Be(e)coming Experts: The Controversy Over Insecticides in the Honey Bee Colony Collapse Disorder

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Be(e)coming experts: The controversy over insecticides in the honey bee colony collapse disorder

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Abstract

In this article, we explore the politics of expertise in an ongoing controversy in the United States over the role of certain insecticides in colony collapse disorder – a phenomenon involving mass die-offs of honey bees. Numerous long-time commercial beekeepers contend that newer systemic agricultural insecticides are a crucial part of the cocktail of factors responsible for colony collapse disorder. Many scientists actively researching colony collapse disorder reject the beekeepers' claims, citing the lack of conclusive evidence from field experiments by academic and industry toxicologists. US Environmental Protection Agency regulators, in turn, privilege the latters' approach to the issue, and use the lack of conclusive evidence of systemic insecticides' role in colony collapse disorder to justify permitting these chemicals to remain on the market. Drawing on semistructured interviews with key players in the controversy, as well as published documents and ethnographic data, we show how a set of research norms and practices from agricultural entomology came to dominate the investigation of the links between pesticides and honey bee health, and how the epistemological dominance of these norms and practices served to marginalize the knowledge claims and policy positions of commercial beekeepers in the colony collapse disorder controversy. We conclude with a discussion of how the colony collapse disorder case can help us think about the nature and politics of expertise.

Keywords

agriculture, controversy, environment, expertise, health, politics of knowledge

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Introduction

David Hackenberg is a veteran commercial beekeeper who has been trucking his beehives (also called 'colonies') and offering their services as pollinators to growers of a wide variety of crops since the 1960s. In the spring of 2005, thousands of Hackenberg's healthy hives 'collapsed' mysteriously while his bees pollinated blueberries in Maine. Bees abandoned his hives and did not return. He had never seen anything like this.

By the fall of 2006, as the mysterious collapses persisted and intensified, it became clear to Hackenberg that his experience was not unique. All around the United States, beekeepers – commercial, sideliners, and hobbyists[1] – were also seeing their hives collapse. As the winter of 2006 began to thaw, news emerged in the mass media (e.g. Barrionuevo, 2007) that several beekeeping operations had lost between 30 percent and 90 percent of their hives, significantly higher than the roughly 15 percent normally associated with factors such as parasitic mites, diseases, and poor nutrition. Today, more than half a decade since beekeepers first saw their bees vanish, average hive losses remain troublingly high, frequently above 30 percent (US Department of Agriculture (USDA), 2010; VanEngelsdorp et al., 2011). Bee researchers have dubbed it 'colony collapse disorder' or CCD.

CCD threatens the very sustainability of US agriculture because honey bees are the primary actively managed pollinating insect species in North America. The value of the increased agricultural yield and quality achieved in the United States through pollination by honey bees alone was US$14.6 billion in 2000 (Morse and Calderone, 2000). Farmers rent an estimated 2 million honey bee colonies each year to service over 90 different crops. Among the crops dependent on honey bee-mediated pollination are almonds, apples, asparagus, blueberries, broccoli, carrots, cauliflower, celery, cherries, cotton, cranberries, cucumbers, onions, pumpkins, squash, and sunflowers. The availability of all these crops is endangered by the loss of honey bee pollination (National Research Council (NRC), 2007).

From a scholarly perspective, CCD and disputes over the role of certain agrochemicals in it offer a valuable opportunity to explore the place of 'nonscientist' stakeholders – actors in occupational fields who typically do not engage in practices commonly associated with certified experts in scientific fields (Bourdieu, 1975) – in technical debates about phenomena that affect their lives and livelihoods.[2] It allows us to understand what these people offer to technical disputes, to consider who government regulators listen to and why, and to understand who defines legitimate research questions, practices, and outcomes.

Drawing on semistructured interviews with key players in the debate over CCD, as well as published documents and ethnographic data, we show how a certain set of research norms and practices from agricultural entomology came to dominate the investigation of the links between pesticides and honey bee health, and how the epistemological dominance of these norms and practices served to marginalize the knowledge claims and policy positions of commercial beekeepers in the CCD controversy. Two national beekeeper conferences, which were held in 2010 in Orlando, Florida, and in 2011 in Galveston, Texas, served as key sites for our interviews and participant-observation, where we could listen and talk to beekeepers as well as to academic, industry, and government scientists, and to government officials. In addition, between 2009 and 2011, we gathered ethnographic data at an academic facility doing peer-reviewed bee research and extension work with beekeepers in the United States.

In what follows, we first provide a portrait of what CCD is thought to be, what the controversy over certain insecticides is about, and what questions it raises regarding expertise. Next, we engage with some widely discussed scholarship on the 'problem of expertise'. We move on to outline the sociohistorical factors that have shaped the debate over CCD and have led to the marginalization of the voices of commercial beekeepers. Finally, our conclusion highlights the broad implications and questions that this article raises for debates over the meaning and role of expertise in contemporary technoscientific controversies.

The CCD controversy

Reports of CCD began in 2004–2005. The bees were 'boiling out' of the collapsing hives in droves, leaving behind the queen, her brood, and frames full of honey and pollen. None of the absconding bees were found dead near the hive. Strangely, the abandoned stores of honey, which would normally have been 'robbed' by neighboring bees or other organisms, remained untouched.[3]

University and federal bee researchers reported several striking anatomical abnormalities and an unusual number of multiple viral and fungal infections in the young bees that remained in the CCD-affected hives (Bromenshenk et al., 2010; Cox-Foster et al., 2007; Johnson et al., 2009; VanEngelsdorp et al., 2007). However, several researchers surmise that the discovered pathogens are *secondary* infections, with the *primary* causes yet to be identified (e.g. Pettis and Delaplane, 2010; USDA, 2010). The emerging consensus is that CCD is not caused by any single factor but is the result of *a complex combination of multiple factors*, including certain agricultural pesticides, beekeeper-applied chemicals, poor nutrition, pathogens, and parasites (USDA, 2010). But which factors or sets of factors are more prominent and how they might combine and interact to provoke the losses are still unresolved. In particular, the role played by certain newer kinds of 'systemic' agricultural insecticides, represented most prominently by the 'neonicotinoids', such as imidacloprid and clothianidin, which are thought to persist in treated soils and plants for longer durations (e.g. Bonmatin et al., 2005), is a major source of controversy within and between groups of beekeepers, researchers, agrochemical representatives, regulatory policymakers, and environmentalists.

Drawing upon their day-to-day experientially based knowledge of bees, several beekeepers have argued that newer systemic insecticides are a crucial part of the cocktail of factors responsible for CCD, and their impact occurs through long-term progressive effects on developing bees, which are chronically exposed to accumulating stores of the agrochemicals and their toxic breakdown products inside beehives. In light of their analysis, many beekeepers have called for a suspension or major cutback in the use of these insecticides.[4]

Researchers in academia, agro-industry, and federal agencies reject or at best equivocate on the beekeepers' knowledge, citing the lack of *conclusive* evidence from scores of field experiments by academic and agrochemical industry toxicologists (e.g. Bayer

CropScience, 2010; Ratnieks and Carreck, 2010).[5] Regulatory officials privilege the toxicologists' knowledge to justify the continued commercialization of the concerned insecticides.[6] How does one explain the asymmetrically large influence of toxicologists in the CCD controversy? What leads actors involved in this case to believe that this variety of expertise is more reliable and trustworthy than that of the beekeepers? We suggest that in order to understand this, one needs to consider the social organization of knowledge production and its validation, in an historically attentive manner.

