Drew University

College of Liberal Arts

# Colony Collapse Disorder: An Exploration of Bee Population Decline and Ways to Prevent Future Losses

A Thesis in Environmental Studies

by

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## Abstract

Bees are some of the most important animals on the planet due to how ecologically crucial they are to the produce we consume. However, the bee population is declining at an alarming rate, and competing theories exist to explain this sudden decline. One theory is Colony Collapse Disorder (CCD). Scientists have yet to arrive at a consensus on the causes of CCD, but several contributing factors have been widely researched. This thesis analyzes CCD and quantifies its impact on the honeybee population (*Apis* genus), specifically in the US. Five possible causes of CCD are identified and explored: pesticides, habitat loss, mites, diseases and climate change. Data from the National Agricultural Statistics Service from 2015-2018 are summarized and visualized spatially to assess the relative impact of potential causes of CCD on overall bee populations. Lastly, existing policy actions to reduce the impacts of CCD are reviewed and compared. The results demonstrate that CCD is one contributing factor to bee losses. However, the causes of CCD contribute not only to bee deaths, but also widespread deaths among the larger insect population. This implies that potential solutions to CCD are also potential solutions to other serious environmental concerns. Future research should thus focus on multinational collaborations to address the pressing environmental issue of honey bee collapse.

## Table of Contents

## List of Figures

**List of Tables**

## Chapter I: Introduction

Recently, scientists have observed a rapid decrease in the population of flying insects. A study in Germany concluded that there was a 75% decline in the flying insect populations in northwest Germany from 1989 to 2016 (Byers, 2018). Honey bees have also been suffering from a decline in population. In addition, studies show that many bees are unable to return back to their hives and thus die. This condition is known as Colony Collapse Disorder (CCD), a disease that further causes worker bees to leave their hives and abandon their duties. This is not an uncommon occurrence, but there is still much we do not know about the condition. In fact, the main symptoms of CCD are inconsistent with every other type of honey bee death known (EPA, 2018). It seems that while honey bees can die from normal causes (old age, predators, diseases, possibly even pesticides and mites), their deaths have never been this frequent. Comments made by the EPA imply that the 'sudden' loss of the colony's workforce is not natural. Acute bee deaths are easier to identify than CCD diagnosis, so there are problems in measurement (EPA, 2018). Due to this sudden and strangely emergent pattern of bee deaths, scientists have been researching what could possibly be the cause of this disease in order to prevent further damage to honeybee colonies.

In this thesis, I will discuss CCD and its effect on honey bees. What is it? How dangerous of a threat is it? What can we, as members of various nations all over the world, do to prevent it? I discuss the background of CCD, its effect on honey bee performance and productivity, its theorized causes, and what people have done and can do to prevent it.

## Chapter II: Background Information

In addition to discussing the possible causes of CCD, it is important to understand the disease's connection to honey bees, how honey bees work, and how bees are more generally affected by CCD.

*Section 2.1. The Importance of Bees to Human Markets*

Bees might very well be one of the most important insects to exist on the planet. Indeed, many animals assist us in our everyday lives. There are animals that provide company, companionship, and some that provide us food, or material for clothing. However, no animal provides for the human race quite as uniquely as bees do. Bees, or at least the worker bees, spend their days flying around from flower to flower, pollinating them. This pollination process is very important, as it is crucial in the growth of flowers and their reproduction along with crops as well. Some of the fruits we eat today would be not be as abundant if it were not for the bees pollinating the budding plants. Bees are responsible for fruit such as pumpkins, apples, peaches and blueberries (Koh et. Al, 2016), fruits that are found in local supermarkets and farmer's markets. As a consequence, bees are very important to our diet, whether people realize it or not.

Without bees, humans would see far fewer crops and flowers than they do today. Supermarkets would lose half the amount of fruits and vegatables that they currently sell and struggle to feed the global population of 7 billion (BBC News, 2014). It is not just the USA that is suffering from CCD. Other nations around the world suffer from CCD, but with different losses (Figure 1).

