Colony Collapse Disorder (CCD) in Honey Bees[1]

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Introduction

Beekeepers around the United States have reported higher-than-usual colony losses since the fall of 2006. These elevated losses have been, in part, attributed to a phenomenon known as "Colony Collapse Disorder" (CCD). A 2015 survey of beekeepers in the United States by the Bee Informed Partnership showed that CCD was a reported cause of colony loss for nearly 20% of surveyed beekeepers. Some beekeepers in states reporting CCD have lost 50%–90% of their colonies, often within a matter of weeks. Despite these high losses, the average number of colony losses has been between 30% and 40% since CCD was first reported in 2006. Regardless, this translates into thousands of dead colonies and millions of dead bees. In a country where honey bees contribute billions of dollars in added revenue to the agriculture industry, these bee losses cannot be taken lightly.

Colony Collapse Disorder may not be a new disorder. In fact, many colonies have died over the past 50–60 years displaying symptoms similar to those of CCD. The disorder as described in older literature has been called spring dwindle disease, fall dwindle disease, autumn collapse, May disease, and disappearing disease. We may never know if these historic occurrences share a common cause with modern-day CCD. They do, however, share the symptoms.

Colony Collapse Disorder

Symptomatically, colonies with CCD can appear healthy just weeks prior to collapse. However, the adult bees soon "disappear" (hence its historic nickname "disappearing disease") from the colonies, leaving behind a box full of honey, pollen, capped brood, a queen, and maybe a few worker bees. Beekeepers report that colonies with CCD do not contain any dead bees, nor are there dead bees on the ground outside of the colonies. The adult bees simply vanish. The final symptom is that small hive beetles, wax moths, and other nearby honey bees ignore the empty hives even though the hives contain foodstuffs on which they ordinarily feed.

Generally, the symptoms of CCD are defined as follows:

Collapsed Colonies

1. complete absence of adult bees in colonies, with few or no dead bees in or around colonies,
2. the presence of capped brood, and
3. the presence of food stores (both honey and bee bread) that are not robbed by other bees or typical colony pests (small hive beetles, wax moths, etc.). If robbed, the robbing is delayed by a number of days.

Collapsing Colonies

1. an insufficient number of bees to maintain the amount of brood in the colony,
2. the workforce is composed largely of younger adult bees,
3. the queen is present, and

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4. the cluster is reluctant to consume food provided to them by the beekeeper.

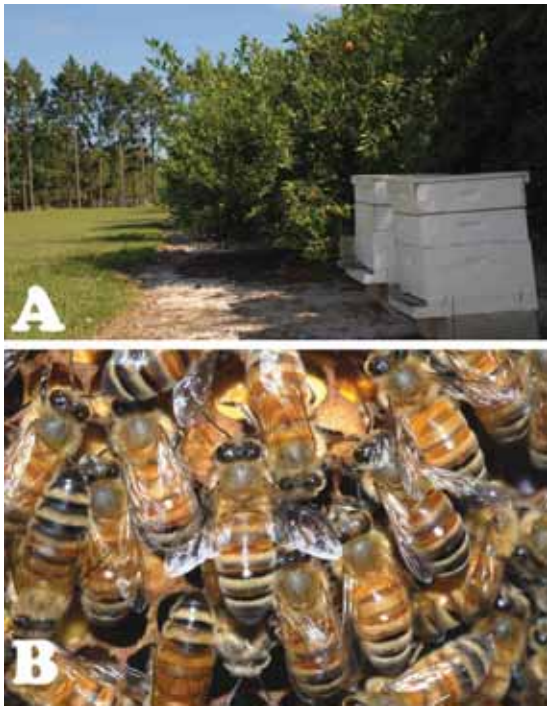

Figure 1. Healthy colonies of bees (a) contain thousands of worker bees (b). Colonies suffering from Colony Collapse Disorder have few or no bees remaining in the hive.
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What causes CCD?

