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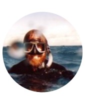

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Honey Bees and Colony Collapse Disorder: A Pluralistic Reframing

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Abstract

Scientific narratives surrounding colony collapse disorder (CCD) are often played against one another. However, oppositional knowledge politics do not neatly segregate the materiality and causal properties of the ecological phenomena they represent. Thus the challenge with CCD is not just to describe the partisan character of how knowledge about it is socially produced. It is also about how to integrate these politics through their less antagonistic material ecologies. We review three dominant discourses underlying CCD and honey bee decline and present a synthesis that conveys how their socially embedded perceptions about ecological causality are more compatible. We invoke a theoretical framework from complexity theory to demonstrate how multiple kinds of ecological causality, from the identifiable and addressable to the more emergent and unpredictable, can align under conflicting policy positions. We argue that this continuum of ecological explanations is a more conciliatory framework for responding to CCD. It provides an alternative to the antagonistic politics that tend to reify and defend either a restrictive search for a singular cause, a paralyzing documentation of all possible permutations of CCD, or a return to a utopian agrarian past. Relating how ecological knowledge is socially produced can illuminate stakeholder positions and strategies. But it is also constructive to map out how the ecological suppositions underlying them relate and inform one under.

Introduction

Human-insect and human-plant connections garner relatively little attention in political ecology and animal geography (Ginn 2014; Head and Atchison 2009). Yet, these relations can inform how public commons and private spaces are designed and managed (Beisel et al. 2013; Shaw et al. 2010; Whatmore 2006). Insects and their functional roles in the biosphere are woven into critical debates about food production, agricultural security, and human health. There is often a dissonance in these and other human-environmental issues between the recognition of their dynamic complexity and the need to articulate immediate solutions (Coimbra 2014; Madsen 2015). In this paper, we review the fractious knowledge claims surrounding honey bees and colony collapse disorder (CCD). Through the scientific literature on bee decline spanning the last decade, we communicate some of the limitations of opposition-focused social conceptualizations of honey bee decline. We show how the complex as well as the reductive inform and indeed require each other to address the causality that constitutes the current state of the relationship between humans and the semi-domesticated western European honey bee, *Apis mellifera*.

The place of apiculture in the geographical literature was historically limited to beekeeping as bucolic service to humans (Zierer 1932). Bees were portrayed as laboring animals, working in the service of the farmer with little concern beyond the immediate economic and material well-being of the farm. More recently, bees became the subject of scholarly case studies about how beekeeper livelihoods in developing countries can be part of a resistance to and independence from neoliberalist agendas (Brown 2001, 2006; Illgner et al. 1998). In the last decade, the bee has been embraced by critical geographers in their exploration of affect, ethnography, and the ongoing capitalist production of nature (Kosek 2010; Moore and Kosut 2013; Phillips 2014).

An underlying motivation for the renewed interest in honey bees is likely to be colony collapse disorder (CCD). CCD raised significant alarm within the scientific community, the media, and the general public because of the abruptness and magnitude of honey bee losses (vanEngelsdorp et al. 2010). The media as well as researchers have conjured up seemingly limitless explanations for CCD, even the erroneous theory that cell phone towers were to blame. The high rate of bee mortality has undoubtedly contributed to the attention surrounding CCD, which has been cast variously as an environmental crisis, the beepocalypse, and a planetary ethical catastrophe. Consequently, public outreach campaigns have been launched by corporations from Burt's Bees to Haagen-Dazs. Their efforts to help the honey bees have included fundraising programs, donations to research, and efforts to educate the public on the threat of honey bee loss. A similar mobilization of resources occurred in the research and development spheres of academia and industry. Honey bee research was never a high priority in agriculture, but with the emergence of CCD, many research labs and funding agencies began to expand in that direction. Along with creating a Pollinator Task Force, President Obama recently called for major funding in pollinator research in the 2015 report *National Strategy to Promote the Health of Honey Bees and Other Pollinators*. The report outlines a goal to reduce honey bee colony losses to sustainable levels and calls for more than $82 million in federal funding to address pollinator health (White House 2015). Addressing CCD and honey bee decline has become the goal of a large number of individuals and organizations with very diverse social, political, and economic perspectives and policy agendas.

