Colony Collapse Disorder: The Vanishing Honeybee (Apis Mellifera)

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COLONY COLLAPSE DISORDER

The Vanishing Honeybee (Apis Mellifera)

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Abstract

Colony collapse disorder (CCD) was first reported on the east coast of the United States in 2006. Symptoms of CCD include the rapid loss of adult worker honeybees, few or no dead bees found in the hive, presence of immature bees (brood) and a small cluster of bees with a live queen present, as well as pollen and honey stores still in the hive. Honeybees (*Apis mellifera*) are a keystone species because they provide a number of pollination services for various ecosystems. They are also extremely important organisms within human society, both agriculturally and economically. With a third of human food coming directly and indirectly from honeybee pollination, colony collapse disorder will have significant economic, ecological, and social impacts if further colony losses are not prevented. The fact that a direct cause has not been determined suggests that CCD is a complex problem with a combination of natural and anthropogenic factors. Possible instigators of CCD include: mites, viral and fungal diseases, increased commercial transportation, decreased genetic diversity, pesticides, and a variety of other factors. The interaction among these potential causes may be resulting in immunity loss for honeybees and the increased likelihood of collapse. This thesis will discuss the various factors that have been researched as possible causes for colony loss as well as explore the long-term effects that this decline could have. Through library research of scholarly texts and involvement with active beekeepers in the community, this thesis will recommend solutions that humans can take to save the organism upon which we, ourselves, depend.
Preface & Acknowledgements

Colony collapse disorder has been fascinating to me since the moment I read about it. Originally, I researched the subject for a class at the University of Colorado at Boulder, but my research did not end once I submitted the paper. I kept an interest in honeybees and even took a beekeeping course at a local garden to get a sense of what it would take to keep my own bees. Surprisingly, it was not as difficult as I had imagined and the class distributed vast amounts of literature about these intriguing creatures. As a college student, I was not in the position to maintain my own hive, but I still have dreams of becoming a beekeeper. Beekeeping is a way in which humans can learn to better appreciate the role that honeybees play in our life.

This thesis has allowed me to develop my knowledge on honeybees, which has become my primary interest and passion. Since writing this thesis, I have been meeting with local beekeepers to strategize the best ways to educate and spread awareness on CCD. Also, I have begun planning my own events, such as a movie screening of Vanishing of the Bees to be held on my college campus. As my dedication to honeybees increases, the more frustrated I become with the lack of policies put in place to prevent further losses. However, it is not too late to turn honeybee loss around. Research and discussions on this issue are gaining momentum so keep your eyes out for ways that you can help to save our precious pollinating friends!

I would like to acknowledge those that have helped me to find resources for this thesis, who have guided me along the way, and who have inspired the movement for honeybee awareness everywhere. First, I would like to thank Dale Miller, a fellow beekeeper and my thesis adviser. Thank you for encouraging me to do a thesis and for helping me become more engaged about the importance of honeybees through intriguing conversation. I very much enjoyed our weekly meetings. I would like to thank my other advisors Diana Oliveras and Michael Breed for giving me constructive criticism when writing this overwhelming paper. I would also like to thank Jessie Lucier, Julie Finley, Angie Giustina and my fellow bee guardian group for helping me accumulate resources and for supporting my campus movie event. You have all inspired me and helped me through writing this thesis and have made it enjoyable. Also, a big thank you to Tom Theobald, a beekeeper who has taken his love for bees combined with his newfound knowledge of pesticides to save the creatures that have supported his lifestyle. Keep up the hard work and know you have a growing support system. Lastly, I would like to thank my family and my boyfriend, Dan Omasta, for taking the honeybee fight seriously and for integrating it with their own work and conversations. Keep spreading bee awareness!
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SECTION I: A Brief Background on Bees

_The Creator may be seen in all works of his hands; but in few more directly than in the wise economy of the Honey-Bee_

~L.L. Langstroth~

Introduction

Honeybees have been disappearing in large numbers across the globe. Where are all of the honeybees going, and why? Honeybees are considered a keystone species because of the significant role they play in supporting various ecosystems through their massive pollination services. Humans are also extremely dependent on these pollination services, which begs the question: How severely will human civilization be impacted if honeybee populations continue to decline? Not only do honeybees produce wax and honey, they are also directly and indirectly responsible for pollinating a third of the food that humans consume. Their ecological and economic contributions are invaluable, which makes colony collapse disorder a very important topic of discussion. Although government researchers, scientists, and beekeepers have been trying to find the answer to why honeybees are disappearing, no single factor has been determined. However, if the disorder remains untreated, continued honeybee loss could drastically affect America’s food supply as well as the larger agricultural, economic and environmental systems.

Colony collapse disorder (CCD) is a phenomenon in which worker bees abruptly disappear from a beehive. Since CCD was first reported on the East coast of the United States in 2006, continued increases in honeybee loss are making CCD an extremely pressing issue. Symptoms of colony collapse disorder include the rapid loss of adult worker bees, few or no dead bees found in the hive, only a small cluster of bees with a
live queen present, and pollen and honey stores remaining in the hive (Debnam 2009). So far, there has not been a conclusive answer as to why seemingly healthy bees are disappearing. Scientists are using a variety of methods to evaluate this collapse disorder to try to find what is responsible for the malady.

There are many theories surrounding the recent honeybee population decline. Natural stressors include various parasites and pathogens, such as fungi, viruses, and mites, all of which can be extremely harmful to bees. Some of the anthropogenic factors that are most likely contributing to collapse include: increased exposure to pesticides, trucking honeybees across long distances for the pollination of commercial crops, poor nutrition, artificial insemination of queens using sperm of limited genetic variability, and habitat loss. It has even been suggested that increased cell phone use may be interfering with the honeybees’ immune system and/or their ability to navigate. This thesis will bring together knowledge about the possible reasons behind the loss of honeybees. It will look into the science and the controversies surrounding this crisis.

In addition to exploring the possible causes of CCD, this paper will also highlight the effects of this disorder. As a keystone species, honeybees play an important role in the ecosystem at large. These insects are anatomically constructed to work symbiotically with flowering plants to receive pollen and, in turn, facilitate pollination. The mutualistic actions by these two groups of organisms maintain both plant and animal diversity in the environment. Additionally, honeybees are considered an index species because the health of the species indicates the condition of the environment. Honeybees are extremely susceptible to change, and as more pathogens and poisons are introduced into the environment, the more adversely affected these pollinators will be. CCD has significant
impacts on the environment and will lead to dramatic repercussions for natural and human systems that depend on the products and services that honeybees provide.

The impacts of colony collapse are an urgent matter. On a small scale, the livelihood of beekeepers depends on the viable supply of honeybees and their role as pollinators and honey producers. With as much as 30-90% losses in a single winter, beekeepers do not have a viable population to sustain themselves economically for future years (Kaplan 2008). On a larger scale, major declines of bee populations will force the United States to rely on food imports from other countries that have not been subject to such great losses. This means that all fruits, vegetables, meat products, coffee, teas, and other staples on which we rely would have to come from other places. The increased price of food and elevated trade deficit, coupled with significant job losses in the agricultural sector, would further cripple the American economy. Eventually, if strategies are not implemented to better understand and mitigate the causes and effects of colony collapse, we could see one of the biggest natural and economic disasters of our time.

The importance of this issue should not be underestimated. Education and research about the larger role that bees play in nature and our human connection to that system need to be strengthened. It is also critical for governments and communities to implement various policies and programs that will protect the livelihood of honeybees as a species and ecological partner. With around 130 agricultural plants in the United States dependent on honeybee pollination (valued at $15 billion annually in the United States and $215 billion worldwide), the disappearance of bees is a crisis we cannot afford to ignore (McGregor 1976, VanEngelsdorp et al. 2008).
Background

Honeybees (*Apis mellifera*) possess traits that make them successful as both pollinators and cooperative social creatures. Their bodies are constructed to work in perfect harmony with pollen producers. Honeybees benefit the larger ecosystem by facilitating pollination, thereby allowing plants to grow, bear fruits and seeds, and provide nutrients for other animals. Human beings have also relied on honeybees for their capacity to produce wax and honey. Understanding the traits that honeybees posses is important to appreciating the contributions that these insects provide to both humans and the ecosystem as a whole.

**Natural History of Honeybees**

Ancient Egyptians worshipped honeybees and believed that bees grew from the tears of Ra (Readicker 2009). As early as 3500 BC, a hieroglyph of a bee represented the King of Lower Egypt, a symbol that lasted more than four millennia. Honey was considered a tribute and wax was used to make sacred figurines. In India, Vishnu described the bee as “the creator and destroyer of all existences, one who supports, sustains and governs the Universe and originates and develops all elements within” (Readicker 2009). In Greek mythology, honey was the food of the Gods (Schacker 2008). Regardless of the specific civilization, honeybees have been considered a treasure, a gift, a blessing, and a creature to be respected.

Bees have been in existence for roughly 100 million years, since the earliest flowers developed; the honeybee evolved as a subspecies roughly 35 million years ago (Readicker 2009). Although there is not a complete record of the history of honeybees, the relationship between bees and flowering plants is undoubtedly one of symbiosis.
Today, there are 250,000 flowering plants, and 20,000 of them rely on bees for pollination (Schacker 2008).