The cause of CCD is unknown but is under investigation. The leading candidates and a brief explanation of their potential role are listed below. This is not a comprehensive list, and the candidates occur in no particular order. It is important to note that this list may change as new information on CCD becomes available. Such changes could result in the addition or exclusion of any of the following potential causes. The author makes no attempt to promote or undermine any one of the following theories.

1. **Traditional bee pests and diseases (including American foulbrood, European foulbrood, chalkbrood, nosema, small hive beetles, and tracheal mites):** Although considered potential causes, "traditional" bee maladies (those nearly-cosmopolitan throughout the United States and globally) likely are not responsible for causing CCD. This is because they do not have a history of promoting CCD-like symptoms. That said, traditional bee pests and diseases may exacerbate the disorder, so scientists have not abandoned experiments investigating them.

2. **Honey bee management practices:** Management style is a broad category, but it can include the type of income pursued with bees (honey production, pollination services, etc.) or what routine colony management beekeepers perform (splitting hives, swarm control, chemical use, etc.). Both of these vary considerably among beekeepers, so this possible cause of CCD is given less attention. That said, poor management can make any colony malady worse.

3. **Queen source:** Scientists are investigating the lack of genetic diversity and lineage of bees, both related to queen quality, as possible causes of CCD. Regarding the former, relatively few breeder queens are used in the United States to produce the millions of queen bees (and therefore all bees) used throughout the United States. Geneticists refer to this as a genetic bottle neck. This lack of genetic biodiversity can make bees increasingly susceptible to any pest/disease that invades the system.

4. **Chemical use in bee colonies:** Like farmers in other agricultural sectors, beekeepers often attempt to chemically-control the various maladies affecting their honey bees in an effort to keep their bees healthy and productive. Investigators have found a number of sub-lethal effects of these chemicals on honey bees (workers, queens, and drones) even when the chemicals were used according to the label and in accordance with best management practices suggested by specialists. These sub-lethal effects have led some to consider the role of in-hive chemical use in the CCD paradigm.

5. **Chemical toxins in the environment:** Another chemically-oriented theory is that toxins in the environment are responsible for CCD. Because pesticides are used widely in cropping systems in an effort to kill herbivorous insects, one is left to consider the potential for non-target chemical effects on foraging bees. In addition to being exposed to toxins while foraging, honey bees also may encounter toxins by drinking water contaminated with chemical runoff, encountering various chemicals (household, commercial, etc.) through contact outside of the hive, or via direct inhalation.

6. **Genetically modified crops:** Some people have proposed that genetically modified crops may be responsible for the widespread bee deaths. Interestingly, many seeds from which genetically modified crops are grown are dipped first in systemic insecticides that later may appear in the plants' nectar and pollen. This makes genetically modified plants suspect because of their chemical treatment history, not just because they are genetically modified. Scientists have begun initial investigations into both theories, but no conclusive data have been collected.

7. **Varroa mites and associated pathogens:** Even with the concerns surrounding CCD, varroa mites remain the world's most destructive honey bee killer. As such, varroa and the viruses they transmit have been considered as possible causes of CCD. Further, varroa often are controlled chemically by beekeepers. So varroa (perhaps not directly) has been considered a potential cause of CCD because the mite itself is damaging, it transmits viruses to bees, and it can elicit chemical responses from beekeepers. Despite this, there have been instances of colonies showing symptoms of CCD when their varroa populations were under control.

8. **Nutritional fitness:** Scientists have proposed nutritional fitness of adult bees as a potential cause of CCD. This topic is being investigated, although little information exists currently to support/refute the role of nutrition. Malnutrition is a stress to bees', possibly weakening the bees, immune systems. A weak immune system can affect a bee's ability to fight pests and diseases.