In this article, we review for geographers how this public and scientific attention has solidified into three narratives comprising knowledge claims about the causes and consequences of CCD. Agricultural entomologists, often housed at large research institutions and funded by agribusiness, have focused largely on finding a single causal factor for CCD. They seek a solution to promptly alleviate pollinator shortages for the agricultural industry. However, some researchers have also realized that CCD is a more intractable, complex problem involving multiple agents and contexts rather than a reductive causality associated with a single initiating factor. In this narrative, there is no single definitive colony collapse disorder. Finding a sole cause is downweighted over documenting the permutations of CCD, its historical context, and potential feedbacks. Although their goal is to remedy honey bee losses, pollination ecologists take a third and temporally deeper view, one that has a singular causality but replaces the search for the complex etiology of CCD with a no less challenging task. In this narrative, the services of wild pollinators are given greatest attention, and the cause of their threatened abundance is industrial agriculture. From this perspective, the debates over honey bee decline distract from the larger issue of global declines in many types of pollinating animals. CCD blurs the very issue of why bees are needed in such large numbers in the first place—to support landscapes dominated by monocultures and lacking native pollinators. This narrative advocates for a restructuring of how crops and food are produced.

Each of these narratives conveys how the responses to CCD reflect the epistemic cultures of honey bee knowledge production (Suryanarayanan and Kleinman 2013). However, identifying and describing these epistemic cultures should not replace a detailed understanding of their individual suppositions about ecological causality and how they may relate to one another. In other words, the issue over CCD is not only that there are multiple competing epistemic forms, but that conflicting knowledge claims and policy recommendations also arise from particular social, political, and economic circumstances. The issue is how to work with and interlace the material ecologies embedded in these socially produced epistemic forms to move in the direction of solutions. Materiality does not become antagonistic in the same way social agents can become reified as oppositional through the production of knowledge (de Vries and Rosenow 2015). Epistemes may tend to organize into oppositional cultures, parties that advocate this or another position along academic or occupational lines. However, the honey bee knowledge they produce and promote arises from biological and ecological causal phenomena that are linked across scalar extents and resolutions. The phenomena of ecology do not parse themselves out neatly according to human agents and the modes of knowledge production that provide paychecks and construct careers. In her 2009 book *Unsimple Truths*, Sandra Mitchell relates how the causal properties of complex ecological phenomena exist along a continuum, ranging from where causation is stable and predictable to where it is more ephemeral and contingent, or unstable. In her integrative view, policy setting must be flexible enough to recognize that there will be some systems that yield to reductionist methodologies and explanations, and others that will not. Causes may also be processual, emergent, with different (and evolving) contributing factors. This pluralism about causality provides a more pragmatic and less oppositional framework for aligning policy recommendations produced in different social contexts.

To give more form to these ideas, we begin with a brief history of CCD and review its potential causes. We then detail the three major narratives on CCD and honey bee decline. By illuminating the constructive pluralism of the material ecologies within these three sometimes oppositional narratives, we sketch out how to steer away from the 'agony of advocacy' that paralyzes environmental problem solving. This trepidation arises today because radically new natures contrast sharply with the knowledge of the baselines that predate our current ecological era (Robbins and Moore 2013). To hold both the old and the new as relevant to environmental problem solving asks us to uncomfortably do many things at once. As we argue, solutions to CCD should involve accommodating novel, unexpected futures. They should also accommodate an appreciation of the present as well as the past in order to identify which stable causal relationships can guide any immediate, essential problem solving and to establish preconditions for when bee decline was not an issue. As Nordhaus and Shellenberger (2007) have posited, forms of environmental problem solving like conservation and regulation depend upon an environmental past in order to give material form to organisms and habitats that require tangible conservation. Yet at the same time, these protectionist approaches rooted in the past must coexist with more contextual social and economic approaches that anticipate the present and a malleable future.