Honeybees are built perfectly to be successful pollinators. They have two different sets of eyes, the ocelli and the compound eyes. The ocelli consist of three eyes, each with a dense lens. They are used to detect the intensity of light, which helps them to remain right side up (Winston 1987). The other set consists of two compound eyes, each with 6,900 hexagonal lenses that are able to decipher different light conditions, colors, and sun position. Hairs on their body are used to detect wind speed and direction, and their sensitivity to ultraviolet light directs them to the plant’s nectar and pollen storage (Benjamin 2009).

Honeybees have antennae on the top of their head that act as smell detectors (see Figure 1; Snodgrass 1984). Bees are 100 times more sensitive than humans to odors such as flowers, nectar wax, and propolis (a plant resin used to seal honeycombs). Honeybees also have a folding tongue called a proboscis that allows them to reach deep into flowers for nectar. Their mandibles hold and manipulate wax and collect propolis (Snodgrass 1984). Other functions of the mandibles include ingesting pollen for food, cutting, cleaning, grooming, and fighting (Winston 1987). Their feet have hooks in order to hang onto flower petals and pads that allow them to walk upside down on flat surfaces. Their front legs are also equipped with hooks that are used to clean the antennae, and their middle legs act as wax collectors (Benjamin 2009). Once the wax is collected, it is passed to the front legs for the mandibles to
manipulate into comb. When a honeybee lands on a flower, the pollen is brushed into the corbicula, which is located on the hind leg and is capable of holding eight milligrams of pollen each time the bee flies (Benjamin 2009).

Honeybees make thousands of visits to one type of flower at a time until the food source has dried up. In a single day, one worker bee will visit, on average, 1,500 flowers to gather one load of pollen (Benjamin 2009). In order to produce one gallon of honey, a hive will collect pollen and nectar from around 500 million flowers, and will have flown around seven million miles (Schacker 2008). According to the USDA Agricultural Statistics Service, the average honey yield per colony was around 65 pounds in 2006, although some colonies can produce around 200 pounds (USDA 2007, Hinke 2007). The amount of honey produced is dependent upon the health of the colony and the availability of forage and flowering plants.

Foraging is crucial for pollination, the collection of food for colony, and the production of wax and honey. Honeybees are directionally sensitized and use the sun and landmarks as points of reference and can travel three miles or sometimes further from the hive in search of food without losing track of where the colony is located (Benjamin 2009). When a honeybee returns to the colony after discovering a rich food source, it will do a “waggle dance” in order to relay directional cues to the rest of the worker bees in the colony. This dance entails shaking the abdomen side to side in order to communicate to the other bees the flying time to a food source, the wind speed, and the sun’s direction. If the dance is merely a fraction of a second, the source is nearby, but if it lasts a couple of seconds, the source is about five minutes away (Tautz 1996). Encoded in the dance are scent clues indicating what the food is and how much of it there is (Readicker 2009).
bee will repeat this dance a number of times in order to convey its message to the other workers. If there are not enough workers that leave the colony to forage, the bee will conduct a “tremble dance” to recruit more workers (Benjamin 2009).

As the honeybees visit flowers, they facilitate pollination. They will visit many of the same species of flowers in a single trip and their hairy bodies pick up pollen grains at each stop. Bees pollinate 16% of the world’s flowering plant species and 400 of the world’s agricultural plants (Delaplane 2000). Bee foraging is advantageous for the flowering plants because they encourage high rates of pollination and plants, in turn, flowers provide nectar and pollen for their honeybee pollinators to produce wax and honey (Delaplane 2000).

Honeybees are social insects, meaning that a division of labor within the hive is a fundamental aspect of efficient organization. In a colony, a bee can be a queen, a male drone, or a female worker. Each bee has its own role within the hive and is responsible for reproducing, bringing in food, or cleaning (Kolmes 1989). Honeybees go through three stages in the process of becoming an adult: egg, larva, and pupa. Together, each of these stages is referred to as the brood. Unfertilized eggs turn into male drones and fertilized eggs mature into either female workers or queens (Readicker 2009).

There is only one queen in a colony at a time, and her primary role is reproduction. She is equipped with ovaries, queen pheromones and a barbless stinger, and she is substantially larger than the rest of the bees (MAAREC 2011). It is her job to lay eggs in order to populate the colony. If she is healthy and has ingested enough food, she will lie about two thousand eggs per day and live for five to seven years (Schacker 2008). Another important duty of the queen is to produce pheromones to keep the colony
together. Honeybees identify themselves by the smell of the colony, which the queen secretes through her mandibular glands (MAAREC 2011). If a larva is destined to be a queen, she is consistently fed royal jelly by the worker bees, which is a white, protein-rich substance that turns her into a “sexually mature powerhouse” (Meyerowitz 2000). As a queen loses her fertility, a new chamber is created for a successor. During the summer, a number of queens are raised in an individual colony, and the ones that do not take over the hive fly off in search of a new home (Benjamin 2009).

If a bee is destined to be a worker, it will take her 21 days to emerge from a pupa (Schacker 2008). Worker bees make up 99% of the colony and have many jobs, the primary one being to forage for nectar, pollen, water, and propolis. Individual worker bees are equipped with brood food glands, scent glands, wax glands, and a pollen basket (MAAREC 2011). Members that are not fully grown have alternate tasks such as cleaning and ventilating the hive, taking care of the brood, receiving nectar and pollen to make royal jelly, building combs, and guarding the entrance (Benjamin 2009). These are all necessary tasks that keep the colony organized and free of diseases.

If a bee is destined to be a drone, it will take him 24 days to emerge (Benjamin 2009). These male honeybees are the biggest in the colony, but they do not have a stinger, pollen baskets, or wax glands. Their job is to fertilize the queen on her mating flight (MAAREC 2011). It takes three to seven days in order for the queen to become impregnated and once she mates, she is equipped with enough sperm to continually populate the colony over the course of her lifetime. The drone dies instantly after he completes his mating duties (Schacker 2008).
The specialization within honeybee colonies demonstrates the cooperation within a functioning and efficient system. However, as various pathogens infiltrate the honeybee’s system, the integrity of the colony can weaken. This is why it is crucial to have a healthy queen and a healthy colony to get through times of infection. If colonies get smaller, the chance of disease increases, making the colonies more susceptible to collapse.

**History of Hive Evolution and Loss**

Honeybees are not native to the United States, but were first introduced to North America when Europeans crossed the Atlantic and facilitated the species’ migration in 1621 (Horn 2008). The natural habitat of honeybees covers a vast area. It ranges from the tip of Africa and the Mediterranean and extends to northern Europe and southern Scandinavia (Winston 1987). Subspecies of honeybees have been determined by the different adaptations they have acquired throughout a variety of climatic conditions. Honey has been used as food ever since the first *Homo sapiens* lived in caves (Benjamin 2009). The first beekeepers can be traced back to 2,400 BC when Egyptians transported their bees to produce honey (Benjamin 2009). Beekeeping spread westward along the North African coast and reached parts of Greece and Rome where beekeepers further disseminated the information known about honeybees (Crane 2004). Throughout Zimbabwe and South Africa, images can be found of hunters obtaining honey by using smokers to lure the bees out of their nests. Honey hunting dates back 15,000-20,000 years, indicating how useful honeybees have been to humans throughout history (Benjamin 2009).
Honeybees were an important element of the colonization of America. As European settlers came over and planted seeds and saplings, the bees were necessary for pollination. Bee pollination resulted in the increased spread of clover, which was used to feed the livestock (Benjamin 2009). The settlers continued to spread honeybees by aiding their move across plains and mountainous regions. The production of honey sharply increased during the 17th century and by 1730, Virginia was exporting around 344,000 pounds of beeswax (Benjamin 2009). Beekeeping became even more commercially feasible during the 19th century as certain tools were invented and made accessible. This equipment included the smoker, the frame hive (Langstroth hive, see Figure 2), the honey extractor, and comb foundations (Horn 2008). By the 20th century, the western honeybee became a vital part of human existence.

However, as humans continued to manipulate the honeybee and deliberately transferred them on a global scale, diseases simultaneously spread and harmed managed colonies. Colony losses have occurred periodically throughout history. Fungus, mites, and starvation have all been thought to be the cause of the deaths. The first recorded collapses were called “May Disease” in Colorado in 1891 and 1896 (Schacker 2008). Investigations pointed to a fungus, *Aspergillus flavus*, as the culprit of the Colorado collapses. *Aspergillus flavus* causes stonebrood, a fungal disease, which targets both the immature and adult bees. Since adults are affected, it is difficult for healthy bees to carry infected bees out to reduce spreading of fungus (Underwood 2010). Another epidemic occurred on the Island of Wight in the United Kingdom. Between 1905 and 1919, 90% of
the bees died and the reason as to why is still debated (Neumann 2010). In the twentieth century, large-scale losses occurred throughout North America (Benjamin 2009). Numerous studies have been conducted to determine the causes of these losses but no definite reason has been found.

In 2006, Dave Hackenberg, a commercial beekeeper residing in Rushkin, Florida, reported what we now call CCD. He was first referred to as an unskilled beekeeper, but once a third of all the honeybees in the United States disappeared, people thought otherwise (Benjamin 2009). Hackenberg lost 2,000 of his 2,950 hives and rebuilding was extremely costly. As seen in Figure 3, by 2007 more than 22 states had reported CCD with some beekeepers losing up to 95% of their hives. Losses continued to grow, as 35 states reported CCD by 2008 (Schacker 2008). These dwindling numbers of bees are now being seen as a crisis.