9. **Undiscovered/new pests and diseases:** Undiscovered or unidentified pests/pathogens are also considered possible causes of CCD. Some believe that a new pest/disease may have been introduced into the United States and is causing CCD. To give one example, *Nosema apis* (a microsporidian that lives in the digestive tract of honey bees) has been present in the United States for many years. In 2006, scientists discovered and identified a new nosema species, *Nosema ceranae*, present in some colonies displaying symptoms of CCD (it also has been found in bee samples dating back to 1995). When this disease is present in bees in elevated levels, the bees leave their colonies, never to return. Although the role of *N. ceranae* in the CCD complex is not understood, it and other new pathogens may play an important role in elevated bee deaths. Israeli Acute Paralysis Virus is another example of a recently-discovered pathogen that may play a role in colony losses.

10. **Synergisms between the above stressors**: Many scientists believe that CCD is caused by a combination of the factors above. To illustrate this point, some dead bees showing symptoms of CCD have had elevated levels of normally-benign pathogens in their bodies, possibly indicating a compromised immune system. In theory, any stress or combination of stresses (chemicals, genetic bottlenecks, varroa, etc.) can suppress a bee's immune system. Considering synergistic effects as a potential cause of CCD makes the disorder increasingly harder to study.

How will CCD affect the general public?

In general, most people recognize the importance of honey bees in producing honey. The production and sale of honey supports thousands of beekeeper families and provides the consumer with an alternative to sugar (incidentally, there is no evidence that honey from CCD colonies is unsafe for human consumption). However, honey is of only minor importance compared to the benefits afforded humans by honey bee pollination.

Honey bees are important pollinators of the nation's crops. Pollen adheres to bees' bodies when they visit flowers (like this citrus flower in Figure 2). As they go from flower to flower, they transport the pollen between flowers, thus pollinating the flower. Flowers that are adequately pollinated produce fruit, vegetables, or nuts. Higher fruit set, larger fruit, uniformly-shaped fruit, and better taste are all indications of successful pollination.

Figure 2. Honey bees are important pollinators of the nation's crops. Pollen adheres to bees' bodies when they visit flowers (like this citrus flower in picture a). As they go from flower to flower, they transport the pollen between flowers, thus pollinating the flowers. Flowers that are adequately pollinated produce fruit, vegetables, or nuts. Higher fruit set, larger fruit, uniformly-shaped fruit, and better taste are all indications of successful pollination.
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Beekeepers managing their bees for purposes of pollination load their colonies on trucks and move them around the country, going from blooming crop to blooming crop. Growers pay beekeepers to ensure that they will have an adequate supply of honey bees to pollinate their crop. In return, the growers benefit by having a higher fruit/vegetable/nut production per acre, larger size and better

shape of the product, and even enhanced product taste in many instances.

The benefits of honey bee pollination are not to be taken lightly. The simple act of beekeepers moving honey bees around the country ensures our country's food supply. Agriculture needs honey bees, and their disappearance is cause for concern. Yet, no one believes that honey bees will disappear altogether, even with the concerns over CCD. Instead, the average American may experience increased food prices and decreased food availability if honey bees continue to die at the current rate. The almond industry illustrates this point well.

Almond producers in California continue to plant more acres of almonds every year, yet managed honey bee populations have remained stagnant over the same time period. More than 60% of commercially managed honey bee colonies in the United States are moved to California to pollinate almonds each year. For now, beekeepers are able to keep up with high levels of colony loss by producing new honey bee colonies. However, the regular loss of honey bees could begin a price war in the pollination industry, resulting in growers being forced to pay higher rent prices for bee colonies. The net effect is that the consumer will have to pay a higher price for the food that they currently enjoy. In the worst case scenario, food availability will begin to decrease as honey bees die.

The benefits of honey bees are undeniable and often underappreciated. Perhaps the worst thing to come from all of this is that the loss of honey bees could signal a decline in the health of our environment. Honey bees are biological indicators, meaning that their status is a reflection of the health of the general environment. If true, bee losses may indicate a much larger environmental issue.

Figure 3. Scientists are trying to determine the source of Colony Collapse Disorder.
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What is being done?

Scientists, beekeepers, government officials, various industries, etc. are investigating various avenues of CCD. In addition, many granting agencies realize the importance of honey bees and have begun to distribute research funds in an effort to find the cause and a cure.

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