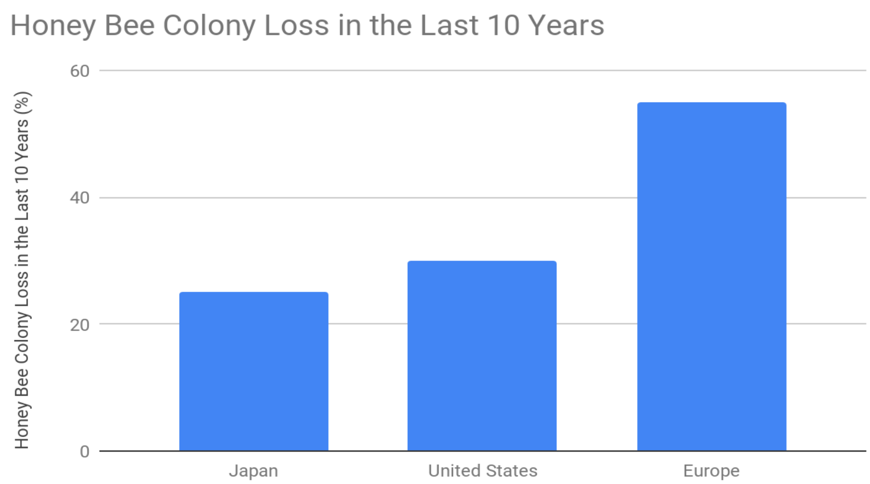



Figure 1: Honey Bee Colony Losses Reported in the Last 10 Years (Chadwick et. al, 2016)

According to this graph, Europe suffers the most colony losses at a loss of almost 53%, with the USA second, losing between 30-40% of colonies, and Japan losing 25% of colonies (Chadwick et. al, 2016). From these differing numbers, it is quite clear that CCD is affecting the whole world and leading to a decline in honey bees.

*Section 2.2: How do Bees Function?*

Unlike humans, bees learn through their olfactory senses, which are vitally important for them to function. With the aid of this service, they can recognize nestmates, forage for food, locate their hive and navigate around (Farooqui, 2012 and Sharpe and Heyden, 2009). A bee's sense of smell is also extremely critical to their memory. As we know, memory is vital, not just for bees, but for all creatures. Memory allows for species to learn and retain information, and recall previously retained information (Farooqui, 2012). Bees can recall whatever job they were assigned to take at birth, identify flowers in need of pollination, and differentiate between two different scents of flowers or those of fruit).

There are many different types of bees. The distinction between them is important for the purposes of this paper. Honey bees represent a small minority of the different type of bees: the larger group are regular wildbees. There are six main differences between honey bees and regular bees. First, honey bees are actually not native to the US (Kiley, 2018). The main honey bee in the US, the Eurasian honey bee (*Apis mellifera*) came from Europe with the early colonial settlers. The non honey bees, on the other hand, are native to the US. These bees include bumble bees, carpenter bees, squash bees, and others. Second, regular bees are solitary. They prefer to keep to themselves and only interact with other bees when mating (Kiley, 2018). Honey bees are much more social, as they interact and work together with many bees. This will be further explored when discussing the hierarchy of the honey bee hive. Third, honey bees live in honeycomb hives (Kiley, 2018). Regular bees, on the other hand, live in nests they build in which to lay their eggs (Kiley, 2018). These can be underground or on patches of ground (Kiley, 2018). This is why honeybees are the only species affected by CCD, as they are the only bees that live in hives. Fourth, regular bees do not have stingers that can break through human skin (Kiley, 2018), while honey bees do. Fifth, honeybees are generalists when it comes to foraging for flowers to pollinate, while regular bees are more specialized (Kiley, 2018). Finally, honey bees typically have black and yellow stripes, while other bees can be dark brown, black, metallic green, blue or other different colors.