Honeybee pollination is vital for commercial agriculture. Without them, the agricultural sector will be significantly affected. Approximately a third of human food is directly or indirectly supported by honeybee pollination (Kremen et al. 2009). Due to the immense importance of honeybees, there needs to be further research on this pressing issue. This thesis will discuss the many factors that may be causing colony collapse as well as potential mitigation strategies and areas of further research.

Methods

Scholarly primary and secondary sources were used to gather information on CCD and honeybees. Sources included journal articles and books outlining information
on honeybees and colony collapse disorder. By researching multiple factors individually as well as compilations of information, the timeline of events connected to the disappearance of hives across the world has become increasingly clear.

Knowledge of the repercussions of colony collapse disorder was also gained by attending beekeeping courses, meeting with beekeepers in Boulder County (Colorado, USA), going to events to educate the public on CCD, and participating in open forums at the Boulder municipal building focused on pesticide use within the city. As an addition to my research, I contributed the knowledge gained through writing this thesis to promote public education on colony collapse. One way I did this was by organizing an event to show the film *Vanishing of the Bees* at the University of Colorado at Boulder in the effort to engage students on this pressing issue. Another way I educated my college campus about the effects of pesticides on honeybees was to insert a description of CCD into *The Turf Management Task Force Summery*, a plan to eliminate the use of synthetic pesticides on CU’s campus grounds. Spreading information about CCD is the first step to reversing the effects of further honeybee loss.

By accumulating knowledge both in person and through library research, I better understand how colony collapse disorder is being portrayed to the general public, the beekeepers, and the government organizations that will have to make important decisions on how to handle this potential disaster. I hope to increase interest and a better appreciation for honeybees among the general population. Once people understand the fundamental role that these pollinators play, I trust people will want to change their habits to accommodate the backbone of pollination and to encourage their elected representatives to do the same.
SECTION II: Potential Causes of Colony Collapse Disorder

*The apple trees bloomed but no bees droned among the blossoms, so there was no pollination and there would be no fruit*

~Rachel Carson~

**Mites and Viruses**

Diseases are problematic for nearly all organisms, but they are particularly a problem for social insects. Honeybee colonies provide a favorable environment for parasites and pathogens because of the warm temperature and the high concentration of hosts (Tarpy 2006). Past colony losses have been associated with mites and viruses, therefore making them important to discuss as stressors linked to CCD. Mites have infested honeybee hives long before severe honeybee loss began. However, mite infections may be having an even deadlier impact on honeybees now that there are a variety of other factors that have been introduced. Increased pesticides loads, transportation stress, and genetic loss have become more prominent and these stressors may be combining with mite and viral infections to weaken the bee’s immune systems.

**Mites**

Varroa mites (*Varroa destructor*) and tracheal mites (*Acarapis woodi*) are parasites known to damage colonies (Genersch 2010). Both of these species of mites were introduced to the United States in the 1980’s and are now widespread in managed colonies (VanEngelsdorp et al. 2009). Prior to their introduction, beekeepers reported 5-10% winter losses, but as mites spread, these losses rose to 15-25%. This trend of loss due to mite infestation has continued to increase (VanEngelsdorp et al. 2008). Although it seems as if mites are a primary cause of colony collapse disorder, according to a recent study that examined colonies with and without symptoms related to CCD, not all colonies...
showing signs of significant loss were attributed solely to mite infestation (VanEngelsdorp et al. 2009). Healthy hives and unhealthy hives have mites. This suggests that these parasites may be combining with other factors to synergistically weaken colonies.  

*Tracheal Mites*

Tracheal mites, *Acarpis woodi*, live in the tracheal tubes of honeybees. They prevent infected bees from working as hard or from living as long as healthy bees (Caron 2000). The mites pass quickly from bee to bee and eventually can pass between colonies. Tracheal mites were first discovered in Europe in the early twentieth century where the disease spread rapidly (Sammataro 2000). Since then, the infestations have become increasingly common.

Mites have a fast moving life cycle, with complete development taking place in 11-15 days. Mites are nourished by bee hemolymph, which they obtain by sucking it out of a bee's tracheae (Donzé 1994). Younger bees are more susceptible to these mites because they have a better chance of living long enough for the mite to complete its life cycle. Once a female mite is embedded within the host, she lays eggs in the tracheae (Sammataro 2000). As the bee gets older, its tracheal mite load increases and may force the insect to innately leave the hive in order to prevent the spreading of the infection (VanEngelsdorp et al. 2009).

Controlling the spread of tracheal mites is difficult when there are vast numbers of them in a hive. Mites can lead to smaller bee populations, cause increases in honey consumption, and, in turn, lower honey yields (Sammataro 2000). As the bee populations decrease, the possibility for the winter bees to make it through the cold season diminishes.
as well. Winter is also when the tracheal mites are the most prevalent because the bees are obligated to stay inside the hive (Sammataro 2000). Studies show that once a colony has tracheal mites, it will remain infested (Caron 2000). The tracheal mite is difficult to detect, so the common thought process among beekeepers to assume the colony has mites and to treat it aggressively. If they do not, the queen may become susceptible as she ages and the whole colony will collapse (Caron 2000).

Symptoms of tracheal mite infection include declining populations, bees of a weakened state crawling on the ground with disjointed hind-wings, and abandoned hives full of honey (Readicker 2009). The best way to diagnose a honeybee for tracheal mites is to dissect it and look inside the tracheae. Once a hive is infested with mites, there are different ways to treat the parasites. The most common way to treat mites is to spray insecticides. Since both of these insects are similar physiologically, the difficulty is finding a toxin that will only harm the mite, not the bees (Sammataro 2000). Mites have caused the amount of pesticides used to rise in order to rid the colony of infestation. Beekeepers have been experimenting with how to rid the hives of the mites without using chemicals at all. More natural ways to prevent and treat mites need to be encouraged. These more organic methods will lower the amount of harmful pesticides released into the environment and give bees an opportunity to gain a resistance to pests through natural selection. Increasing poison loads is only a temporary solution.

*Varroa Mites*

The varroa mite, *Varroa destructor*, is the primary pest of the honeybee and is now found in all parts of the world except for Australia, New Zealand, and Hawaii (Sammataro 2000). It was first discovered in Java and while limited to Southeast Asia, it
was a pest to primarily the Asian honeybee, *Apis cerana* (Readicker 2009). Throughout the twentieth century, the mites spread through commercial transportation and began affecting colonies of all bee types worldwide. By 1994, 98% of the wild honeybee population was destroyed by mites and the various diseases that they bring with them (Schacker 2008).

Varroa mites are major pests to the honeybees. They can hinder the ability of the queen to reproduce, which can then be fatal to the colony at large (Johnson 2007). They can also attack both female worker bees and male larvae, although they are built to better parasitize the drone cell (Donzé 1994). Mites attach to adult bees by piercing the drone or the worker bee’s abdomen or behind the head and ingesting the hemolymph. Mites can enter into the cells and hide in the liquid brood food before the cell is capped. Once the cell is capped, the mite begins laying her eggs on larvae (Sammataro 2000). Depending on the number of mites, the bee can be severely weakened, perhaps fatally. If no preventative measures are taken against the mites, a whole colony can be killed due to either direct effects of the mites or the viruses that they spread (Tarpy 2007).

Some symptoms of varroasis include visible dark mites within the white pupae (see Figure 4), punctured holes on the drone or worker brood cells, or deformed adults crawling around inside or outside of the hive (Sammataro 2000). It is difficult for a beekeeper to determine why a colony may appear weak because various factors may produce similar symptoms. For example, the effects of toxins within a bee’s system may appear the same as a mite-infested colony, making colony collapse difficult to examine.
**Mite Treatment**

To treat mites, many beekeepers use miticides, such as fluvalinate (Apistan®), a pyrethroid, or coumaphos (Bayer CheckMite™), which are applied to the hive as plastic strips (Sammataro 2000). Mites, however, are beginning to develop a natural resistance to the chemicals, thus making it more difficult for beekeepers to control them (Ambrose 2000). The use of essential oils, smoke, and traps are alternate, more organic methods of controlling mites, and many beekeepers are increasingly choosing these over synthetic insecticides. Their effectiveness, however, may depend on the number of mites within the hive (Ambrose 2000). Although mites and the chemicals to treat them may not be the direct cause of CCD, the increased dosages of toxins may result in worse problems for bees.

According to Pat Flinn, a beekeeper in Alberta, Canada, varroa mites have become a worse problem than ever before (Flinn 2011). Some beekeepers in the area have lost as many as 50% of their bees in the winter months. The provincial government has sent inspectors to look at hives in order to identify the problematic mites and accompanying diseases. In addition, workshops on Integrated Pest Management (IPM) have been established to educate beekeepers on the procedures that should be used to monitor their hives and treat for mites. Flinn uses Apivar®, (Amitraz, formic acid) strips like many beekeepers worldwide whose hives have suffered from mites. Other insecticides include formic acid and Mite Wipe absorbent pads, which can be used to treat tracheal mites as well as varroa mites. CheckMite and Apistan strips can also be obtained, she said, but there are strong concerns about resistance and residues left in the
wax. According to Pat, there is too much fear of losing hives by not using these chemicals.

Although treating symptoms with pesticides seems to be a common solution, other solutions need to be researched so that the mites do not develop resistance. When insecticide resistance happens, mites essentially turn into “super” mites and stronger toxins will need to be used. Such escalation in drug use may compromise the health and immune system of the bees (Schacker 2008). It is critical to continue research on mites and the procedures we use to treat them, because the synergistic effects may be fatal to honeybees.