The problem of expertise

The problem of expertise has been the focus of pivotal scholarship in science and technology studies (e.g. Collins and Evans, 2002, 2007; Epstein, 1996; Wynne, 1992, 1996, 2003). In recent years, Collins and Evans (2002) have suggested that understanding expertise is 'the pressing intellectual problem of the age' (p. 236). Unlike previous work, Collins and Evans are not focused on how expertise works in actual practice and how and when the boundary between experts and so-called laypersons is breached. Instead, they are engaged in a definitional or typological exercise. They wish to provide tools that will allow us to distinguish between experts and nonexperts in a domain, and between varieties of experts. They seek to develop a logical warrant for categorizing the skills and knowledge possessed by different varieties of experts.

Collins and Evans (2007) consider the experience that one possesses in negotiating the discourses and practices of a given domain to be a more accurate gauge of one's expertise than one's formal credentials. Thus, for example, they treat Epstein's (1996) study of AIDS treatment activism as a case of noncertified actors gaining 'contributory expertise'. Epstein (1996) describes how AIDS treatment activists put pressure on biomedical researchers and regulators to acknowledge their concerns regarding clinical drug trials. It is worth noting in this case that the AIDS activists had to develop some facility with dominant scientific ways of knowing in order to gain credibility for their knowledge claims. Similarly, Collins and Evans (2007) read Wynne's (1992) investigations of sheep farming and radiation exposure to mean that while the sheep-farmers were not scientifically trained and did not necessarily have a broad understanding of radioactivity, they did have a specialized expertise regarding grazing and farming practices in the local hill conditions by dint of their deep practical experience. This enabled the sheep-farmers to offer a compelling alternative explanation to that provided by government officials for how radioactive material was likely to work its way through the local ecosystem. Collins and Evans suggest that Wynne's sheep-farmers possess 'contributory expertise', which should entitle them to contribute substantively to technical debates along with the involved scientists.

Readers of Wynne's (1992) work will, however, know that the 'contributory expertise' of the sheep-farmers was largely ignored by government and corporate officials. Possession of 'contributory expertise' does not guarantee recognition. Thus, while Collins and Evans provide a valuable service by clarifying and sharpening definitions of expertise, in a world where experts' proclamations have profound effects on the lives and livelihoods of laypeople who have interests in a given controversy, their typological categorization fails to address an important set of issues. Collins and Evans do not consider the factors that legitimize certain claims about methods, data, and truth while delegitimizing others, factors that thus define certain actors as experts and others as nonexperts (Jasanoff, 2003). Their solution to 'the problem of expertise' involves bringing together the real-world knowledge of noncertified actors and the capacities of certified scientists. However, the problem of expertise is not solved simply by *calling for* the inclusion of noncertified experts to contribute solutions to problems for which they have relevant knowledge. Knowledge constitution – indeed, what comes to count as legitimate knowledge – does not occur on a symmetrical field, but rather in a complex structure of relations of domination and subordination. Here, dominant scientific cultures define what counts as legitimate knowledge acquisition methods, data, and analysis (Wynne, 2003). Thus, in Wynne's famous sheep case, even if scientists did consider the sheep-farmers' specialized expertise about local variations, the capacity to define the questions and meanings of issues remained with the certified experts and those with state power – the scientists and government officials (Wynne, 2003). Following this logic, we build on Wynne's critique by considering the factors that allow actors possessing certain kinds of expertise to impose their perspectives and marginalize the knowledge claims of other stakeholders.

In contrast to Collins and Evans' effort to provide a context-independent warrant for distinguishing between varieties of experts, and thus for the legitimacy of certain voices and not others, we believe it is crucial to understand the circumstances under which different actors are listened to or ignored in technical controversies. That different actors will have differing understandings of a problem, and that their relative clout will shape their relative influence in debates, is fairly obvious. Not so apparent are the factors that enable the dominance of certain knowledge perspectives over others.

Using the CCD controversy, we argue that credibility and influence in disputes over knowledge – *epistemic dominance* – is shaped by the historically established social organization of knowledge production. Certain forms of knowledge production – particular *epistemic forms* – gain credibility over time and become institutionalized. Actors who draw on them begin with a kind of credibility that those who would challenge them lack. Understanding the historical establishment of particular epistemic forms is valuable for comprehending why certain kinds of knowledge and not others garner legitimacy among elites and the broader population. We suggest further that how actors approach the framing, methods, data, and analyses of issues – that is, the epistemic forms that they adopt – is influenced by their stakes and interests as defined by the historically shaped institutions in which they practice, and that relative epistemic dominance shapes those institutions' influence. To clarify, our argument is *not* that specific individuals or groups self-consciously or strategically manipulate knowledge practices to suit their own ends. While that may occur, our focus is less on intentional behavior and more on structural factors, such as cultural norms and practical constraints, that shape the approaches to knowledge making that are adopted by various actors. The epistemic dominance of these actors reflects not whether their knowledge and skill fall into a logical category but the link between their knowledge and the historically established stature of the variety of knowledge they possess, and the research methods and standards of assessment they utilize. We view the historically established social organization of knowledge production as a crucial mechanism in defining what counts as legitimate knowledge and who can produce this knowledge. In what follows, we illustrate how the varying approaches of different actors to issues of honey bee health, and in particular the CCD debate over insecticides, are shaped by historical developments in the institutional contexts of commercial beekeeping, honey bee toxicology, and federal pesticide regulation in the United States.

US agriculture, commercial beekeeping, and CCD

Commercial beekeepers' understandings of, and worries about, CCD in relation to insecticides are intertwined with the historical trajectory of US agriculture, and the rise of the crop pollination business in an industrial agriculture setting. The practice of using honey bees specifically for transferring pollen from flower to flower (pollination), and thus enabling (increases in) crop production, is thought to have begun in the late 19th and early 20th centuries on orchard plantations in the United States (Crane, 1999: 475). Honey bees are powerful pollinating agents because they live in massively populated hives that require lots of pollen for their growth and survival (Spivak, 2010). Prior to the 1940s, beekeeping for pollination was largely an extension of already existing practices for producing honey (Crane, 1999). Thus, even though beekeepers and fruit-growers came to recognize the value of managing honey bees for pollination by the first two decades of the 20th century, the historical record suggests that it was not until the 1940s that crop pollination became established as a primary or even common source of revenue for commercial beekeepers. Indeed, while hive manipulations and the renting of bees for the purposes of commercial crop pollination are scarcely discussed in the 1920 edition of A.I. Root and E.R. Root's *The ABC and XYZ of Beekeeping* (a popular manual of beekeeping practices, bee diseases, and bee laws), whole sections are devoted to these topics in the 1947 revised version. Prior to the 1940s, beekeepers hauled beehives into relatively small crop fields, where their hives gained strength and produced honey from the flowers that bloomed in the crop and surrounding areas. Since beekeepers made honey in the process of pollinating farmers' crops, they usually didn't require much more than 'a handshake' as remuneration for pollinating the crop (Spivak and Mader, 2010). Moreover, beekeeping manipulations and treatment inputs were relatively minimal, reflecting a then-prevailing philosophy that honey bees were best left to take care of themselves.[7] Farmers, in turn, benefited greatly, since their crops' quality and quantity improved dramatically. All this changed around the period of World War II.