In addition to how bees function in their day to day lives, the overall structure of honey bees is very important to defining what they are. At the core, bees fall into different categories depending on their gender (Table 1).

Table 1: Types of Bees in a Colony (BeeSpotter, 2001)

| Type of adult bee | What they do | How many in a honey bee colony |
|---|---|---|
| Queen | Lay eggs | 1 |
| Worker | Take care of larvae, build and clean nest, forage | 10,000-50,000 |
| Male | Leave nest to mate, then die | 100-500 |

As the above table illustrates, here are three types of honey bees: the queen bee, the male bees, and the worker bees. The worker bees, all of which are female, have the most responsibilities out of the three. They are responsible for caring for the young bees, building and cleaning the nests and foraging for nectar and pollen. They are also the most numerous of the three, which makes sense due to the amount of duties they perform. The job of the male bee is less labor intensive than that of females. They leave the nest to mate with the queen bee of another colony and then die. The queen bee does not have control over the rest of colony. The idea that the queen exert a hivemind over the colony is a common misconception. Rather they are the sole reproducer, providing eggs for the colony. The structure of honey bees is extremely rigid; the slightest change will have negative consequences to the entire colony.

*Section 2.3: The History of CCD and Its Effects on Honey Bees*

Despite the recent studies, CCD has been around for many years. The condition was given many different names as early as 1869, like disappearing disease, May disease and autumn collapse (Oldroyd, 2007). While CCD believed to be seasonal at first, this was proved to not be the case, as its symptoms can happen in any season. The name Colony Collapse Disorder was only coined in the year 2006 to reflect recent revelations of disappearing bees and diminished food supply (Oldroyd, 2007). The most well known symptoms of CCD are documented in Figure 2 below.

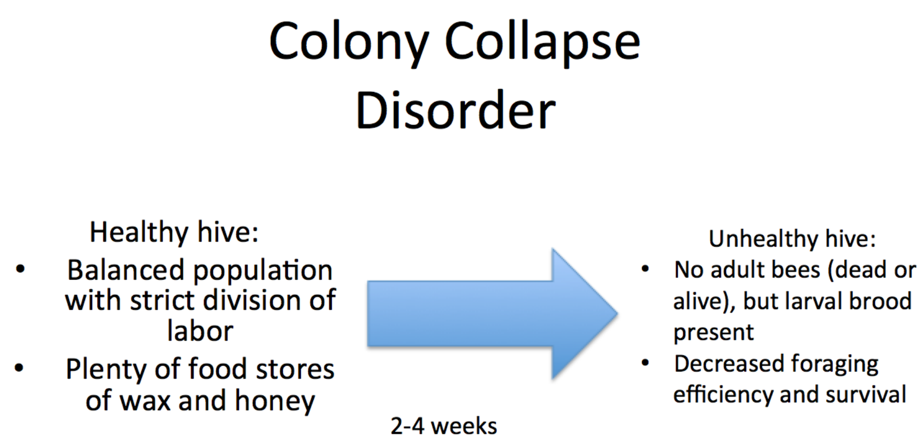



Figure 2: Difference between a Healthy Hive versus an Unhealthy Hive Affected by Colony Collapse Disorder (Adapted from Harvard University, 2015)

CCD causes worker bees to disappear and leave their duties, which decreases the amount of nurses caring for the young bees in the hive. This collapse happens very rapidly and colonies tend to die either in the fall or in the spring (Caron and Connor, 2013). This also negatively affects the amount of food in the hive. Without worker bees, the amount of food foraged decreases and the hive is unable to function. This causes the hive to collapse. Currently, CCD has happened in half of colonies (Caron and Connor, 2013). If this continues, the multiple honey bee species will go extinct.