HONEY BEES AND THE POTENTIAL CAUSES OF COLONY COLLAPSE DISORDER

Recognized for their abilities as efficient pollinators, the western European honey bee pollinates more than one-third of global produce (Spivak et al. 2011). The majority of the world's major grains, including wheat, rice, and corn, do not rely on insect pollination. However, many fruits, nuts, spices, and vegetables must be cross-pollinated to set fruit—including almonds, squash, melons, blueberries, apples, pears, cherries, and plums. Alfalfa, which is an important source of livestock forage, is also pollinator-dependent. As a result, honey bee pollination is an essential ecosystem and agricultural service. The attributed value of crops in the USA that are directly dependent on insect pollination was estimated at $15 billion in 2009, including an estimated $12 billion of crop value directly attributable to honey bees (Calderone 2012). Globally, insect pollinators generate $168 billion for services they provide for 100 of the major food crops humans depend upon (Gallai et al. 2009).

Since 2006, CCD has left beekeepers in the USA facing annual honey bee mortality rates averaging 30 percent with some individual beekeepers reporting higher losses (Ellis et al. 2010; Lee et al. 2015). Other countries in Europe and in Canada have reported similar declines (Neumann and Carreck 2010; vanEngelsdorp and Meixner 2010). Honey bee researchers have established a set of symptoms distinguishing CCD from other conditions that cause a loss in honey bee populations (vanEngelsdorp et al. 2009). The most tell-tale symptom is the sudden absence of worker bees. Bees from a seemingly healthy hive leave to forage and never return.

In the last decade, the causes of CCD have clustered around two agents. Neonicotinoids have been shown to have unanticipated negative impacts on honey bees (Henry et al. 2012; Kessler et al. 2015). They are also the largest group of pesticides currently used in agriculture, supporting a multi-billion dollar industry in both the USA and Europe. Applied directly to agricultural crops and used as seed treatments, these neurotoxic chemicals are water soluble and systemic, meaning that their exposure to insects can occur in all parts of the plant, including pollen. On par with neonicotinoids as a driver of CCD are pests and pathogens, most notably the arrival of the parasitic varroa mite (*Varroa destructor*) from Asia in the 1980s, which marked a turning point for beekeeping in North America and Europe as colonies were greatly weakened. A suite of viruses and the fungal parasite *Nosema ceranae* have also been linked to CCD (Evans and Schwarz 2011; Higes et al. 2008; McMenamin and Genersch 2015).

Another driving cause of CCD has been the eutrophication of floral resources associated with anthropogenic land cover (Naug 2009). Floral diversity is required to ensure the supply of nectar and pollen paramount for colony health (Scofield and Mattila 2015). Monocultures do not necessarily provide pollinators with a steady year-round supply. Yet, even when pollen and nectar are abundant, they may be inadequate in nutritional value for the proper development of a colony (Axel et al. 2011; Huang 2012). However, natural land covers may not necessarily be more beneficial for honey bees. Urban and suburban landscapes, for example, may be more productive due to greater year-round availability of forage from horticultural plantings (Lecocq et al. 2015). When lacking forage or to stimulate the growth and reproduction of the hive, beekeepers supplement their colonies' nutritional needs with an artificial diet of high-fructose corn syrup and pollen patties.

Industrial-scale migratory beekeeping may also be a driver of CCD. Long-distance transport exposes bees to dramatic temperature fluctuations, and diminished natural foraging opportunities can stress colonies. Upon exposure to high temperatures, the high-fructose corn syrup that supplements the diet of these highly mobile bee populations can produce a contaminant shown to be harmful (LeBlanc et al. 2009; Zirbes et al. 2013). Additionally, the massive influx of honey bees to pollinator-dependent monocultures each season introduces bees to the diseases and pests from thousands of other hives arriving from all corners of the country.