**Viruses**

It is important to study viruses in relation to mites because mites are often carriers of viral pathogens and are able to directly inject them into the bee’s hemolymph (Tentcheva et al. 2004). The only virus that will be discussed in this paper is the Israeli Acute Paralysis Virus because it has been commonly discussed as a predictive factor of CCD.

*Israeli Acute Paralysis Virus (IAPV)*

Israeli Acute Paralysis Virus (IAPV) was first described in 2004 in Israel and was said to be imported from Australia in 2005 (USDA 2008, Berry 2007). IAPV can affect both brood and adult bees and is transmitted by varroa mites (Sammararo 2000). The virus is spread when mites feed on honeybees. Other ways the virus is transmitted is when honeybees have physical or mouth-to-mouth contact with an infected bee or if a nurse bee cleans up virus-infested feces (Sammararo 2000). Symptoms of Israeli Acute
Paralysis Virus include shivering wings and eventually paralysis and death outside of the hive (Schacker 2008).

IAPV research has proven that the virus is not a recent introduction from Australia and has been present in the United States since 2002 (USDA 2008). The virus can appear in hives with or without CCD, meaning that the correlation between the two may not be significant (Schacker 2008). However, phylogenetic analyses have shown that IAPV is an important pathogen that should be considered as a candidate for what is causing CCD (Palacios et al. 2008).

The type of colony management may also be another factor to consider. Large commercial beekeepers have been more affected by IAPV than small-scale beekeeping operations, suggesting that the stress of the honeybee, pesticides, or poor nutrition may be correlated with weakened immune systems and infection (Readicker 2009). Further tests are being done to determine if viruses should still be considered a relevant factor in explaining CCD and the differences between imported and domestic strains of IAPV (Kaplan 2008).

According to Eric Mussen, an entomologist from UC Davis, “Honey bee colonies are being stressed by a large number of things and when those stresses become overwhelming, the bees simply fly away from the hive” (Mussen 2011). Researchers who study colony collapse disorder are exploring viruses, such as IAPV, in combination with other stressors in order to understand why honeybees are becoming more susceptible to disease.
**Fungal diseases**

Some of the honeybees that have been recovered and dissected have shown high levels of bacteria and fungi. Nosema and other pathogens such as American foulbrood and chalkbrood can contaminate hives. Some researchers have suggested that once honeybees are infected with disease, their immune systems are compromised and they are more likely to disappear from the colony (Johnson 2009). On the other hand, immune deficiencies caused by other stress-induced factors may be causing honeybees to become more vulnerable to infection.

**Nosemosis**

Nosemosis is caused by a single-celled fungus (microsporidia) that is an obligate intra-cellular parasite (Paxton 2010). The parasite’s only means of multiplying is by living in honeybee mid-gut cells, where it takes over the cell’s functions of obtaining nutrients. It eventually ruptures and kills the cell and is then released into the gut lumen and into other mid-gut cells (Schacker 2008). A *Nosema apis* infection prevents the development of the glands that secrete royal jelly, leading to sick bees unable to feed the brood (Vivian 1986). Queens who get infected usually stop producing eggs, slowing down growth of the entire colony (Somerville 2007). The parasite is spread easily through defecation by infected bees because other healthy bees, which naturally clean the hive, ingest the parasite. The hive will have dark and yellow streaks on the front and on the comb (see Figure 5; Vivian 1986). The bees will twitch and will be unable to fly due to disjointed wings. They will also have enlarged abdomens and lack body hair (Vivian 1986).
*Nosema ceranae* was reported in Taiwan in the spring of 1995, when the virus had transferred from the Eastern honeybee (*Apis cerana*) to the Western honeybee (*Apis mellifera*) (Paxton 2010). The parasite spread and was eventually discovered in Europe in 2006. Although the bees suffered from nosemosis, *nosema* is still not described as causing symptoms that are commonly associated with CCD (Schacker 2008).

While nosemosis is not considered to be the cause of CCD, it is still viewed as a major stressing factor that can infect hives and potentially kill the colony (Paxton 2010). A major difference between *N. ceranae* and *N. apis* is in the severity of the infection. *N. ceranae* is more aggressive and can occur year round, collapsing a hive in merely eight days (Schacker 2008). *N. apis*, on the other hand, usually only appears in the winter months when the bees are under more stress. It often goes away once the spring comes and foraging begins again (Somerville 2007).

One way to treat nosemosis is by using an anti-parasitic drug called Fumagilin-B®. The chemical is effective against the parasite within the gut of the bees, but not against the spores (Vivian 1986). A strong colony can resist nosemosis. However, when honeybees are under increased stress, they are more prone to infection.

*American foulbrood*

American foulbrood (AFB) is a crippling disease caused by *Paenibacillus larvae* ssp., a spore-forming bacterium (Spivak 2001). Young larvae no more than three days old are the most susceptible to this particular disease and can be infected by feeding on spores (Antúnez et al. 2009). The spores then develop inside of the larvae’s guts (Vivian 1986). Once a honeybee is infected, both the population and the overall production (e.g. honey, pollen, propolis, royal jelly, and beeswax) decrease (Spivak 2001). When the
bacteria infect a larva, the larva first turns a tan color. Death makes the larva look dark brown and shriveled up (Antúnez et al. 2009). An irregular brood pattern may be another sign that a hive is infected (Conrad 2009). This irregularity may be evidenced by a number of empty cells among capped cells meaning that the brood is not being formed at the same time. Lastly, there will be a foul smell emanating from the infected combs (Conrad 2009).

AFB is one of the most serious and common diseases for honeybees. Its spores can remain viable for up to fifty years waiting for the perfect environment for growth and reproduction (Antúnez et al. 2009). Once the spores germinate, they contaminate honey and comb as well as permeate into wood fibers. AFB is easily transferred between bees within a colony as well as between colonies (Vivian 1986). This is why it is imperative that the beekeeper is immediately aware of the signs indicating AFB.

American foulbrood is a worldwide outbreak and two percent of all colonies have it at a given time (Vivian 1986). Treatment includes burning the bees, combs, and the equipment, or using antibiotics. Burning seems to be an effective method, but it is an extremely destructive approach. Antibiotics only work against active bacteria, not spores (Antúnez et al. 2009). The spores still remain in the honey, wax, and pollen and may infect the hive again when the antibiotic is removed (Conrad 2009). American foulbrood does not lead to colony collapse by itself, but additional studies need to examine if the chemicals that are used to combat AFB are further weakening the bee’s immune system making them more susceptible to infection (Conrad 2009).
**Chalkbrood**

Chalkbrood is a fungal disease caused by *Ascosphaera apis* (Vivian 1986). It was first reported in California in 1968 (Vivian 1986). Fungal spores are ingested by the bee and the growing fungal mycelium causes the infected larva to mummify and turn white. If the mycelia of are opposite sexes, the mummies will turn a darker gray color (Gilliam 1983). Larvae that are about to be sealed or have just been sealed are the most vulnerable to the disease (Flores 2005). Pollen combs may be a primary source of transmittance and if infected pollen combs are transferred to healthy hives, the healthy brood will ingest the spores (Flores 2005). Further research needs to be conducted to better understand how to prevent the conditions that make brood susceptible to chalkbrood.

Researchers have found *Nosema ceranae*, chalkbrood, and other pathogens in infected hives suggesting that high levels of contamination are severely harming the immune system of honeybees (Johnson 2009). However, natural resistance to these particular pathogens is more successful when a honeybee colony is in good condition. When colonies receive an adequate food supply and the bees within that colony are healthy and maintain hygienic grooming, the colony will have a higher resistance to disease. However, as honeybees are weakened by a variety of other destructive anthropogenic factors, less hygienic grooming takes place, meaning the colony will have less of a resistance to disease.

Increased stress is most likely leading to the honeybee’s weakened immune system and the bee’s frail state may be allowing infection to take over the hive. Scientists, researchers, and beekeepers are still trying to correlate the symptoms of natural causes such as mites and pathogens with the stress induced by anthropogenic
causes. If all of the potential causes of CCD are well understood, then we can begin to find ways to reverse the dramatic honeybee losses.

**Human-related Factors**

Anthropogenic causes of CCD include: transportation of honeybees for commercial pollination, malnutrition, genetic loss due to artificial queen insemination, and increased amounts of pesticides used on colonies and in the environment. Although mites, viral infections, and pathogens can cause honeybee fatality and diminish the population within a colony, disease does not explain the unprecedented widespread losses that are occurring today. There must be other factors that are contributing to the colony’s weakened state. It is mandatory to understand all of these potential stressors in order to better grasp the complexity of colony collapse disorder. This knowledge will be what drives a change in human behavior that is vital to minimizing the future loss of pollinators.

*Transportation of Honeybees*

Western honeybees are considered one of the most valuable agricultural pollinators because they can be transported easily with relatively little maintenance (Williams et al. 2010). Industrial-scale beekeeping requires hundreds of thousands of hives to be trucked around the country for short seasons of pollination (Stokstad 2007). According to the Food and Agriculture Organization (FAO), the global population of commercial honeybee colonies has increased by 45% since 1961 (Aizen 2009). This statistic suggests that fast-paced economic globalization has been raising the demand for managed hives as a service for agricultural pollination. However, this increased demand
is occurring more rapidly than the supply of managed hives, which may be stressing the global pollination capacity (Aizen 2009).