It is important then to remember that CCD and the decline in the honey bee population may not be mutually exclusive. It appears that CCD is not the only cause of honey bee population decline. There are other factors responsible, and some might be easily mistaken for CCD symptoms. For example, a common misconception is that multiple dead bees found via acute poisoning is linked to CCD, but that is not true (EPA, 2018). There is also recent information stating that CCD might not be as significant as originally believed. The effects of CCD are actually decreasing and CCD is no longer the main cause of bee deaths (EPA, 2018). In fact, the number of managed colonies that beekeepers have reported losing specifically from CCD has been waning since 2010 (EPA, 2018). The beekeeping industry continues to report losing a high percentage of their colonies each year to other causes (EPA, 2018). Major factors threatening honey bee health can be divided into four general areas: parasites and pests, pathogens, poor nutrition, and sublethal exposure to pesticides. In reality though, these factors tend to overlap and interact with one another, which complicates issues. In addition, there are other issues that have impacts on honey bee health such as the narrow genetic base of honey bees in the United States (EPA, 2018). Nonetheless, the potential causes of CCD need to be identified, and research has been conducted on the extent of these theories and their future impact.

*Section 2.4: Research on CCD*

Most of the research conducted on CCD in the US has been spearheaded by the National Agricultural Statistics Service (NASS), which have produced four Honey Bee Colony Loss surveys to ascertain the number of colonies that 20,000 beekeepers had from January 2015 to January 2016 (United States Department of Agriculture). This survey was part of the "National Strategy to Promote the Health of Honey Bees and Other Pollinators," which was released in the summer of 2015. It appears that, from the various graphs released, honey bee loss is measured by the number of colonies that are able to function properly instead of the amount of functioning honey bees in the hive. The majority of this data, however, does not account for losses caused by CCD. The specific criteria for CCD infected hives includes little to no build-up of dead bees in the hive or at the entrance, rapid loss of adult honey bee population despite the presence of queen, capped brood, and absence or delayed robbing of the food reserves. This loss of food reserves is not attributable to varroa mites or nosema bacteria loads. The overall colony loss data is recorded, along with the number of colonies lost to CCD (Figure 3).

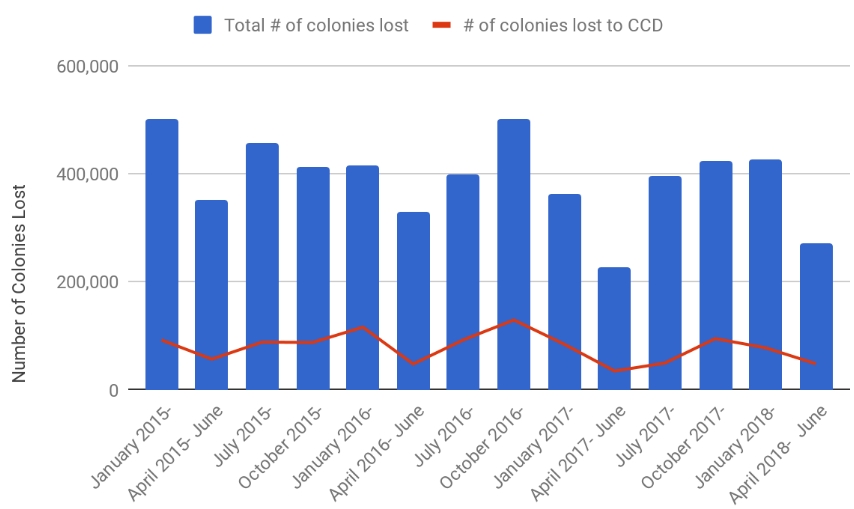


Figure 3: Total Loss of Colonies Compared to Losses to CCD from January 2015 to June 2018 (National Agricultural Statistics Service, 2015-2018)

Throughout the years of studying honey bee colony losses, CCD only constitutes a small portion of honeybee loses, ranging from 14-28% of total colony losses. This ties into what other reports have found, that CCD is not the main reason that colonies are dying.