A range of other factors have also been suggested to contribute to CCD, including, as only a partial list, climate change (Le Conte and Navajas 2008), air pollution (Girling et al. 2013; McFrederick et al. 2008), the alteration of the bee microbiome (Cox-Foster et al. 2007; Mattila et al. 2012), predation by other insects (Core et al. 2012), electromagnetic radiation from the sun (Ferrari 2014), the total chemical environment of honey bees (Mullin et al. 2015), bee colony personality and exposure to early life stress (Rittschof et al. 2015; Wray et al. 2011), ecosemiotic collapse (Harries-Jones 2009), and nanomaterials (Milivojevic et al. 2015). The question among some researchers then, as these explanations convey, is not what causes CCD but what may have not yet been discovered.

THE THREE NARRATIVES OF BEE DECLINE

These causal factors have coalesced around three explanatory narratives about honey bee decline and how to address it. They were distilled from scientific journals and the frequent expert opinions offered as to what causes CCD and what policies should be enacted (Paxton 2015). These narratives encapsulate epistemic forms, the collection of concepts, methods, measures, and interpretations that shape the ways in which actors produce knowledge and where we draw its limits (Kleinman and Suryanarayanan 2013).

The Ecological Conservation Narrative

In this narrative, the causal primacy of industrial agriculture as an influence on the ecology of all kinds of pollinators is paramount. Honey bee decline is part of an overall loss of pollination services provided not only by insects but also by other invertebrate and vertebrate species. In the past, native insect pollinators, including solitary bees, bumble bees, and flies, played a key role in pollination services. However, with the continued expansion of agricultural monocultures and the resultant disappearance of natural and semi-natural vegetation, these wild pollinators have declined (Klein et al. 2007; Koh et al. 2016; Kremen and Ricketts 2000). The conservation literature has recognized the threats of industrial-scale agriculture on insect pollinators for several decades (De la Rúa et al. 2009; González-Varo et al. 2013; Vanbergen et al. 2013). These studies acknowledge that agriculture contributes to a pollinator crisis whether discussing the loss of honey bees or the decline of other pollinators (Bretagnolle and Gaba 2015; Brown and Paxton 2009; Potts et al. 2010). Still, anthropogenic influences may have a much more complex influence on pollinator abundances and plant productivity (Bretagnolle and Gaba 2015; Ghazoul 2005; Winfree et al. 2009). But more important, this narrative takes the position that attention to CCD detracts from efforts to understand and value the complex and dynamic relationships among humans, domesticated honey bees, other animal pollinators, and wild and domesticated plants (Ollerton et al. 2012).

The Reductionist Regulatory Narrative

Isolating and responding to the most proximate causal agent is prioritized over any larger historical analysis in this narrative. It seeks to establish the primacy of a single causal factor. Neonicotinoids were very early on suspected of having an undesired effect on honey bees. Following negative impacts on honey bees in the 1990s, the French government began to tightly control and limit the use of neonicotinoids. Germany banned the use of certain neonicotinoids in 2008 due to honey bee losses (De la Rúa et al. 2009). In 2013, nearly three million Europeans signed a petition against the continued use of neonicotinoids, which ultimately led the European Food Safety Authority to impose a 2-year moratorium on the use of these chemicals until additional research is carried out to assess their environmental impacts. However, the Environmental Protection Agency in the USA continues to allow the widespread use of neonicotinoids pending completion of toxicological assessments presently underway. A growing body of evidence suggests neonicotinoids may have cascading impacts on vertebrates given these water soluble compounds may remain in soils and water after application (Goulson 2013; Hallmann et al. 2014; Mason et al. 2013). The negative biotic interactions between honey bees and hive pests are the other reductionist causal factor, most notably the varroa mite, but also fungal organisms and viral pathogens (Bromenshenk et al. 2010; Evans and Schwarz 2011). Although a web of organisms may be involved in this pest scenario (Cornman et al. 2012), it reflects the isolation of causal power in non-human organisms rather than in agricultural chemicals.