Honeybees are responsible for pollinating roughly 100 different kinds of fruits and vegetables produced in the United States (see Figure 6; Stokstad 2007). Dairy and beef products are also reliant on honeybee pollination because bees help facilitate large yields of alfalfa. Without honeybees, we would have a much more difficult time obtaining the foods that we consume everyday.

In the last half century, there has been a major expansion in the cultivation of pollinator-dependent crops due to modern industrialized agriculture, resulting in a high demand for pollination services. However, populations of honeybees, both managed and feral, have been steadily falling due to a variety of stress factors. These losses are directly affecting commercial agriculture industries. The almond industry, for example, is an important and lucrative business that exemplifies a crop heavily reliant on honeybee pollination. The United States supplies 80% of the world’s almonds, and in 2006, almond exports were estimated to be worth $1.5 billion (Schacker 2008). Pollination of thousands of almond acres in California’s central valley requires the rental of honeybee colonies from all over the country. As honeybee populations continue to dwindle and as almond acreage continues to expand, the price of renting colonies has increased.

From 2004 to 2006, the price of honeybees for almond pollination rose from $54 per colony to $136 per colony, directly affecting the cost of almonds (Sumner 2006). Also, more land acreage has been dedicated to growing almonds. In 1996, there were 430
thousand acres for almonds in California and in 2004, this number rose to 550 thousand and is expected to increase even more (Sumner 2006). Decreased populations of honeybees as well as the increased competition between industries needing pollinators during the same months of the year for their respective crop has become extremely problematic, especially for the producers and the beekeepers involved in commercial crop pollination.

Increased transportation of hives and poor nutrition has been known to cause increased problems for bees. Honeybee colonies are often loaded onto eighteen-wheel flatbed trucks for days and are shipped through a range of time zones, causing their immune systems to be compromised (Stokstad 2007). The number of U.S. honeybee colonies dropped from 5 million in 1940 to 2 million in 1989 and it has been suggested that economic shifts in farming are to blame (Stokstad 2007). Colony loss, however, is a complex issue. The varroa mite, for example, was introduced to the U.S. in 1987 and since the parasite has nearly eradicated all wild honeybee colonies, farmers have to rely on rented colonies (VanEngelsdorp et al. 2009). This has resulted in the growth of large-scale beekeeping operations, which is causing bees to be more at risk for disease. There is an unsustainable positive feedback loop that is occurring and as honeybees are affected by increased stress associated with industrialized agriculture, colony collapse continues to worsen.

Malnutrition

In the United States, hives that are rented for commercial purposes tend to move from the West in the spring, often for the almond crop, to the North, Midwest, and East in the summer for a variety of other crops, including blueberries (Schacker 2008). It is an
intense process that is cumulatively putting a strain on the honeybee’s immune system. Nonetheless, commercial pollination remains imperative for big agricultural growers and the beekeepers that count on the fixed income from this operation.

Malnutrition is a consequence of shipping bees cross-country to pollinate a crop. According to Eric Mussen, “Most bees used for commercial pollination are placed in areas where only one, or perhaps just a few, pollens are available” (Mussen 2011). He continued to say that, “A good mix of pollens is required to rear healthy bees and many times this is not the case. Also, many commercial beekeepers that transport their bees long distances to pollinate crops use high-fructose corn syrup and soy protein to feed their bees during their travel. These food sources, however, are not the best replacements for the enzyme and nutrient-rich raw honey and pollen that normally make up a bee’s diet (Schacker 2008). Mussen continued to say, “Feeding bees man-made pollen substitutes and supplements will increase bee numbers, but those bees are not as nutritionally well fed and physiologically robust as are bees that have been living on a mixed pollen diet” (Mussen 2011)

The transportation of hives throughout the country has been happening for years, even before CCD was reported. On the other hand, colony collapse has worsened since there have been increases in habitat loss and decreases in nectar and pollen biodiversity (Naug 2009). A loss of bee forage may be synergistically combining with disease as well as a variety of other stress factors to lower bee population. Further research needs to be conducted on the health of honeybees, especially at times when they are not receiving a diverse diet.
Genetic Loss

Scientists have been researching the lack of genetic diversity in managed honeybee colonies as another factor contributing to colony collapse disorder. The commercial beekeeping industry relies on only about 500 breeder queens to produce the millions of queens used to start colonies, which can be seen as a “genetic bottleneck” (Ellis 2009). The shortage of genetic diversity may be causing honeybees to become more susceptible to disease, despite the fact that honeybees have numerous defenses against parasites and pathogens (Oldroyd 2007). According to a survey that reported reasons of colony loss from 305 beekeeping operations in the U.S. (13.3% of managed colonies in the country), although starvation, varroa mites, and CCD were significant to colony loss, the primary problem for beekeepers was “poor queens” (vanEngelsdorp 2008).

In many cases, honeybee colonies are able to overcome times of infection because worker bees have an innate behavior to constantly rid the hive of diseased brood. However, for a colony to be resilient to pathogens and to overcome times of infection, it requires a high level of genetic variation (Oldroyd 2007). As the single egg layer in the hive, it is critical for the queen to be healthy. During mating flights, a queen will mate with an average of 12 drones, which is among the highest levels of polyandry in social insects, and this genetic variability is reflected in the gene base of her workers (Tarpy 2003).

Multiple studies have tested the association between genetic diversity and disease susceptibility in honeybees. Results have shown that the higher the genetic diversity within a hive, the more resilient the hive is to parasites and pathogens. This is because the
worker bees have an increased fitness that allows them to engage in hygienic behavior more effectively and there is higher brood viability (Tarpy 2003). As artificial insemination of queens and honeybee domestication become more common and as the honeybee gene pool becomes smaller, infestations of parasites and pathogens will become more common. It is therefore becoming increasingly necessary to understand the factors that are contributing to “low-quality queens” (Delaney et al. 2010).

**Pesticides**

Many people believe that pesticides, especially a newly released class of insecticides, called neonicotinoids, are the cause of CCD (Kaplan 2008). Modern industrialized agriculture relies on vast amounts of chemicals to produce high crop yields. Also, as mites and viruses have become more prevalent, beekeepers are increasing how often they use miticides and chemicals to treat their colonies. Therefore, honeybees have become more exposed to pesticides when foraging as well as during times of infection.

**Neonicotinoids**

Beekeepers and scientists all over the world have become more interested in the harmful effects of pesticides, particularly since a new class of neuro-active insecticides, called neonicotinoids (modeled after nicotine) have been released on the market (Matsuda 2001). Neuro-active insecticides are extremely dangerous to honeybees because they disturb the organism’s neurobehavioral and immune system, both of which are crucial to the insect’s well being (Schacker 2008).

Most of today’s farmers depend on chemicals for an increased yield. In the past, insecticides were sprayed aerially, but now most seeds are chemically treated before they are even planted. For example, imidaclorpid, a neonicotinoid, is either painted on seeds
or is poured around a plant in a “soil drench” (Schacker 2008). This is problematic because the toxins are now systemic, meaning that they are integrated throughout the entire plant. Thus, the toxins are likely to be taken up by honeybees even though they are not meant for the pollinators (Theobald 2010).

Corn, for example, is considered an important protein source for honeybees and covers more than 88 million acres of U.S. farmlands (Schacker 2008). Most conventional corn seeds and nearly all genetically modified corn seeds containing Bt are coated with nicotinyl seed treatments, making it nearly impossible for honeybees to resist exposure (Benbrook 2008). The two examples of neonicotinoids that will be discussed in this paper are imidacloprid and clothianidin, each of which is gaining momentum as causal agents of CCD (Theobald 2010).

Imidacloprid

Imidacloprid (IMD) is a neonicotinoid manufactured by Bayer CropScience under the name GAUCHO. It is a patented chemical used for pest control, seed treatments, and insecticide spray. IMD was first registered in the U.S. in 1994 and is now used on a wide variety of crops (Theobald 2010). IMD is similar to DDT in the sense that they are both neurotoxins and have properties similar to nerve gas and are both designed to block important parts of the pest’s nervous system to keep them from properly functioning (Matsuda 2001). However, even though honeybees are not the targeted insect, they are experiencing the same symptoms. When the chemical was first authorized, Bayer’s studies reported that GAUCHO was safe for bees because only the roots of the plant would get IMD and not the flower or the nectar (Schacker 2008). However, researchers have continued to conduct studies on neurotoxins and many of them have found that
imidacloprid at a concentration of 100 ppb disrupts honeybee communication, therefore resulting in a decline in foraging activity (Bortolotti et al. 2003). Further research needs to be conducted in order to better portray the effects of imidacloprid on honeybees.

Clothianidin

Clothianidin is another example of a highly toxic neonicotinoid that has been said to be a culprit for honeybee deaths (see Figure 7). The pesticide is manufactured by Bayer CropScience under the name PONCHO and was granted registration by the EPA in 2003 (Mogerman 2008).

Clothianidin is used to coat corn, soy, sugar beets, sunflowers, as well as other seeds and is now extremely common in the market (Kay 2008). Since its release, farmers have purchased more than $262 million worth of the insecticide (Keim 2010). Before a pesticide can be approved for use, a company must submit a report attesting its safety to honeybees, and Bayer’s report indicated that clothianidin was harmless to bees (Kay 2008). However, in 2008, a leaked EPA memo revealed flawed testing that Bayer conducted on honeybees. Later investigations reported that the study by Bayer was an unsuitable way to observe the effects of the pesticide on honeybees (Theobald 2010).