Managed pollination emerged as a systematized need for farmers and a source of revenue for beekeepers in the mid-20th century, amidst rapid upsurges in large specialized monocultures (Dimitri et al., 2005), pesticide and fertilizer usages (Aspelin, 2003), and die-offs of endemic pollinators (Cameron et al., 2011; Spivak and Mader, 2010; Stefan-Dewenter et al., 2005). As farmers' demands for managed crop pollination grew, beekeepers realized that their bees were worth much more than a handshake. Since then, 'pollination-for-hire' has supplanted honey production as the primary driver of the US honey bee industry.

Beekeepers' commercial pollination practices have come to be shaped by an escalating, and, according to some, 'unsustainable demand' for pollination in industrial agriculture settings (Spivak and Mader, 2010). As of 2002, approximately 1400 commercial beekeeping operations owned an estimated 88 percent of all managed beehives in the United States (Daberkow et al., 2009), which are crucial cogs in its industrial agriculture economy. Beekeepers routinely truck several thousand hives all year around, placing them in crop settings all across the United States. In the process, they employ a range of manipulations that seek to keep hives sufficiently strong and primed to gather pollen, rather than nectar (Crane, 1999). For pollinating early flowering crops like apple and almond, hives are often stimulated to grow at a time that would normally be considered unseasonal in a beehive's life cycle (Spivak and Mader, 2010), and beekeepers 'prepare' hives by treating them with cane sugar syrup, high fructose corn syrup (HFCS), antibiotics, and other dietary supplements. These efforts to prepare honey bees to maximize their pollination potential have had consequences. The practice of feeding bees HFCS has come under increased scrutiny, primarily because it breaks down into a compound thought to be toxic to honey bees (LeBlanc et al., 2009). Similarly, preemptive use of antibiotics to control bacterial diseases in hives is thought to have created antibiotic-resistant strains of these bacteria (Miyagi et al., 2000).

Beekeepers, especially large-scale commercial ones, also routinely douse their hives with mite-killing pesticides (Mullin et al., 2010). The arrival of parasitic mites in the globalizing marketplace of the 1980s wiped out several beekeeping operations (Horn, 2005). Amidst ever-growing agricultural demands and in the absence of effective non-synthetic treatments, commercial beekeepers have, thus, themselves become pesticide applicators (Spivak, 2010). In-hive miticides, the technoscientific products of agrochemical commerce, research, and regulation, came to be seen as essential to the commercial interests of beekeepers and to their stakes in keeping beehives alive and sufficiently strong for pollination (Spivak, 2010). But long-term and often preventative use of these chemicals has taken a toll on honey bee health. For example, miticides are associated with a lowering of the reproductive and immune capacities of queen bees, on which all beekeepers rely for building their hives (Haarmann et al., 2002). They have also resulted in the emergence of a new generation of chemical-resistant super mites (Spivak, 2010).

In the course of pollinating multiple crops, beekeepers directly expose their hives to other industrial agricultural practices. Large monoculture crops – for example, almond orchards – constrain beehives predominantly to single nutritional (floral) sources, leading to potential problems of honey bee malnutrition (NRC, 2007; Spivak, 2010). In the process, foraging bees become exposed to mixes of insecticides, fungicides, and herbicides that farmers use heavily to avert 'pest' and 'weed' outbreaks in particularly vulnerable monocultural ecosystems (Altieri, 2000). The coincidence of all of these factors is thought by some to have created the 'perfect storm' (USDA, 2007: 7) that first gave rise to CCD in such commercial pollination settings of industrial agriculture (Stokstad, 2007).

While the highly heterogeneous community of US beekeepers (Daberkow et al., 2009) has serious disagreements about CCD and its causes, with some beekeepers stressing the possibility that a complex cocktail of factors likely causes CCD, and others arguing that CCD is simply the result of 'piss-poor beekeeping', several commercial beekeepers with decades of migratory beekeeping experience between them stress an especially consistent correlation between the occurrence of CCD and the proximity of their hives to agricultural crops that were treated with neonicotinoids such as imidacloprid (Suryanarayanan and Kleinman, 2011). In letters to the US Environmental Protection Agency (EPA), the primary federal agency for pesticide regulation, these beekeepers reported a temporal lag in the occurrence of CCD following exposure to imidacloprid.[8] This prompted them to suggest that presence of low doses of the neonicotinoids in the nectar and pollen of treated crops leads to a situation where foraging bees, instead of dying immediately from acute poisoning, might return to their hives with potentially poisoned food, which when fed to their brood could have adverse effects that eventually show up in future generations in the form of CCD. Clint Walker, of Walker Honey Inc., methodically thought through the possible culprits in the spread of CCD among his hives in 2006 and 2007 and concluded,

> These hives did not have mite loads. Neither were they exposed to other managed bees, since they were in relatively isolated areas with no other beekeepers around. We ruled out every variable except for the [migratory] transit or something in the cotton fields. We've been hauling bees trans-state for 72 years, and I know how to take care of bees while transporting them. And this was just 200 miles – almost zero stress. Nutritional deficiencies due to these CCD hives having only one kind of pollen [cotton] also don't make sense because they came out of cotton with strong brood, went into a good fall with lots of diverse ambient pollen and were strong in December. The only other variable that stood out was that every inch of the cotton fields that year had been treated with imidacloprid presumably in order to combat a drought-induced aphid [pest] outbreak. (Interview, Clint Walker, 14 January, 2010)

Walker's studies and other beekeeper-initiated investigations reveal some of the key epistemic qualities that embody the material practices from which commercial beekeepers derive their knowledge of CCD. Their studies can be said to be *in situ* since they are based upon the examination of CCD in *actual* fields that were being treated with imidacloprid. They are also *real-time* in that the honey bees are subject to the same set of spatiotemporal and practical constraints as they usually would in a commercial operation. Additionally, these beekeeper studies are characterized by a lack of formal procedures and measures, involving sharp controls and quantifications. *Informal* measures like 'strong brood', 'lots of diverse pollen', and 'almost zero stress' do not easily lend themselves to standardization or quantification and are considered anecdotal from the standpoint of academic scientists. At the same time, these informal measures package complex information with multidimensional aspects into knowledge useful and meaningful to beekeepers. For example, beekeepers rapidly gauge multiple aspects of hive health by monitoring the overall pattern in which honey bee brood are distributed across a hive comb. The 'brood pattern' not only provides important signs about how the brood is developing but also about the queen's health,[9] the hive's nutritional status, and the prevalence of diseases. In other words, it reflects a complex response to multiple local factors. By contrast, bee scientists tend to assess brood health by statistically informed monitoring and counting of the number of individual cells containing live/dead brood (e.g. Cutler and Scott-Dupree, 2007; Dively et al., 2010). In sum, beekeeper knowledge is constructed via practices that take an informal epistemic form, which makes them conducive to the highly dynamic, local, variable, and complex aspects of their operations.