As with any good mystery story, the reductionist narrative desires to isolate and restrict a perpetrator unambiguously. On the one hand, there are the biological causes, whereby blame can be placed on pests and pathogens for CCD. On the other hand, the attribution of blame can be placed on neonicotinoids. A very public, sometimes acrimonious debate has arisen between those who hold neonicotinoids accountable and those that view pests as the major cause of decline (Cressey 2015; Eisenstein 2015). The latter group was accused of a research conflict of interest when it was uncovered their research was funded by corporate entities affiliated with the manufacture of neonicotinoids. A growing body of evidence suggests neonicotinoids cannot explain all cases of colony collapse (Lundin et al. 2015).

The Socioecological Complexity Narrative

In this narrative, researchers take the position that there is unlikely to be a single universal causal agent behind CCD (vanEngelsdorp and Meixner 2010; vanEngelsdorp et al. 2009). The contingent and unstable social and ecological causality of CCD and bee decline is emphasized. The limits to what might define useful knowledge for addressing bee decline are far from finite and not readily delineable. CCD occurs due to a combination of factors acting together to weaken honey bees and leave them vulnerable to disease (Goulson et al. 2015; Oldroyd 2007). Many of the single causal factors have been shown to be dependent upon predisposing conditions and contingencies of place. For example, with neonicotinoid exposures, it is their concentration, routes of delivery and uptake, the presence of other chemicals and plants, crop type, beekeeper practices, bee subspecies, and colony mechanisms of immunity that interact to shape how they impact honey bees (Henry et al. 2015; Nazzi and Pennacchio 2014; Rinkevich et al. 2015; Rittschof et al. 2015). The debate for neonicotinoids under this narrative is less a binary question as to whether neonicotinoids are toxic or not. Instead, it is when and where and at what quantifiable levels can neonicotinoid exposures lead to mortality and actionable measures to establish guidelines for use (Suryanarayanan 2013).

Similarly, the role of parasites and pathogens is more complex and uncertain as new indirect biotic interactions are discovered. Viral loads can be influenced by the abundances of hive pests, like *Varroa* and *Nosema*. Exposure to neonicotinoids can impact bee immune system health and increase susceptibility to diseases transmitted by pests and pathogens (Doublet et al. 2015; Pettis et al. 2013). Increasingly, discussions about causality reference land cover as a proxy for this large suite of predisposing factors and conditions (Clermont et al. 2015; Donkersley et al. 2014). Floral diversity, pollen quality, plant phenology, climate change, chemical exposures, pests, and pathogens play a role in explaining the decline in honey bee populations (Alaux et al. 2011; Goulson et al. 2015; van der Zee et al. 2015).

The causes of CCD in this narrative have also become more historical, socioeconomic, and dependent upon spatial and temporal scalar extents (Moritz and Erler 2016; Smith et al. 2013). As a primary example, the number of managed honey bee colonies in the USA can be seen as part of a long-term decline that began after World War II (vanEngelsdorp and Meixner 2010). Beekeeping was encouraged during wartime in the USA as a way to offset sugar sent overseas to troops and to provide wax for lubricating machinery. After the war, the returns on beekeeping and the total number of colonies began to fall in the USA because of globalization and international competition from beekeeping operations in China and Argentina that led to a rise in bee numbers overseas and falling domestic honey prices (Aizen and Harder 2009a; Daberkow et al. 2009). Bee decline has also been exacerbated by changes in affluence and diet. Since the 1960s, the planting of pollinator-dependent, high-value fruits and vegetable crops has tripled in response to rising global demand (Aizen and Harder 2009b; Aizen et al. 2008; Hayes 2010). These luxury crops include fruits and nuts like raspberries, cherries, mangoes, cashews, and almonds. These foods have been introduced and promoted in newly ascendant middle class economies and are sought out by the health conscientious. Currently, the demand for these crops is outpacing the availability of bee colonies to pollinate them (Aizen and Harder 2009b). While the total number of honey bees worldwide may actually be increasing (Xu et al. 2015) in countries like China, Argentina, and Turkey, the demand for honey bees is far greater than the supply in the USA and Europe (Breeze et al. 2014). Thus the history and economics embedded in the globalization of agriculture and labor are as important an influence on the demographics of domesticated bees as biological factors.

