world—and from the past two decades of scientific research—is that there is no singular cause of honey bee losses. Beekeepers have mostly stopped seeing the unique symptoms of CCD, though the term is often misapplied to describe other types of colony die-offs. Still, beekeepers continue to face crippling die-offs each year. They'll crack open their hives in January only to find dead or dwindling colonies, sometimes losing 30 to 50 percent of their operation. Beekeepers often describe these die-offs as “death by a thousand paper cuts.” While it's an apt metaphor, it also risks being too vague, too amorphous.

Bitter Honey offers a new way of understanding the bee crisis. It's not a mystery with a single culprit but a symptom of something bigger: the industrialization of our food system. In modern agriculture, this transformation often begins with specialization, like when farmers shift from growing a range of crops to focusing on monoculture crops like corn, wheat, or soy. To scale up, they standardize practices, streamline genetics and production timelines, and rely heavily on synthetic inputs like pesticides or antibiotics to manage the pest problems simplified farms tend to invite.

As this book will show, the rise of monoculture farming hasn't just harmed wild pollinators and ecosystems, it's reshaped the relationship between farmers, managed honey bees, and their keepers. Over the past several decades, commercial beekeepers have adopted more intensive practices as they've shifted from a focus on honey production to providing pollination services for almonds and other crops. This transition has meant beekeepers push their bees hard as they ramp up the use of supplements, select bees from a narrowing genetic stock, and truck their hives on grueling cross-country migrations. Yet without these changes, beekeepers worry their operations will fold.

This is why I prefer the terms "colony losses" and "vulnerable honey bees" rather than "CCD" and "honey bee declines"—because they better capture what's happening on the ground. Some articles have questioned the idea of a honey bee crisis, pointing out that US colony numbers are not declining, and have actually held fairly steady since the mid-1980s.¹¹ And technically, they're right. Colony totals have remained stable over the past decade, despite the occasional headlines warning of an impending honey bee apocalypse.

But those numbers don't tell the whole story. Annual colony counts only tell us that the beekeeping industry can produce a similar number of colonies year after year. What they don't reveal is how much harder and expensive it has become to sustain them. They don't reflect beekeepers' growing reliance on inputs as forage (bee-friendly flowers) disappears, the extra labor needed to control mites and disease, the financial strain of heavy winter die-offs right before a pollination contract begins, the logistical stress of moving bees cross-country, or the consolidation that's pushing smaller beekeepers out.

Perhaps most importantly, they don't measure bee health. Yes, if you just track the numbers, the industry appears to be holding steady, and managed bees aren't facing potential extinction like some wild insects. But most beekeepers and researchers will tell you that honey bee *health* is declining, and that over the past couple of decades, beekeepers are producing an increasingly vulnerable bee.

Understanding bee vulnerability through the lens of industrial agriculture matters for several reasons. Too often, we focus on isolated



FIGURE 0-2. Honey bee on an almond flower (photo courtesy of the Almond Board of California).

threats—pesticides, mites, poor nutrition—without recognizing that they’re symptoms of a deeper system.¹² It’s like playing a game of Whac-A-Mole, where problems keep popping up, and we scramble to fix them, shifting our focus from this crisis here to this one over there, without figuring out how to stop playing the game—or at least change the rules.

That’s not to say that research and action on these individual threats aren’t essential, because they absolutely are. But without understanding the system that produces them, we risk applying Band-Aids on bullet wounds. Understanding bee declines as a product of industrialized agriculture helps us steer toward transformative, long-term interventions to support bee health while we take short-term steps to stem immediate losses.

The second reason this framing is helpful is a stubbornly hopeful one. Understanding the numerous drivers of bee vulnerability can highlight the equally numerous opportunities to support bees. In other words,

yes, bees face many issues, but this also means there are many ways we can help them too.

And we should care about helping bees—*all* bees, including wild and managed ones—because they sustain far more than just the beekeeping industry. Insects and animal pollinators help produce about a third of every bite we eat, from blueberries to almonds to coffee and chocolate. Their efforts support between \$235 and \$577 billion in global food production each year.¹³ They also make our diets more nutritious: Many essential vitamins and minerals come from crops that depend on them. In short, pollinators' largely invisible labor makes our world more beautiful and our plates more diverse—and beekeepers play a vital, and often thankless, role in ensuring that managed bees are there to help.

Bitter Honey aims to capture the complex bargain that beekeepers have made to stay in business despite all the stressors they face, and the impact of that bargain on bee health and the environment. Literally, the title refers to the acrid honey that bees produce as they pollinate almonds, honey that beekeepers typically do not sell but let their bees consume instead. Figuratively, however, it refers to the compromises beekeepers make to keep their operations afloat: pushing colonies harder each year, medicating against parasites and pathogens, coping with pesticide exposure inside and outside the hive, and chasing increasingly elusive bee forage. It's hard to keep bees alive these days, especially for almond pollination, but demand is high and the money is decent, so beekeepers keep doing it, year after year.

Bitter Honey explores these processes in two sections. Part 1 focuses on the relationship between commercial beekeepers and industrial agriculture, and how pollinating crops—California almonds, in particular—has deepened bee vulnerability. Beekeepers often describe almond pollination as a Faustian bargain. It's become essential to sustaining their operations, but comes at the high cost of industrializing their bees and increasing their fragility. The first four chapters provide an inside look at how beekeepers have transformed bee management over the past two decades to pollinate almonds and other crops. The final three chapters examine other drivers shaping bee vulnerability,

including pesticide exposure, the loss of bee-friendly forage in the Midwest, and the mounting effects of climate change.

Part 2 turns toward hope. It explores solutions for supporting bees and other pollinators through large-scale forage projects, by transforming our agricultural system, and, finally, through actions we can take at home. Many of these solutions are emerging from the beekeeping and farming communities, but others are steps anyone can take, such as planting pollinator gardens, reducing pesticide use in home and community spaces, and supporting native bees through citizen science. While part 1 lays out the challenges, part 2 reveals just as many ways to help.

Industrial agriculture is making it increasingly difficult for all bees—both wild and managed—to live in the world around us, and *Bitter Honey* highlights the bold steps we'll need to take to help them survive. For years, beekeepers have done what Darren Cox once did: work through the risks, push forward, and hope the tools they have on hand will be enough. But these approaches often offer only short-term relief and aren't lasting solutions for bee health. To help pollinators thrive—and maintain access to the nutritious, diverse food crops we depend on—we'll need more than stopgaps and emergency measures. We'll need a food system that works with nature, not against it; one that places the well-being of pollinators, wildlife, farmers, and the rest of us at its center.

A Note on Names

To protect the privacy of certain individuals, I've used pseudonyms for some of the beekeepers and other subjects featured in this book. These pseudonyms are indicated by an asterisk (*) the first time each name appears.

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