It is worth noting that there is sometimes a difference between the informal methods used by beekeepers and their rhetoric. Indeed, one might make the case that Clint Walker's rhetoric, stressing the elimination and isolation of individual causal factors, is no different from the formal, deductive, experimental logic that researchers use in their reports. But our analytic focus here is not on the rhetorical form that these commercial beekeepers employ to describe their studies. If anything, this similarity suggests to us that beekeepers, like Walker, are trying to increase the credibility of their claims by seeking to express their observations in the dominant epistemic rhetoric of experimental science.

More crucially than by rhetoric, professional beekeepers' epistemic forms are shaped by their work lives, stakes, and interests, which are, in turn, defined in the historically shaped pollination market. Contemporary pollination contracts include specifications such as the number, location, strength and health of the beekeeper's hives; kinds of pesticides that the farmer can (or cannot) apply while hives are in the crop setting; and arrangements for the pollination rental fees (Burgett et al., 2010; Spivak and Mader, 2010). A farmer's dissatisfaction with the pollination performance of rented beehives could mean a significant reduction in the fee for the beekeeper and no renewed pollination contracts. Commercial beekeepers' practices of hive manipulation reflect growers' short-term interests in having hives with sufficient strength to carry out maximal pollination in the relatively short duration of crop bloom.

At the same time, commercial beekeepers also have at stake the long-term health of their hives, which they use for subsequent pollination operations. Perceived damage to bee health from crop-related sources could lead a beekeeper not to renew contracts and, at worst, to sue farmers for compensation. After all, sick bees make poor pollinators (Spivak and Mader, 2010). As a result, beekeepers also have a high stake in developing practices that gauge and enhance the long-term health of their beehives, without which immediate and subsequent pollination ventures are likely to fail. While beekeepers can replenish lost beehives by simply purchasing commercially available 'package bees', keeping hives alive and healthy remains a significant concern for commercial beekeepers. Usually the practice of purchasing package bees occurs alongside other practices that seek to cultivate hives over a long term. Furthermore, package bees are traditionally not made available until the beginning of warmer weather in the following year. This means that a commercial beekeeper would need to keep his or her hives healthy at least through most of the year before attempting to start hives from package bees.

Beekeepers with such bottom-line concerns reckon with hives that exist in real contexts where they interact with, and are affected by, environmental factors in complex ways. Here, beekeepers rely on an informal on-the-ground epistemic form that engenders knowledge about factors impinging on the health of their hives; this approach is unquestionably *practical* (useful and meaningful) but not sufficiently definitive from the standpoint of scientists. The beekeepers' knowledge practices reflect their long-term interests and thus err toward arriving at false-positive conclusions (type I errors). Their approach conforms to the precautionary principle, according to which the use and commercialization of synthetic chemicals is prohibited in the absence of evidence that such substances are safe, with the burden of proving the chemicals' harmlessness falling on manufacturer(s). This approach is shaped by beekeepers' high livelihood-stakes in keeping beehives healthy. This also means that commercial beekeepers will seriously consider the possible influence of multiple and difficult-to-quantify environmental factors, not just those that are easily isolatable and thus measureable.

In addition, commercial beekeepers' perspectives on CCD reflect a century-long history of tension with growers regarding the latter's use of insecticides. Beekeepers are reported to have experienced massive bee kills from insecticide exposure since the early 20th century (VanEngelsdorp and Meixner, 2010). Writing in 1920, Root and Root (1920/1947) describe the destruction of entire apiaries from indiscriminate insecticide spraying (p. 336). By World War II, 'traditional' insecticides such as organophosphates, captured in the American imagination by low-flying spray airplanes, were being doused periodically and increasingly over expanding farm acreage (Horn, 2005). These toxins did not discriminate between 'target' insect pests, and 'nontarget' insects, such as bees and other pollinators. Their application, especially during periods when bees foraged on blooming crop plants, caused considerable economic damage to beekeepers, with an acute insecticide kill being discernible by the stack of dead honey bee bodies piled up in front of a poisoned hive's entrance. Between 1962 and 1971, beekeepers lost hundreds of thousands of hives due to direct and indirect effects of pesticide contamination, accounting for greater than 20 percent of the total number of California's hives lost to 'other causes' (Atkins et al., 1978). Beekeepers attempted to adapt to farmers' continuing insecticide usage in various ways. They usually moved their hives to a different locale or covered their hives to protect them from contact with the insecticide during the temporary spray period. They also made contractual arrangements with client-farmers not to apply insecticides during the time when bees were foraging (Spivak and Mader, 2010). These shifts in beekeeping and farming practices worked to a certain extent because the toxic 'mode of action' of the 'traditional' insecticides occurs mostly via direct contact with insects on the treated plants and lasts for relatively short durations, ranging from a few hours to a few days (e.g. Anderson and Atkins, 1958).

However, with the introduction of insecticides with 'systemic' modes of action, which persist for extended periods in treated soils and plants, and accumulate in plant pollen and nectar (Bonmatin et al., 2005), protecting bees from adverse effects of chemical exposure posed a serious challenge. Systemic insecticides emerged in the post-World War II context of heightened chemical insecticide development (reviewed in Bennett, 1957). By the 1960s, bee scientists were noting that plants produced nectar toxic to bees after exposure to systemic insecticides (e.g. Jaycox, 1964). The systemic insecticides posed a different challenge to beekeepers because the toxin was active and persistent in treated plants for much longer after the application period than in traditional insecticides. This made not only just those bees directly exposed vulnerable, but also later foraging bees as well.

As potentially carcinogenic traditional insecticides began to be phased out by the EPA in the last decade of the 20th century, newer systemic insecticides became increasingly prevalent (EPA, 1999). Because newer systemic insecticides, such as the neonicotinoids (e.g. imidacloprid and clothianidin) and the ketoenols (e.g. spirotetramat), have much greater levels of insect toxicity and persistence compared to the older systemic and non-systemic chemicals (Bonmatin et al., 2005; Jeschke and Nauen, 2008; Rortais et al., 2005), they are said to provide more effective and long-term crop protection for farmers than their predecessors; at the same time, they are considered by the EPA to pose a 'reduced risk' to human users and the environment (EPA, 1999). Their increasingly widespread usage around the beginning of the 21st century has occurred in the shadow of 'unprecedented' honey bee losses in the United States and elsewhere. In France, in the 1990s, protests by beekeepers and suggestive studies by researchers led the government to limit the usage of some of the neonicotinoids (Maxim and Van der Sluijs, 2007; Suryanarayanan and Kleinman, 2012). This controversy, which received mention in the major US honey bee trade journals,[10] along with the history of tensions between beekeepers and farmers regarding agrochemical usage, additionally informs the context in which US commercial beekeepers link CCD to the newer systemic insecticides.