The socioecological narrative acknowledges how observations of similar die-offs going back a century and half in Europe, the UK, and the USA (Underwood and vanEngelsdorp 2007) are relevant to understanding recent collapses. Given that the scale and circumstances would have been different, these prior sudden declines in honey bees suggest that CCD is not a consistent, recurring phenomena. There is not just one CCD, but many, in the past and today and in different circumstances. Consequently, despite the popularity of the term, researchers, beekeepers, and agriculturalists subscribing to this narrative are distancing themselves from the label CCD. Williams et al. (2010) stress the importance of viewing CCD in the context of the many other more clear-cut causes of honey bee morbidity worldwide. They argue that all colony loss should not immediately be blamed on colony collapse disorder if there are other apparent and explainable causes. They do not deny that much of the colony collapse happening worldwide is genuinely unexplainable. But they caution against synonymizing CCD with all colony loss and favor objective discrimination between the varieties of honey bee morbidity factors worldwide.

THE LOGICAL NECESSITY OF A PLURALISTIC APPROACH

Each of these narratives is relevant for addressing bee decline. The conservation narrative conveys how recent honey bee decline fits into the broader global ecological issue about the status of all pollinating animals. The regulatory narrative has relevancy because it targets a specific cause with a specific remedy for protecting crop productivity. The socioecological complexity narrative provides a viable game plan because it suggests the adoption of a more flexible, precautionary approach. Nonetheless, these narratives have been played off one another on the basis of how and when their knowledge was produced.

For example, the recognition of the complexity of CCD led to a bit of apologizing about the premature demonization of individual causal agents, notably neonicotinoids and a viral pathogen (Nordhaus 2011). Toxicologists and entomologists continue to squabble over the value of highly controlled experiments that yield reductionist insight versus studies that assess more realistic yet difficult to replicate field conditions (Carreck and Ratnieksi 2014). From the perspective of ecologists who uphold the greater functional importance of non-*Apis* pollinator species, the reductionist narrative about CCD has dangerously oversold the importance of honey bees for pollination. It has also sidestepped the culpability of industrial agriculture for general pollinator decline and for our dependence upon the domesticated honey bee (Ollerton et al. 2012). Native bees, for example, can be equally effective or better pollinators than honey bees for some food crops (Garibaldi et al. 2013; Ghazoul 2007; Winfree 2010). Non-bee insects provide a valuable pollination service and provide potential insurance against bee population declines (Rader et al. 2016).

Yet, rather than reject one of these narratives over another because its knowledge involves a degree of social production, a more conciliatory view is that the phenomena they describe reflect a position along a continuum of ecological causality. Taking this more pluralistic, material approach makes possible the identification of immediate versus realistically long-term goals. It also illuminates the repercussions if one or the other of these narratives is ignored because of its inherent social embeddedness.

For example, if problem solving involves only immediate industry-driven remediation of present-day honey bee decline or if it pursues the documentation of all the permutations of CCD, the potential for remaking agriculture is diminished. Honey bees were introduced as the solution for declining native pollinators. They are a rescue pollinator, a fix for ecosystem services that were provided by other animals. Given the institutionalization of honey bee research within large agricultural universities with ties to agribusiness, it is perhaps not surprising that the role of industrial-scale agriculture could be downplayed in the search for a solution (Kleinman and Suryanarayanan 2013). Business-as-usual approaches will be challenged to address the larger agricultural crisis, given that the trajectory of industrial agriculture has contributed to CCD and declines in other insect pollinators. Industry research to find a cost-effective single proximate cause and solution for CCD diminishes the possibilities for engaging deeper, ultimately structural, changes. Conversely, debates over all the possible permutations of CCD and bee decline can be a red herring. Multiple causality enhances the likelihood of controversy because what gets identified as causal will inherently exclude or downplay other factors, leading to claims of bias and potentially paralyzing inaction. Documenting all the factors contributing to bee decline may not necessarily be a productive, pragmatic way to address more immediate concerns. Regulatory intervention may be needed to accompany the more laborious approaches of adaptive management that seek to establish the full socioecological context.