According to recent reports, the Bayer safety tests on clothianidin were conducted on two acre-plots of land for each of the treated crops. Honeybees, however, usually fly at least two miles away from the hive to forage, so most likely, the bees did not collect very much pollen from the treated crops. Also, the tests used treated canola rather than
corn – the major plant species that bees rely on as a primary protein source in the winter (Theobald 2010). It appeared that Bayer designed tests that were not realistic with respect to known honeybee foraging patterns.

In a statement by commercial beekeeper Dave Hackenberg:

What folks need to understand is that the beekeeping industry, which is responsible for a third of the food we all eat, is at a critical threshold for economic reasons and reasons to do with bee population dynamics. Our bees are living for 30 days instead of 42, nursing bees are having to forage because there aren’t enough foragers and at a certain point a colony just doesn’t have the critical mass to keep going...

The bees are at that point, and we are at that point. We are losing our livelihoods at a time when there just isn’t other work. Another winter of more studies are needed so Bayer can keep their blockbuster products on the market and EPA can avoid a difficult decision, is unacceptable.

Clearly, the fight between beekeepers and pesticide companies is a controversial issue. At this point, 121 different pesticides have been found in bees, wax, and pollen (Benjamin 2010). According to Eric Mussen, “Many beekeepers are convinced that exposure to pesticides is causing the problem. While it is true that ALL pesticides are detrimental to the physiology of exposed honeybees, residue analyses have shown that apparently healthy colonies have as many or more pesticide residues than collapsing colonies” (Mussen 2011). Although specific chemicals are known to have adverse sub-lethal effects on honeybees, further research is important in order for the scientific community to have a consistent understanding of the relationship between pesticides and CCD.

**Cell Phones**

Cell phones were once mistakenly thought to contribute to CCD. This idea came about when two German scientists at Landau University conducted research to better understand the effects of radioactive waves on honeybee’s ability to navigate (Kuhn
2003). However, the study did not use a mobile phone, but rather a cordless phone base (Schacker 2008). *The Independent*, a UK-based newspaper, published a story called, “Are Mobile Phones Wiping Out Our Bees?” The story reported that the scientists claimed that cell phones were interfering with the bees’ ability to navigate and that bees refused to return to their hives when cell phones were placed nearby (Lean 2007). Similar articles were published internationally, causing people to automatically relate cell phones to CCD. It turned out that *The Independent’s* reporters got their facts wrong considering cell phones were not even used in the experiment and the reporters had not even spoken to the German scientists (Schacker 2008) It is imperative that colony collapse disorder is not undermined due to faulty communication between researchers and the media.

**SECTION III: Effects of Colony Collapse Disorder**

“If the bee disappears from the surface of the earth, man would have no more than four years to live.”

~Albert Einstein~

**Effects**

If colony collapse disorder continues to worsen, there will be costly economic, ecological, and social effects. Honeybees play an integral role in the environment, which affects the biological system as a whole. As the biological system breaks down, humans will face consequences that will severely impact their health and their livelihoods. It is mandatory to consider these repercussions when discussing the possible extinction of the honeybee.
Economic Effects

According to the CCD Steering Committee, honeybees are economically worth $15 billion to the U.S. economy though the enabled production of food (CCD Steering Committee 2007). If CCD continues to worsen in the United States, there will be a variety of direct and indirect economic costs. Direct costs include the loss of jobs and commercial farming sectors, while indirect costs include increased trade deficits and food prices.

With losses of 50% or more each year of honeybee colonies, commercial beekeeping is already struggling to remain in business (Schacker 2008). If losses continue, there will be a rise in the cost of managing bees causing the price of honeybee rentals to increase. This price increase will severely impact many agriculture industries, including the California almond growers who rely on honeybee colonies to support the $2 billion almond industry (Sumner 2006). As production costs rise and crops that depend on honeybee pollination decrease, farmers will be forced to convert to growing plants that do not depend on pollination or abandon their farms all together (Munawar et al. 2009). Small farmers will be predominately affected because of the high variety of crops they grow and the lack of subsidies from the government. Also, dairy and beef farmers will be affected because their livestock depends on clover and other foraging crops for food (Berenbaum 2007).

As colony collapse disorder leads to larger local extinctions of honeybees, there will be a loss of crops that rely on pollination. This will lead to the importation of bees and food from foreign countries (Berenbaum 2007). If the United States is forced to import more food, the prices may be higher than they are now and the U.S. will face an
increased trade deficit (Berenbaum 2007). This deficit will be compounded as production and commodity exports decrease. For example, the U.S. supplies 80% of the world’s almonds, a crop that is heavily reliant on honeybees for pollination. If there is a significant loss of bees, then almond orchards face the risk of going bankrupt (Schacker 2008). Furthermore, the remaining beekeepers in the honey industry may be forced to leave the sector because they will be competing with cheaper, imported honey (Aizen 2009). There is also a major risk of importing bees to local fauna because of the introduction of new pests.

With increased pollination costs, the total price of crops grown in the United States will most likely increase and result in a reduction of consumer welfare (Berenbaum 2007). For example, if apple orchards on the Western Slope in Colorado are forced to import honeybee colonies for pollination (a service already in high demand), then there will be a rise in internal production costs – this increased cost will be passed onto consumers.

Pollination services support an entire system of agriculture, and if we do not take significant action, repercussions of further honeybee loss will distress the entire nation. If economists need to monetize nature to show the benefits of honeybee services to make positive environmental change, then I think it is well worth a more in-depth analysis to create agricultural and conservation policies.

Ecological Effects

As both a keystone species and index species, honeybees provide a service that supports a large range of ecosystems, while also indicating the health of their surrounding environment. Honeybees promote ecosystem vitality through services that provide
pollination and help maintain genetic diversity by enabling reproduction of a wide variety of plant species. Biodiversity is extremely important for an ecological system because it allows for competition and natural selection among different plant species, thus reducing the risk of disease and vulnerability to pathogens. These plants also provide shelter for animals and generate the fruit and seeds on which they depend (Berenbaum 2007). If vital pollinators such as honeybees are lost, the ecological effects will be detrimental to an entire biological system.

Honeybees also serve as an index species because they are able to show the condition of the environment. The fact that honeybees are dying in significant numbers suggests that there is an important imbalance to be addressed in the environment. The analysis of honey, wax, and the bees themselves, is helpful in providing a better understanding of the diffusion of pesticides in the environment (Chauzat 2006). Studies have also indicated that radionuclide contamination and heavy metal contamination can also be monitored using honeybees (Chauzat 2006). The close relationship that these insects have with the environment allows them to serve as indicators for contamination. This is an important service to humans because, similar to bees, we require a healthy environment to remain a viable species.

**Social Effects**

If colony collapse continues to worsen and crops that depend on pollination become increasingly scarce, there will be dramatic social effects. It is possible that middle and low class families will be forced to pay three to four times more than what they already pay for food (Schacker 2008). After years of inflation and rising prices for oil, electricity, and healthcare, these added food costs will be significant and could
potentially limit access to nutritional foods. If families do not receive nutritional food, health problems such as obesity and diabetes will most likely increase and further raise the price of healthcare (Schacker 2008).

In addition to the stratified effects described above, CCD will also affect the livelihoods of beekeepers and farmers. Generations of families who have farmed their land for centuries will be forced out of business. Effects will also be felt throughout the food sector as a whole. Grocery stores and restaurants will experience increased prices, scarcity of crops for food, and a diminished consumer base (Berenbaum 2007). With 11.2 million people working in the food service industry and 400 thousand people working in the agricultural industry in the United States, a loss of honeybees will have significant repercussions (Bureau of Labor Statistics 2010).

Honeybees are responsible for pollinating a diverse range of flowering plants, thus maintaining ecological diversity and providing valuable commodities for humans. There will be severe losses ecologically, agriculturally, and economically if honeybee populations cease to exist. It is mandatory for people to evaluate the effects of continued colony loss as an incentive to promote honeybee awareness and contribute to preventing further losses.

SECTION IV: Mitigation Strategies for Colony Collapse Disorder

“We allow the chemical death rain to fall as though there were no alternatives, whereas in fact there are many, and our ingenuity could soon discover many more if given opportunity.”
~Rachel Carson~

Policy Recommendations

The consequences of colony collapse disorder are broadly distributed among the general public. Moreover, the potential causes of CCD - such as pesticides, commercial
pollination, and decreasing biodiversity in agriculture - are firmly ingrained into the daily processes of our society. Therefore, government policies must play an important role in the protection of public health and the promotion of a safer environment for key pollinators.

Examples of useful policies include: pesticide bans, rooftop beekeeping in urban environments, funding and technical support for community gardening, organic farming, public education, scientific research, and support for local and commercial beekeepers. Several countries that have also been impacted by colony collapse have reacted to the disorder through a mix of public education initiatives, policies, and further research. Some of these efforts are described below, in addition to examples of local government action in the United States.