In response to the perceived threat to their livelihoods from the newer systemic insecticides, commercial beekeepers voiced their concerns to their grower clients, bee researchers, agrochemical manufacturers, and US governmental agencies. Beekeepers sought to make changes in the way pesticides are used and regulated, at both policy and grassroots levels. Their mission to establish a more 'balanced pesticide policy' has, in practical terms, meant advocacy against the increasing usages of newer systemic plant protection chemicals in urban and agricultural settings.[11] As a result, beekeepers' calls for the EPA to take a precautionary approach have focused predominantly on the immediate suspension or significant limitation in grower-used neonicotinoids. However, after following established processes of regulation promulgation, the EPA essentially dismissed beekeepers' concerns. In response to calls by several beekeepers, environmental groups, and citizens, who cited potential harm to honey bees as a warrant to suspend the commercialization of imidacloprid, in 2008, the EPA issued a letter stating that 'In order to suspend the registration of a pesticide ... EPA must find an "imminent hazard" exists ... [Y]our request for suspension does not demonstrate a causal link sufficient to justify the suspension of these pesticides ...'.[12]

In their ongoing dispute with farmers, beekeepers have consistently underemphasized the potentially deleterious effects of the use of beekeeper-applied chemicals. In face-to-face and electronic interactions, skeptical bee researchers, beekeepers, and agrochemical representatives do not tire of pointing out the potential double-standards in commercial beekeepers' opposition to systemic insecticide use by growers and their implicit acquiescence to the use of damaging in-hive miticides. While this contradiction is, of course, denied by the beekeepers, their utterances and mobilizations reflect their commercial interests and stakes, where miticidal chemicals are seen as being necessary in the absence of viable nonchemical alternatives.

The complex and contradictory situation notwithstanding, Collins and Evans (2007) would likely argue that beekeepers, by the virtue of their experiences and skills in managing bees, are entitled to have their knowledge claims about CCD recognized. So why is it that the beekeepers' knowledge is delegitimized as 'anecdotal', 'simply trial and error', 'ad hoc', and 'not data' by regulatory, academic, and agro-industry actors?[13] One explanation would be that agrochemical industry actors have the *direct* economic power to bankroll more toxicologists, lobbyists, and lawyers to advocate on their behest, and thus impose their views on regulatory and academic actors. Indeed, a wealth of literature provides evidence that big corporations use their financial resources to 'manufacture ignorance' as a strategy to combat knowledge about the negative effects of their products on aspects of public and/or environmental health (e.g. Oreskes and Conway, 2010; Proctor, 2008). Certainly the politics of bee expertise is intimately related to the ignorance about dying bees manufactured by the agrochemical industry (see Kleinman and

Suryanarayanan, 2012). While agrochemical companies undoubtedly shape the 'social production of ignorance' about CCD, the central dynamic at work in this case is *not* intentional or strategic efforts by them to ignore as a way to avoid responsibility. Equally, the perspective of beekeepers has not been dismissed simply because they argue for restricting systemic insecticides while engaging in various practices and using various chemicals that may make their bees more vulnerable.

Instead, we suggest that the CCD dispute over legitimate knowledge should draw our attention to *indirect* dimensions of epistemic dominance. The fact that toxicologists' knowledge is privileged over that of commercial beekeepers is not an inevitable outcome of science or money or political power but a matter of social history that needs unpacking. In the following section, we argue that the legitimacy of beekeepers' knowledge in the CCD controversy is undercut by a historically shaped confluence of the epistemological positions of academic bee toxicologists and regulatory officials, which agrochemical industry actors can draw on to their political and economic advantage.

Honey bees, agrochemicals, and disciplinary science

This section traces the historical development and rise to power of a particular form of entomological research related to agrochemicals and how this epistemic form has come to gain legitimacy and shape academic scientists' efforts to ascertain links between CCD and the newer systemic insecticides. Our narrative begins at the turn of the 20th century, when insect and honey bee scientists strove successfully to demonstrate that their varieties of scientific expertise were indispensable to solving *practical* problems in farming and beekeeping, respectively.

Entomology developed as a scientific discipline in the decentralized organizational environment of agricultural research in the United States, beginning in the late 19th century (Palladino, 1996; Sleigh, 2007). Through national policies, such as the Hatch Act of 1887, agricultural scientists had already paved the way for the primacy of their perspectives in agricultural affairs (Marcus, 1985), and these became institutionalized in the decentralized terrain of land-grant universities, state agricultural experimental stations, and the USDA. Here, entomologists sought to strengthen their tenuous professional positions by persuading farmers and others that prevailing agricultural problems were mainly due to pest insects and that they, the entomologists, were the best equipped to deliver the solutions (Palladino, 1996). Experimenting predominantly with assorted modes of chemical control, state entomologists demonstrated their success in relatively rapid, easily quantifiable, and striking fashion (e.g. Lowe and Parrott, 1902). From these practical roots, entomological studies on the life-histories, behavior, and biology of various insects came to be synonymous with the science of insecticide development (Palladino, 1996).

Meanwhile, honey bee science was unfolding as a branch of agricultural entomology.[14] As with agricultural research in general, bee scientists sought to exercise significant influence over beekeeping affairs. State and federal bee scientists conducted studies of aspects of honey bee management, such as increasing the production of honey, and the analysis and treatment of prevalent bee diseases (e.g. USDA, 1907). They also performed chemical analyses to test honey purity during a period in which adulteration had become a problem for beekeepers and their clients (Horn, 2005). In their roles as university professors, experimental station scientists and state apiary inspectors, bee scientists educated and regulated beekeepers as well as future cadres of scientific professionals (Horn, 2005: 145–198). Apart from technical reports in the state's agricultural research bulletins, they wrote in bee trade magazines and gave keynote speeches at state conventions where beekeepers gathered. Through these activities, bee scientists asserted that while beekeeping itself could be pursued by anyone as a hobby and a business, the 'technical problems' that increasingly confronted beekeepers were best left under the purview of scientifically trained specialists.[15] Beekeepers, in general, embraced this vision of the value and place of honey bee scientists to their business concerns (e.g. Horn, 2005). As we have described, by the time World War II arrived, commercially managed bees were coming increasingly in contact with (now more toxic) pesticides (Anderson and Atkins, 1958; Horn, 2005; VanEngelsdorp and Meixner, 2010), and these were developed with the help agricultural entomologists and the support of an expanding agrochemical industry (Palladino, 1996). In this context, beekeepers looked to the state's honey bee scientists for guidance.

Bee scientists at state agricultural stations were prototypical environmental toxicologists. They doused bees in laboratory and/or field-station settings with predetermined amounts of an insecticide, and then measured the number of bees that died in a particular time span, compared to nontreated 'control' bees (e.g. as reviewed in Anderson and Atkins, 1968; Jaycox, 1964; Weaver, 1951). Laboratory studies traced an insecticide's lethal effects through statistically expressed 'dosage-mortality curves', 'time-mortality curves', and 'time-concentration' curves, from which they calculated toxicological parameters such as the LD_{50} – the dose at which 50 percent of the exposed bees die 2 to 3 days after exposure[16] – and the range of times and doses in which they could detect lethal effects.[17] Bee scientists utilized these measures to rank different insecticidal chemicals as being more or less toxic to bees. They also manipulated environmental parameters, such as temperature, humidity, and light, to document the conditions under which properties of pesticide toxicity changed. In the field, researchers constrained miniaturized beehives to experimental plots using screened cages and subjected them to varying pesticide doses, timings, and modes of delivery. They documented poison-induced bee deaths, changes in hive brood number, and pollen and nectar storage (reviewed in Anderson and Atkins, 1968). Through studies published in state 'extension' periodicals, honey bee scientists sought to provide farmers and beekeepers with a practical know-how about ways to minimize pesticide-induced damage to honey bees (e.g. Anderson and Atkins, 1958). They also published technical reports in the *Journal of Economic Entomology*, the flagship journal for entomologists in the United States (e.g. Jaycox, 1964; Weaver, 1951).