If the recommendations of the reductionist narrative are ignored, then the benefits of any singular addressable solution are diminished, as well as the production of any ancillary causal evidence stemming from its adoption The evidence to date suggests that phasing out neonicotinoids could diminish honey bee declines. It might also address the harmful toxicological effects of these chemicals on other invertebrates and vertebrates that recent research is suggesting. Neonicotinoids used to treat seeds have been temporarily phased out for a period of 2 years in the European Union (Carrington 2013). However, the use of neonicotinoids in the USA is expected to continue in the short term (Suryanarayanan 2014). While a neonicotinoid ban could provide a temporary solution to colony loss, it is not entirely unproblematic. Farmers in the UK and Germany had lower than expected yields of oilseed rape in 2014 and 2015 due to the return of a pest that was previously kept in check by now banned neonicotinoids (Jones 2015). The use of older second-generation pesticides has been revived in Germany, and their environmental impacts may be no less problematic. In the UK, oilseed rape crops were recently given approval for treatment with a specific neonicotinoid in anticipation of crop shortfalls due to pests. Nonetheless, more restrictive use of neonicotinoids does address an immediate concern and is more in line with the precautionary principle (Suryanarayanan and Kleinman 2011).

But it is in this way that reductionist strategies can illuminate aspects of other causal narratives. In other words, adopting a single shot reductionist solution can reveal ancillary information and unforeseen socioecological relationships. For example, the single-shot solution in practice by beekeepers is to restock bees that perish by purchasing them or splitting healthy colonies as they increase in size. Consequently, US honey bee colony numbers have been able to recover after each year's losses, and the total number may have actually increased since 2006 (Lee et al. 2015). However, restocking honey bees to meet demand may result in even greater rates of honey bee decline. Bees and beekeepers worked harder, further locking in the treadmill of industrial beekeeping that promotes more bee decline (Suryanarayanan 2014). The enticement to restock bees is strong. Despite the difficulty of maintaining healthy bees, pollination services for high-value crops have become a major source of revenue for beekeepers. If the cost of replacing lost honey bee colonies can be absorbed, deviations from the current model are unlikely and therefore could ultimately prolong or intensify pollinator shortages.

Ignoring the complex socioecological causality of pollinator decline limits understanding of its possible futures and how place is central to them. The research of honey bee scientists is animated by forms of expertise that isolate individual factors and their direct, causal roles, and preclude a serious consideration of the environmental complexity impeding upon domesticated honey bees (Suryanarayanan 2013). But understanding the ecological details of this complexity is necessary for anticipating unexpected feedbacks and possible futures. For example, because honey bee declines are driven in part by the demand for luxury crops, more land may be converted to agricultural uses in an effort to make up for the declining yields in these pollinator-dependent crops (Aizen et al. 2009; Garibaldi et al. 2011, 2014). In this scenario, declining yields can result in greater conversion of forested land to agriculture, thus intensifying pollinator decline and exacerbating dependence upon honey bees. As another example, some analyses of pollinator-dependent crop production have found that nutritional content, rather than abundance of food, may be the more critical factor for human well-being (Chaplin-Kramer et al. 2014; Eilers et al. 2011; Ellis et al. 2015). As pollinators and their services decline, geographically specific nutritional insecurity is a more probable scenario than the global human starvation predicted by the media in reference to honey bee decline. In parts of the world where there is already a limited availability of some vitamins and micronutrients, a shortage of nutritionally rich fruits and vegetables may disproportionately impact the poor (Smith et al. 2015).