**France**

In July of 1994, French beekeepers noticed that shortly after sunflowers were in full bloom, hives began to collapse (Theobald 2010). Worker bees flew off and never returned, leaving the queen and some brood to die. Beekeepers also noted that GAUCHO, a new insecticide containing imidacloprid (IMD), was recently approved as a product by Bayer CropScience (Schacker 2008). Between 1996 and 1999, production of sunflower honey fell from 110,000 metric tons to 50,000 tons and between 1995 and 2000, 76% of French apiaries suffered high winter losses of their bees (Schacker 2008). French beekeepers appealed to the government for help while French researchers began conducting a variety of studies (Underwood 2010). The protest by beekeepers was successful. In 1999, France banned IMD on sunflowers and in 2003 they banned the chemical on sweet corn (Underwood 2010). However, even after the ban was put into
place, French beekeepers continued to see declines in their bee populations. They
discovered another insecticide in the soil, Regent, that contains fipronil (Schacker 2008).
Fipronil is an insecticide that was commonly used to coat sunflower seeds in the South of
France and tests showed that the insecticide negatively affects honeybee perception,
olfactory learning, and motor function; all which are required for foraging behavior
(Hassani et al. 2005). As a precautionary measure, in 2004, the head of ministry
suspended the use of fipronil, and by 2005, beekeepers saw a return in their bee
populations (Schacker 2008). The resurgence in honeybees suggested that IMD and
fipronil were the culprits causing CCD. The fight in France to ban pesticides set a
precedent for beekeepers and government agencies around the world: create policies to
limit harmful environmental toxins in order to prevent further colony collapses.

**Germany**

In May of 2008, the Baden-Wurtemberg region of Germany lost two-thirds of its
colonies (Theobald 2010). Scientists traced the losses to pesticides, specifically
clothianidin, which had been registered in Germany in 2004 (Theobald 2010). Within two
weeks, Germany suspended the registration of clothianidin (Schacker 2008). Since
France and Germany have banned imidacloprid, fipronil, and clothianidin, many other
countries and provinces have followed suit, including Italy, Japan, the United Kingdom,
and British Columbia.

**New York**

In addition to pesticide bans, governments have engaged in other strategies to
fight colony collapse disorder, including methods to encourage beekeeping and promote
bee awareness. For example, in the spring of 2010, New York overturned its statewide
anti-beekeeping ordinance (Navarro 2010). The original fear of policymakers was that bees were too dangerous to be in a busy city and that people would be stung. By making urban beekeeping legal, beekeepers were able to show that honeybees are not dangerous creatures and are actually beneficial. Andrew Cote, president of the New York City Beekeepers Association said, “Honeybees are interested in water, pollen, and nectar and the real danger is the skewed public perception of the danger of honeybees” (Navarro 2010). Beekeeping is still illegal in 89 U.S. cities, a policy that should be changed in order to promote the collective welfare of honeybees and humans (LeVaux 2010).

**Other Recommendations and Strategies**

There are a number of actions that our communities can take to reverse or eliminate colony collapse disorder. First, we can increase the funding that we put into research on this pressing issue. It is important to collect data on pollination services, colony movement between states, and the general heath of bees. Such information will show the economic value of honeybees as well as their condition (Berenbaum 2007). Also, it is important to better examine wild bees. Wild pollinators are important for crop pollination and are actually more versatile than the honeybees, but are also experiencing rapid loss (Berenbaum 2007). As honeybees continue to disappear, there needs to be a better understanding of the impacts that other native pollinators have on our agricultural system and larger ecosystem, as well as their current level of vitality. This information will be useful as researchers and elected officials begin to implement strategies to cope with the effects of CCD in the effort to sustain agriculture over time.
It is also important for elected officials and community leaders to engage in actions that promote sustainable agriculture, foster bee awareness, and help to reverse CCD. For example, Michelle Obama made a statement when she announced the White House was going to plant an organic vegetable garden as a way to promote healthy living and the need to tackle obesity throughout the country. The garden also includes a beehive that helps to pollinate crops and serve the educational mission of the program (see Figure 8, Flottum 2009). Planting gardens and keeping bees are some ways that the general public can better appreciate the importance of honeybees and the direct role that these pollinators play in our lives. By being directly involved with bees, people can better understand colony collapse disorder and make informed decisions about honeybee policies.

Many people who live in cities and do not have access to garden space or room have begun keeping beehives on their roofs. Policies have been enacted that allow people to keep hives on the roofs of apartments and municipal buildings (see Figure 9). Mayor Richard Daley of Chicago put beehives on top of City Hall (Hinke 2007). Harvesting of the honey is done by a trained beekeeper in conjunction with city youth programs. The 200 pounds of honey that they retrieve annually is jarred and sold in the city hall gift shop, and the proceeds benefit Chicago Cultural Center projects (Hinke 2007). The Chicago urban beehive project is now a model for other cities interested in expanding the welfare of bees. This is a perfect example of how to tie the importance of honeybees into
an entire city. Urban hives are a way to promote bee awareness and support healthy bee colonies.

Education is another important strategy to combating CCD. Colleges and communities can both have a major impact. It is important to educate their constituents about the stressors that are playing a role in honeybee disappearance and to provide them with opportunities that will contribute to the prevention of further losses. Personally, I have been involved with a number of efforts to promote education in both my college and my community. At the University of Colorado at Boulder, I planned an event to screen the movie, *Vanishing of the Bees*. This film addresses the broad spectrum of what may be contributing to colony collapse as well as provides ways for viewers to take action. In addition to public education events, CU has pledged to completely rid the campus of pesticides by 2015. As described earlier in this paper, pesticides have been demonstrated to have severe consequences to honeybees. As part of my strategy to combat colony collapse, I contributed a crucial element to the campus pesticide reduction plan; more specifically, a brief excerpt on colony collapse disorder and a description of how honeybees are affected by the widespread use of pesticides (see Appendix 3). I hope that this plan to make the campus pesticide-free can serve as a model for other universities.

In my Boulder community, I have joined a group of beekeepers and concerned citizens. The group, called *Coalition 4 B’s* (bees, birds, bats, butterflies), has bi-monthly meetings to discuss ways in which we can promote honeybee awareness and plan events where we can educate the general public. We have also worked with other groups around the United States to combat honeybee loss. Contributions such as these are some of the most effective ways ordinary citizens can help resolve the problem of honeybee losses.
Through grassroots organization and willingness to change, communities can influence the decisions of elected officials and encourage them to pass strong policies that support the health of our most vital pollinator.

**Conclusion**

Since CCD was reported in 2006, beekeepers have seen as many as 90% of the bees within their hive disappear, making this issue of great importance (Mogerman 2008). In testimony before Congress, May Berenbaum said, “If honeybee numbers continue to decline at rates documented from 1989 to 1996, managed honeybees will cease to exist by 2035” (Berenbaum 2007). Honeybee pollination is an essential service that must be preserved. Honeybees need to be given an economic valuation in order for their services to be quantified (Draxler 2011). Right now, they are worth $15 billion to American agriculture, but their ability to support an entire ecosystem is worth much more. If there are no more honeybees to pollinate crops, the food supply would not be completely destroyed in terms of how many calories we consume. Plants that do not require insect pollination such as grains could still be produced, but the bulk of the food we consume for vitamins and nutritional content would not exist if there were no insects to pollinate them (Berenbaum 2007). Food security is at risk, especially as our population continues to rise.

A perfect storm of stressors is putting the honeybees at risk of extinction. The lack of diversity within our agricultural system is even more dangerous because there is not enough variety in agro-ecosystems to support healthy pollinator communities (Steffan-Dewenter 2005). If we do not change how crops are grown and the amount of
chemicals that are dumped into the environment every day, pollinators will continue to suffer and humans will risk losing one of our most valued necessities, food.

In the winter of 2009 alone, according to the Apiary Inspectors of America and the US government’s Agricultural Research Service, the number of managed honeybee colonies in the United States fell by 33.8% (Benjamin 2010). The pollen collecting skills that a honeybee possesses are vital for the lives of farmers, the environment, and humanity as a whole that depend on crops to survive. Unfortunately, there has still been a devastatingly slow response by the federal government.

**Further Research**

The 30% loss of honeybees suffered in the last several years to colony collapse disorder has prompted ecologists to investigate other pollinators. All pollinators depend on a healthy ecosystem. Already, bats, hummingbirds, and butterflies have been disappearing (Schacker 2008). Although I examined many of the current hypotheses surrounding colony collapse, other factors are also being considered. These include the effects of habitat loss and the overall effects of climate change (Konkel 2009).

Habitat loss is most likely not a direct cause to colony collapse disorder, but the loss of open space for foraging is putting pollinators at a major risk. Habitat is being lost because of agriculture, grazing, fragmentation, and development. Honeybees rely on a variety of flowers and flowering plants for nectar and pollen sources and as fragmentation increases, pollinator species and numbers are decreasing (Kearns 1997). When there are fewer pollinators, plant reproduction and fitness are adversely affected. Also, when there are fewer pollinators, the production of seeds and fruits is reduced, which affects all the species that depend on these sources of food. With entire ecosystems
dependent on pollinators for survival, it is wise to include habitat loss in the discussion concerning CCD.

In the past century, large-scale monocultures have been the most prevalent way to farm and by doing this, the amount of wild vegetation has been compromised. This affects honeybees because it is important for them to be able to feed from a wide variety of sources for pollen and nectar (Kearns 1997). Also, increased development is causing more habitat fragmentation, which also may affect the bees and other pollinating species that forage in a specific way. For example, flowers that are in a small population may be passed by pollinators that usually look for large patches of flowers, thus causing certain plants to not get mandatory pollination services (Kearns 1997). Biologists who study habitat fragmentation speculate the possible loss of species because of the ecological changes that result from it. They have also said that the collapse of pollinator-plant relationships is likely as well, but further studies need to be done (Harrison 1999).