In the period leading up to the 1960s, honey bee scientists' studies of the effects of insecticides on 'nontarget' bees embodied the epistemic forms – concepts, procedures, and measures – of agricultural entomology, which were *single-factor, causal* approaches sensitized to *rapid, lethal effects* on *individual target insect pests.* Significantly, in this context, toxicological measures, such as LD_{50} were originally devised to aid in the development of more effective chemical insect killers (e.g. Abbott, 1925). As a result, bee scientists ended up emphasizing the relatively rapid, lethal effects of individual insecticides on bees. Effects of low or 'sublethal' levels of insecticides, in plausible *interactions* with ambient factors, such as other pesticides and pathogens, which could lead to slow, progressive effects over multiple generations in a beehive's life cycle, were not a central concern for the researchers. Thus, bee scientists concluded that in general 'modern pesticides ... are less hazardous to honey bees' and

> although the newer pesticides are used in greater quantities over larger areas and over a greater variety of crops ... they can usually be used with safety if the ... facts [from studies] and precautions are taken into consideration. (Anderson and Atkins, 1968: 231)

Honey bee scientists' practices and utterances regarding insecticides highlight the professional tightrope on which they walked, seeking to balance the emerging norms and demands of the agricultural research institutions for which they worked, and where they sought peer recognition, and the needs of beekeepers for information to undergird policies that would protect their livelihoods. Ultimately, the ways in which honey bee scientists approached insecticide issues were influenced by the broader agricultural organizational and scientific communities within which they were situated, where the dominant agro-entomological knowledge framed insects as pests that they needed to be targeted through chemicals. This orientation often raised the professional status of these scientists but did not always help protect the livelihoods of beekeepers.

An emphasis on a single-factor, causal approach attentive to rapid, lethal effects on individual 'target' insect pests ultimately became the institutionalized epistemic norm among honey bee scientists.[18] Subsequently, this agro-entomological approach to honey bees and pesticides influenced the academic and regulatory forms of honey bee toxicology that became prevalent in the 1970s, when widespread social concerns about the contaminating effects of synthetic chemicals on public health and wildlife provoked the emergence of the interrelated academic disciplines of environmental toxicology, eco-toxicology, and genetic toxicology (e.g. Frickel, 2004; Newman and Unger, 2003; Wright and Welbourn, 2002).

Although the boundaries and branches of toxicology have historically been ill-defined in the United States (Brickman et al., 1985),[19] we focus on environmental toxicology since it is the most inclusive disciplinary formation in which both laboratory and field studies of agrochemicals and honey bees are carried out. Environmental toxicologists seek to understand and predict the potentially toxic, real-world effects of various chemicals on living organisms in their environments by studying pathways of chemical exposure, modes of toxic action, and toxins' interactions with the environment. Although interested in real-world effects, the methods used by environmental toxicologists to study honey bees largely mimicked those of their scientist predecessors. While understanding that the relationship between insecticides and honey bee health is a *practical problem* for beekeepers, for academic environmental toxicologists this relationship is first and foremost a *key research problem*, and their efforts to understand it are oriented toward professional peers, and thus toward publication in scholarly scientific journals such as *Environmental Toxicology and Chemistry* (e.g. Aliouane et al., 2009), fellow members of professional societies such as the Society of Environmental Toxicology and Chemistry, and tenure in university departments[20] in environmental toxicology, entomology, and ancillary fields.

In laboratory experiments, honey bee scientists (mostly from Europe) exposed individual honey bees to low levels of newer systemic insecticides (representative of those found in crop pollen and nectar) and documented 'sublethal' and 'chronic' effects on learning, behavior, and development (reviewed in Desneux et al., 2007). Their lab studies also suggest enhancement of the toxicity of these insecticides to honey bees by synergistic interactions with other synthetic toxins and pathogens (e.g. Alaux et al., 2009). These findings are consistent with those of the beekeepers we discussed in the previous section. However, because highly controlled laboratory experiments eschew a consideration of other environmental factors, such as the social organization of honey bees in whole hives, US academic scientists, regulatory officials, and agro-industry actors consider any connection to CCD at best to be *suggestive* (Bayer, 2010; EPA, 2008; Johnson et al., 2010). Suggestive evidence is not sufficient to reorient understanding or prompt reconsideration of established regulations.

Academic toxicologists in the United States have looked to field experiments for *definitive* causal evidence of the role of the newer systemic insecticides in CCD (e.g. Johnson et al., 2010). Field studies of hives chronically exposed to low levels of neonicotinoids have found little measurable evidence of harm, let alone any clear and direct link to CCD (e.g. Cutler and Scott-Dupree, 2007; Dively et al., 2010[21]). Such field studies typically involve statistically based comparisons between a set of 'treated' hives that are experimentally exposed to a range of doses of the individual chemical, and a set of 'untreated' or control hives, while other (ambient) factors, such as nutritional intake, temperature, and location are either kept equivalent or monitored to the extent feasible. The underlying assumption in these field experiments is that the tested chemical is the only one that an adult honey bee encounters in its environment. But this is an implausible assumption. Honey bees can forage over a distance of 3 miles (Spivak, 2010), and this means that beehives are continuously exposed to multiple toxins and other factors. Thus, even though academic honey bee scientists conceptualize CCD as a complex, *multifactorial* phenomenon of *whole hives*, their experimental research is animated by historically institutionalized agro-entomological forms of expertise that are wont to isolate *individual factors* and their *direct, causal* roles, and preclude a serious consideration of the environmental complexity impinging upon beehives.

A recent survey of North American commercial beekeeping operations found the hives on average to be awash in over 100 different pesticides, which could affect bees in complex and interacting ways across their life cycle (Mullin et al., 2010). This survey found relatively few instances of hives or bees containing abnormally high or even detectable levels of the newer systemic insecticides, compared to other 'traditional' pesticides and beekeeper-applied miticides, which to several scientists constitutes further evidence that the systemic chemicals have little to do with the honey bee die-offs (e.g. Blacquière et al., 2012; Ratnieks and Carreck, 2010). But this could plausibly be a problem of measurement, pointing again to the limitations of the standard research methods deployed by honey bee scientists. In this context, according to James Frazier, a honey bee toxicologist and a coauthor of the published survey (Frazier et al., 2008), such survey results by no means provide conclusive evidence that the systemic chemicals and their toxic breakdown products do not exist in hives at levels below instrument detection limits, levels where they still have effects on developing honey bees through interactions with other prevalent pesticides and pathogens (e.g. Pettis et al., 2012).[22]

Furthermore, the statistical practice of basing 'conclusive evidence' on 95 percent certainty levels means that experimental field studies will tend to conclude that there are 'no differences' between treated and untreated beehives, when, in fact, there might be. This preference for erring toward false-negative conclusions, where a substance that is harmful is incorrectly concluded to be safe, is not a transparently appropriate means for measuring the effects of honey bee exposure to pesticides; it is a professional academic norm that is compatible with the career stakes of academic toxicologists (Kleinman, 2005; Mulkay, 1976). A false-positive might be professionally damaging when it is revealed to be incorrect and causes a researcher to retract published research results. By contrast, a false-negative would lead a researcher to miss a discovery but not damage his or her reputation.