An appreciation of complexity in the human-honey bee relationship has other benefits. Viewing CCD as unstable and contingent reiterates how the non-human and the biological will defy our attempts to ontologize them into human institutional and regulatory frameworks. The biological mutability of organisms thwarts our capacity to manage and care for them (Atchison 2015; Davies 2012; Hinchliffe and Lavau 2013; Schrader 2010). The specific biological qualities of the honey bee, especially its colonial organization, impart a plasticity at odds with our attempts to fix or freeze hive management in any command and control strategy characteristic of the reductionist narrative. In this way, ambiguity in defining CCD may be strategic, not a failure as the reductionist narrative might suggest. It allows for new information to be accommodated as it is encountered. For geographers, biological mutability and instability in causal relations makes place a central feature of CCD. Where honey bee-human interactions take place shapes the health of bees and how humans respond to them. The failure to incorporate this place-based complexity (e.g. Coimbra 2014; Nowotny 2015) is perhaps a reason CCD has been surrounded by a degree of confusion, distortion, and politicization of science.

Conclusion

The goal of this paper was to reframe discussions of CCD in a pluralistic way, one that accommodated the competing narratives about the causes of honey bee decline and their particular recommendations for addressing it. The narratives we have documented—the conservation narrative, the reductionist regulatory narrative, and the socioecological complexity narrative—encapsulate the tensions between epistemological containment arising from the social production of knowledge and the inevitable ontological fluidity and interconnectedness of material ecologies. CCD is a consequence of interlinked ecological interactions and the partisan capacity of humans to identify and repackage them into narratives for communication and knowledge construction. These ecological interactions form a continuum and span causes that are stable and replicable to those that are highly contingent and ephemeral. Working with multiple forms of ecological causality is necessary to comprehend how to move beyond the useful, but ultimately limited description of how knowledge about CCD is socially produced. The benefit of a materialistic, pluralistic approach to understanding CCD is that it deepens explanatory power while limiting the influence of human biases that anchor us into fixed categories of causality derived from how these knowledges were socially produced.

By focusing only on saving the bees through a single-shot solution lacking any skepticism about causal reductionism, we may inadvertently reinforce the emergence of complex socioecological circumstances and feedbacks that contribute to CCD. Elevating the primacy of these reductionist strategies (Dennett and Rogers 1995; Nordhaus 2011) downplays the heterogeneity of socioecological phenomena. It may even hinder the adoption of more useful, open-ended exploratory approaches (Carpenter and Brock 2008). Yet, reductionism should not be rejected outright. Immediate, single-shot solutions to the problem of bee decline can be strategic. Neonicotinoid pesticides, as well as common hive pests, have more causal stability. Though not universally replicable, their predictability is greater than many other suspected CCD agents. It is a disingenuous, counterproductive strategy to ignore stable evidence because of its epistemic affiliations and to oppose reductionist approaches because there are less predictable and more contingent manifestations of CCD.

Ultimately, the role of industrial agriculture in establishing many of the predisposing conditions of CCD and general pollinator decline will need to be addressed. Ecologists suggest implementing less-intensive agricultural practices, including conserving or restoring (semi) natural areas, enhancing farmland heterogeneity, planting smaller crop fields, and reducing the use of synthetic pesticides (Garibaldi et al. 2014). However, a thorough implementation of these recommendations will require a sustained coherence among all three narratives. There is a need to find balance between societal concerns surrounding the loss of pollination services versus the loss of pollinators (Aebi et al. 2012; Ratamaki et al. 2015). An appreciation of a past before these services were lost informs the conservation narrative. An appreciation of the present motivates the reductionist's goal of ensuring the availability of honey bees for fruit and vegetable production.

Solutions to honey bee decline must also embrace the idea that existing institutions and epistemic cultures may be handicapped by the novelty and complex openness that define the ecological relationships between humans and pollinators. There is a need to invest in diverse kinds of research and to expect that future ecological surprises are inevitable. The possibility of the emergence of a new species of invasive varroa mite (Roberts et al. 2015), changes in honey bee genetics over time and space (Desai and Currie 2015; Locke et al. 2012), and the vagaries of economic and political instability (Moritz and Erler 2016) highlight the importance of maintaining an appreciation of the novelty and possibilities of the future.

Note

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