Another factor that has shown to be correlated with CCD is climate change. Weather patterns affect bee’s foraging behavior. As warmer temperatures and the severity of droughts become more prevalent, there could be major effects on pollinators. Droughts will limit the amount of available water causing bees to be at increased risk for fatality (Willmer 1991). Also, oftentimes warm weather allows the increased migration of parasites and pathogens. The spreading of disease is already a major problem facing honeybees and climate change could worsen the situation. As global temperatures are steadily rising, it is important to understand the potential effects in order to take proactive measures to save this vital species.

Although further research needs to be conducted on other potential causes that
may be contributing to colony loss, it can be said with certainty that the amount of
disease infecting honeybees rose as the number of toxic chemicals available to treat them
increased and modern beekeeping turned into a business to produce the maximum profit
with little regard to the honeybee’s overall health. Natural processes to treat honeybee
infections have been slowly disregarded and organic beekeeping has become nearly
impossible to do because of the widespread use of pesticides. Honeybees are being
pushed past their normal work capacity and becoming stressed by a variety of factors.
These incredible social creatures have been functioning as a system for millions of years
and the more fast-paced that human society becomes and the more rapidly we expect
these bees to work for us, the more collapse we will see.
Bibliography


Flinn, Pat. E-mail interview. 09 Feb. 2011.


Mussen, Eric. E-mail interview. 26 Jan. 2011.


Tarpy, David R., Joshua Summers, and Jennifer J. Keller. "Comparison of Parasitic Mites in Russian-Hybrid and Italian Honey Bee (Hymenoptera: Apidae) Colonies across Three


Appendix 1

Possible causes of honeybee losses

Colony Collapse Disorder (CCD)?
Appendix 2

Avoid using these neonicotinoid pesticides
Synthetic nicotine-based pesticides toxic to honeybees and native pollinators

Ingredient names of products used in agriculture
Acetamiprid  ADJUST, ASSAIL, CHIPCO, INTRUDER, PRISTINE
Clothianidin  ARENA, BELAY, CLUTCH, PONCHO, TITAN
Dinotefuran  VENOM
Imidacloprid  ADMIRE (used on potatoes, corn, grapes, vegetables, citrus), ADVANTAGE, CONFIDOR, GAUCHO (used on corn, cotton, potatoes), HACHIBUSAN, KOHINOR, LEVERAGE (cotton), MERIT (turf), PREMISE (termites), PROTHOR, PROVADO (fruits, vegetables), WINNER
Thiacloprid  CALYPSO (used on apple, pear, quince, crabapple)
Thiamethoxam  ACTARA, ADAGE, CENTRIC, CRUISER, FLAGSHIP, HELIX, MERIDIAN, PLATINUM

We are asking growers not to use these products until more research is done.

Products found in local nurseries and hardware stores for home use:

**AVOID:**
Bonide Systemic Insect Spray: *Look for the active ingredient: Imidacloprid*
Bonide Systemic Insect Granules: *Active Ingredient: Imidacloprid*
Bonide Systemic Houseplant Insect Control: *Active Ingredient: Imidacloprid*
Bayer Season Long Grub Control: *Active Ingredient: Imidacloprid*
Bayer Advanced 3 in 1 Insect Disease and Mite Control: *Active Ingredient: Imidacloprid*
Bayer Advanced 2 in 1 Systemic Rose & Flower Care: *Active Ingredient: Imidacloprid*
Bayer Advanced 12 Month Tree & Shrub Protect & Feed: *Active Ingredient: Imidacloprid*
Bayer Advanced Tree & Shrub Insect Control 12 month: *Active Ingredient: Imidacloprid*
Bayer Advanced Dual Action Rose & Flower Insect Killer: *Active Ingredient: Imidacloprid*
Bayer Advanced Lawn Season Long Grub Control: *Active Ingredient: Imidacloprid*
Bayer Advanced Lawn Complete Insect Killer for Soil & Turf: *Active Ingredient: Imidacloprid*
Bayer Advanced Fruit Citrus & Vegetable Insect Control: *Active Ingredient: Imidacloprid*
Bayer Termite Control: *Active Ingredient: Imidacloprid*
Bayer All in One Rose and Flower Care: *Active Ingredient: Imidacloprid*
Ortho Max Tree & Shrub Insect Control: *Active Ingredient: Imidacloprid*
Ortho Max Flower, Fruit & Vegetable Insect Killer: *Look for the active ingredient Acetamiprid*
Ortho Rose Pride Insect Killer: *Active Ingredient: Acetamiprid*
Green Light Tree & Shrub Systemic Insect Killer: *Active Ingredient: Imidacloprid*
Green Light Systemic Rose & Flower Care: *Active Ingredient: Imidacloprid*

Never use a neonicotinoid pesticide on a blooming crop or on blooming weeds if honeybees are present.
Appendix 3

Excerpt from *The Turf Management Task Force Summery*

*Colony Collapse Disorder*

Colony collapse disorder (CCD), sometimes referred to as honeybee depopulation syndrome (HBPS), is a phenomenon in which worker bees from a beehive abruptly disappear. Symptoms include the rapid loss of adult worker bees, few or no dead bees found in the hive, and only a small cluster of bees with a live queen present and pollen and honey stores remaining in the hive. It was first reported in the United States in 2006 and has been dramatically affecting hives across the nation since. A direct cause has not yet been concluded for CCD, but potential stressors of this problem include commercial land-use, mites, pathogens, pesticides, and insecticides. A combination of these may be to blame, but studies have not yet found results that could be fully responsible for the problem, and may never, due the various concerns that could be causing the death of honeybees 1. As a member of the Boulder community, the University should limit its negative impacts on honeybees that will significantly affect local beekeepers, farmers, gardeners, and the general public.

Pesticides have often been suspected as the cause of CCD, and many studies conducted by the USDA and the EPA as well as by governmental agencies abroad, like the French Agriculture Ministry, have noted that various pesticides affect a bee’s ability to forage and may affect the fertility of a colony’s queen. Additional research has indicated that pesticides can be lethal to honeybees. Sublethal pesticide effects, however, are subtler, although tests indicate that even small doses of pesticide exposure can affect honey production, cause foragers to disappear and kill off colonies (Underwood, vanEngelsdorp: 4). 2

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Appendix 4

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
Ariel Rios Building, MC 1101A 1200 Pennsylvania Avenue NW
Washington DC 20004

Dear Administrator Jackson:

In light of new revelations by your agency in a November 2, 2010 memorandum that a core registration study for the insecticide clothianidin has been downgraded to unacceptable for purposes of registration, we are writing to request that you take urgent action to stop the use of this toxic chemical. Clothianidin is a widely used pesticide linked to a severe and dangerous decline in pollinator populations. As we are sure you appreciate, the failure of the agency to provide adequate protection for pollinators under its pesticide registration program creates an emergency with imminent hazards: Food production, public health and the environment are all seriously threatened, and the collapse of the commercial honeybee-keeping industry would result in economic harm of the highest magnitude for U.S. agriculture.

The debate on clothianidin and the neonicotinoid pesticides is not new to the agency, but the recognition of the past failure of the Office of Pesticide Program’s (OPP) 2007 scientific review, now acknowledged, requires immediate action to stop use while new studies are conducted. We refer you to the memorandum entitled “Clothianidin Registration of Prosper T400 Seed Treatment on Mustard Seed and Poncho/Votivo Seed Treatment on Cotton,” November 2, 2010 (see pp. 2, 4). The science that the agency has, and the independent literature find that clothianidin-contaminated pollen and nectar presents an imminent hazard. Because the hazards to honeybee health are present within registered use parameters, it is clear that label changes alone will not offer adequate protection. The issue is not one of application error, in other words. We therefore urge the agency to issue a stop use order immediately. Our nation cannot afford, and the environment cannot tolerate another growing season of clothianidin use.

In addition, because this problem reflects an overuse of the conditional registration program in OPP, we urge you to set an immediate moratorium on the use of such registrations until the program is fully evaluated for compliance with its underlying
statutory responsibilities. The conditional registration of clothianidin in 2003 with outstanding data critical to its safety assessment represents a failure that could and should have been avoided. Clearly, the impacts on pollinators were not adequately evaluated prior to the issuance of the conditional registration, despite knowledge of “chronic toxic risk to honey bee larvae and the eventual instability of the hive.” This is the case with pollinator protection and a host of other issues that have direct bearing on environmental protection and public health.

In redoing the clothianidin study and evaluating the causes of Colony Collapse Disorder and the larger issue of the pollinator decline crisis, we urge you to establish protocol that fully assesses the complexities that come together to threaten the honeybees. To be fully protective of bees, reviews must consider multiple chemical and cumulative exposures, persistence, and synergistic effects. We can no longer rely on studies of individual chemicals in isolation.

Thank you for your attention to the pollinator crisis and efforts to stem the tide of contamination and poisoning. We look forward to your reply.

Sincerely,

National Honey Bee Advisory Board
Steve Ellis.
Secretary

American Honey Producers Association
Kenneth Haff
President

Pesticide Action Network North America
Heather Pilatic
Co-Director

American Beekeeping Federation
David Mendes
President

Beyond Pesticides
Jay Feldman
Executive Director

Center for Biological Diversity
Justin Augustine
Staff Attorney