Many have pointed to the ways in which the intimate relations between academic science, agrochemical companies, and regulatory agencies have led to specific pro-pesticide policies and supporting research (e.g. Busch and Lacy, 1983; cf. Henke, 2000). Scholars have also documented how the land-grant university system fuels a climate of coercion of and hostility toward scientists who are critical of the pro-pesticide approaches taken by their academic colleagues (e.g. Hadwiger, 1975; Van Den Bosch, 1989). While these factors may have affected legitimate knowledge and policy about the role of agrochemicals in CCD, our focus here has been on the ways in which less direct, less explicit, and less strategic actions across a substantial historical expanse have shaped the institutionalization of a set of research norms and practices, and have thus affected accepted knowledge about CCD and about who possesses the valid expertise to contribute to this knowledge.

Pesticide regulation

In the aftermath of well-publicized chemical disasters, such as the infamous case of insecticide-induced pollution of river waters in Hopewell, Virginia (Brickman et al., 1985), and their threats to public health and the environment in the 1970s, a new generation of regulation schemes shaped the context in which environmental toxicology research on honey bees developed. Up until then, the regulation of pesticides had been under the purview of the USDA, which advocated for growers and is thought to have been co-opted by the very interests that it was supposed to regulate (Brickman et al., 1985). The Nixon administration weakened the USDA's regulatory role by entrusting the responsibility for creating and enforcing the pesticide regulations to the newly formed EPA, which environmentalists hoped would avoid capture by chemical industry interests (Brickman et al., 1985).[23] Significantly, the new regulations created far-reaching obligations for the chemical industry to test products before their commercialization in order to show that they were environmentally safe. This led chemical companies and the EPA to invest heavily in the expertise of academically trained environmental toxicologists, and led to an enormous increase in private contract laboratories that performed requisite studies for pesticide registration (Brickman et al., 1985).

Environmental toxicologists working in federal, academic, and corporate research facilities studied the 'fate' and 'safe concentrations' of single 'active ingredients' (considered the main killing chemicals in the mixture that a pesticide product is composed of) in parts of the environment, and their toxicity to select animal species in laboratory and field settings (EPA, 1998). Rodents in laboratories were used by toxicologists to model carcinogenic effects on humans, whereas the honey bee came to be a key 'bioindicator' of terrestrial environmental contamination (e.g. EPA, 1982, 1996). The EPA's environmental toxicologists and administrators assessed the safety information provided by chemical companies and determined whether the chemical(s) in question posed an 'unreasonable risk' to human and environmental health.

The early years of pesticide regulation at the EPA were marked by a predominantly *precautionary* approach, a false-positive orientation where regulators prohibited the commercialization of pesticides in the face of suggestive evidence of prospective harm (Brickman et al., 1985; Jasanoff, 1990). Their precautionary approach was nevertheless based on formal, quantitative assessments, so even this orientation may not have allowed space for the kinds of evidence beekeepers have highlighted in the CCD controversy. At the EPA, this formal, quantitative orientation lent regulatory decisions a veneer of scientific credibility in a fragmented and highly adversarial political context of chemical policymaking, where key battles between deregulating industry interests and proregulatory labor leaders and environmentalists were played out in congressional hearings and court cases (Brickman et al., 1985; Jasanoff, 1990). Importantly, courts tended to defer to the EPA whenever its decisions plausibly amounted to overregulation of chemicals, and conversely, treated skeptically not-to-regulate agency decisions. Perceiving a 'tendency toward overzealous regulation', members of Congress pushed back (Brickman et al., 1985: 79).

Broadly speaking, since the mid-1980s, the EPA has moved to a nonprecautionary 'sound science' approach toward pesticide regulation (Brickman et al., 1985; Jasanoff, 1990). This is a false-negative orientation, where the EPA permits the use and commercialization of chemicals and biological materials in the absence of definitive evidence of prospective harm to human health or the environment. Congressional hearings and initiatives by chemical industry interests led to the enactment of amendments that weakened agency officials' discretionary powers, required the EPA to consult with the USDA before suspending any pesticide, pushed the EPA to incorporate economic impacts of pesticide usage in its assessments of environmental safety, and began to require outside-agency review by panels comprising university and industry scientists (Jasanoff, 1990). The EPA also instituted a so-called good laboratory practices (GLPs) approach, establishing traditional scientific standards for how experiments used for regulatory purposes are conceptualized, performed, recorded, and interpreted in environmental safety assessments (40 C.F.R. 160, 2002; Brickman et al., 1985; EPA, 1996). These changes in the EPA's regulatory culture prompted a wholesale internalization of the evidentiary norms and related practices that are prevalent in academic fields. Indeed, the standards set by GLP are consistent with the epistemic form that ultimately emerged among university-based honey bee toxicologists and provided a basis for excluding the kinds of informal, *in situ* evidence commercial beekeepers have highlighted to justify their precautionary approach to the regulation of the newer systemic insecticides.

A raft of laboratory toxicity studies, which were based on the false-negative standards of 95 percent certainty, accepted, in principle, by scientists and regulators, *suggests* that the low levels of the newer systemic insecticides have multiple cumulative, sublethal, and developmental effects on honey bees that *could* lead to CCD in real-world settings (Alaux et al., 2009; reviewed in Desneux et al., 2007; Pettis et al., 2012). Although these findings corroborate the conclusions of beekeepers, EPA officials note that these laboratory studies are inconsistent and are not necessarily relevant to 'to bee colonies under *natural* conditions' (our emphasis).[24] Mirroring dominant academic perspectives, EPA scientists demand more *definitive causal evidence* from field experiments on beehives that are exposed chronically to the systemic insecticides before considering any limitations on the usage of these chemicals (e.g. EPA, 2008; Suryanarayanan and Kleinman, 2011).[25] Thus, with the EPA's concurrence, the epistemic dominance of experimental forms that have come to be accepted among academic toxicologists is reinforced, and beekeeper data are dismissed.

This historically shaped convergence in the epistemic orientations of academic toxicologists and the EPA has served the companies that produce the newer systemic insecticides, such as Bayer CropScience, well. They have every reason to support these approaches. Bayer CropScience's imidacloprid (Confidor®/Gaucho®/Admire®/Merit®) and clothianidin (Poncho®) are among its top 10 products, grossing roughly US$824 million and US$265 million, respectively, in 2010 worldwide (Bayer, 2010: 66). While neither Bayer nor the EPA deny the possibility of complex interactions involving the newer systemic insecticides, the epistemic forms that they draw upon make it extremely challenging to find acceptable evidence of complex causal relations and sublethal effects. Bayer scientists draw on the dominant agro-entomological epistemic form in arguing that they have found 'no adverse effects [of newer systemic insecticides on honey bees] ... under natural conditions' (Maus et al., 2003: 54). Crucially, the epistemologically dominant approach advocated by academic toxicologists, the EPA, and agrochemical manufacturers justifies the dismissal of the evidence provided by commercial beekeepers, and indeed, even their expertise.

Conclusion

We began with the observation that commercial beekeepers' knowledge claims are subordinated to those of academic and agro-industry toxicologists in the CCD controversy. Collins and Evans' (2002, 2007) framing of the problem of expertise does not help us explain how and why commercial beekeepers' variety of expertise becomes delegitimized in the CCD dispute. In order to understand this, we traced the historical development of the *epistemic forms* that have become dominant in understanding links between pesticides and honey bee health, and in developing regulations relevant to these connections.

In the CCD controversy, commercial beekeepers' practices are constituted by an informal, on-the-ground epistemic form that incorporates multidimensional aspects of the hive and errs on the side of false-positive conclusions. Their knowledge leads them to a precautionary approach to the use of the newer systemic insecticides, an approach that calls for either suspending or limiting the use of these insecticides. This form and the epistemic position that it engenders reflects beekeepers' practical experiences, commercial interests, livelihood-stakes, and historical tensions with farmers as shaped by the political economy of US agriculture and the crop pollination market.

Honey bee scientists' practices, however, 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. We traced the prevalence of this approach to the primacy of the agricultural research organizations such as the USDA and agroeconomic contexts within which early state entomologists and honey bee scientists practiced. Academic toxicologists' preference for this agro-entomological approach reflects their career stakes and interests in enhancing their cultural capital and achieving intellectual distinction.

The EPA's regulators have come to adopt dominant academic forms, perspectives, and norms, such as false-negative standards, in judging whether a pesticide poses environmental harm to honey bees. This reflects a historical shift in regulatory assessments of prospective harm from being broadly precautionary to nonprecautionary, which was precipitated by a highly fragmented and adversarial political context where chemical policymaking became a key ground for battles between pro-regulatory and deregulatory forces.

In sum, the primacy of toxicologists' knowledge in the CCD controversy is not evidence of its inherent superiority. Rather, the dominance of toxicologists' epistemic form reflects a particular history. In turn, the agrochemical industry has been able to draw on the epistemic form now institutionalized in regulatory policy and largely taken for granted in order to advance their interests and perspectives over and above those of commercial beekeepers in the CCD controversy. In this context, commercial beekeepers' variety of expertise is characterized as merely 'anecdotal'. The EPA, Bayer, and many academic scientists make it clear that beekeepers cannot make credible knowledge on their own and thus need to work with certified institutional environmental toxicologists and honey bee researchers, who are *the* experts. Doing so, however, means that the knowledge gets constructed in terms of the established agro-entomological form of expertise, and beekeepers' influence is limited. At the same time, at a practical level, the governing standards and high expenditure required to comply with the EPA's GLP means that investigations undertaken by beekeepers will tend to fail to meet those standards (Suryanarayanan and Kleinman, 2011).

Collins and Evans (2002, 2007) would presumably argue, by analogy with their stance on the sheep-farmers of Wynne's (1992) study, that the beekeepers' expertise entitles them to a voice in the debate over CCD. However, beekeepers' grounded insight notwithstanding, their knowledge is not taken seriously by the EPA, Bayer, or many academic scientists. *Entitlement* does not guarantee *influence*. Understanding why certain actors should be granted a voice and others should not, as Collins and Evans' work does, is a useful starting point for research on expertise, but their taxonomic work cannot help us explain *why* certain actors' knowledge has legitimacy and influence and other actors' does not – indeed, why some actors are seen as having expertise and others not. Understanding why certain knowledge claims are recognized and others are not demands an analysis that takes seriously the historical and structural bases for the influence of different actors' claims in technoscientific controversies. Comprehending context and history is crucial to explaining epistemological dominance.

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Notes

1. Commercial beekeepers rely predominantly on their beekeeping operation in order to make a living. Sideliners make some earnings from keeping hives but rely on other sources of income. Hobby beekeepers typically do not depend on their beekeeping to manage their livelihood and tend to keep fewer hives.
2. In our case study, we consider regulatory agencies and agrochemical manufacturers to be scientific stakeholders because they depend either solely or primarily upon certified scientists in order to support their claims.
3. Interview, David Hackenberg (14 January 2010).
4. See, for example, the National Honey Bee Advisory Board's letter to the Office of Pesticide Programs, US Environmental Protection Agency (17 March 2009; Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0844-0102).
5. Also, see the letter from David L. Fischer (Director, Ecotoxicology, Bayer CropScience) in response to the National Honey Bee Advisory Board's 17 March 2009 letter (5 June 2009; Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0844-0115). For academic perspectives, see Blacquière et al. (2012) and Ratnieks and Carreck (2010).
6. For a representative example see 'EPA Response to Sierra Club's Request to Suspend Nicotinyl Insecticides' (10 October 2008; Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0844-0120).
7. Interview, Ken Warchol, Apiary Inspector of Worcester County (Massachusetts) and beekeeper, 19 October 2009.
8. See the letter by commercial beekeepers belonging to the National Honey Bee Advisory Board to the EPA (17 March 2009; Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0844-0102).
9. As suggested by the queen's pattern of egg laying (Jeff Anderson, Commercial beekeeper, August 2010).
10. See for example, 'French Beekeepers Demonstrate' under 'News Notes' (p. 85) in the February 2001 issue of *American Bee Journal*.
11. For example, *Pollinators and Pesticides 2011: Fundamental Flaws of Pesticide Policy in the United States*, an 'opinion paper of the National Honey Bee Advisory Board' distributed at the 2011 North American Beekeeping Conference in Galveston, Texas.
12. 'EPA Response to Sierra Club's Request to Suspend Nicotinyl Insecticides' (10 October 2008; p. 3; Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0844-0120).
13. Based on ethnographic field notes of conversations with academic and industry environmental toxicologists.
14. For instance, the US Department of Agriculture (USDA)'s Bee Culture was part of its Bureau of Entomology (Henneberry, 2008).

15. The writings and utterances of E.F. Phillips, a prominent figure in the pre–World War II field of US honey bee science, highlight the sorts of boundary work that early bee scientists performed toward establishing their indispensability to beekeeping affairs (e.g. Phillips, 1923, 1951).
16. Lower levels of LD_{50} indicate a higher degree of toxicity.
17. This is used to set thresholds such as 'No Observed Effects Level' (NOEL) below which no adverse effects are thought to occur (Hodgson, 2010).
18. US beekeepers' critique of the single-factor, causal approach echoes critiques made by environmental justice and advocacy groups, who have long criticized conventional quantitative risk assessments, which tend to overlook the multiple hazards that are borne disproportionately by low-income neighborhoods and communities of color (Corburn, 2002).
19. Researchers constantly construct, blur, and negotiate the disciplinary boundaries of these non-exclusive academic fields-in-formation. For example, Kareiva et al. (1996) argue for ecotoxicology to be more than 'largely toxicology with ecology added as a "seasoning" as opposed to a "main ingredient"' (p. 13). Others (e.g. Wright and Welbourn, 2002) have sought to blur the divides in stating 'it is fair to say that the modern science of environmental toxicology embraces the disciplines of classical toxicology and ecotoxicology' (p. 4).
20. For example, The University of California-Davis.
21. A non-peer-reviewed research report.
22. James Frazier, Interview, 11 November 2009.
23. Palladino (1996) argues that the Nixon administration's creation of the EPA was a public relations bid to mobilize electoral support through an environmentally friendly action that nevertheless largely left the agrochemical industry's feathers unruffled.
24. See EPA's 'Technical support document for the response to the emergency citizen petition' seeking suspension of registration for clothianidin based on claims of imminent hazard to the environment' (17 July 2012; Docket # EPA-HQ-OPP-2012-0334), pages 12, 13.
25. See also 'EPA Response to Sierra Club's Request to Suspend Nicotinyl Insecticides' (10 October 2008; Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPP-2008-0844-0120)

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