In terms of colony loss in particular, the worst honeybee hive losses were during the winter, the highest losses were in January 2015-March 2015 and October 2016-December 2016. This lines up with reports that bees affected by CCD die in the winter (Figure 4-5).

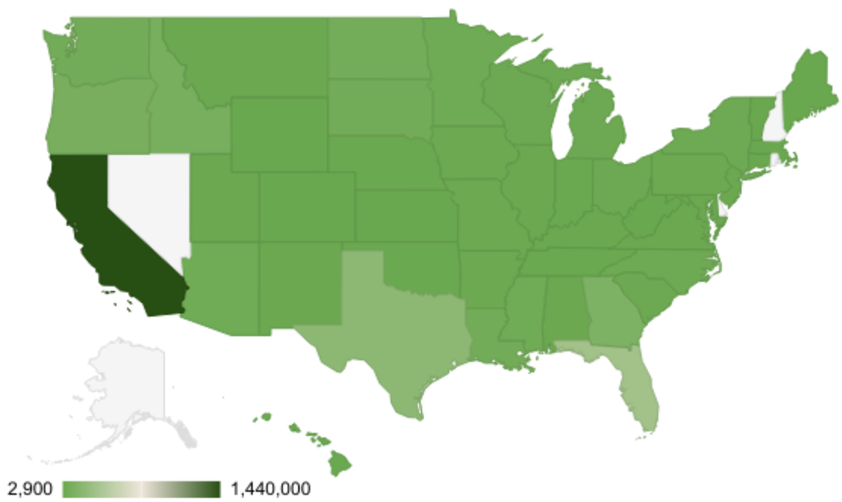



Figure 4: Number of Colonies Across the US from January 2015 to March 2015 (National Agricultural Statistics Service, 2015) Note: Data from Alaska, Delaware, Nevada, New Hampshire and Rhode Island are not shown

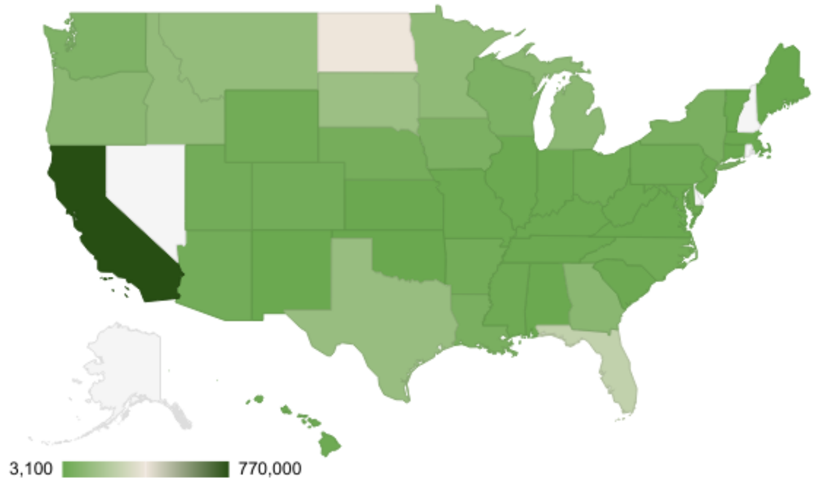



Figure 5: Number of Colonies Across the US from October 2016-December 2016 (National Agricultural Statistics Service, 2016) Note: Data from Alaska, Delaware, Nevada, New Hampshire and Rhode Island are not shown

The two figures above illustrate the number of functional honeybee colonies in the United States. In both maps, the state with the greatest number of colonies is California with a recorded 1,440,000 colonies in 2015 and 770,000 colonies in 2016. The other states do not even come close to reaching that number, most being around 2,900-81,000 in 2015 or 3,000-30,000 for 2016. Very few states recorded total hives over 100,000. However, the amount of colonies lost in that time is extremely interesting (Figures 6-7).

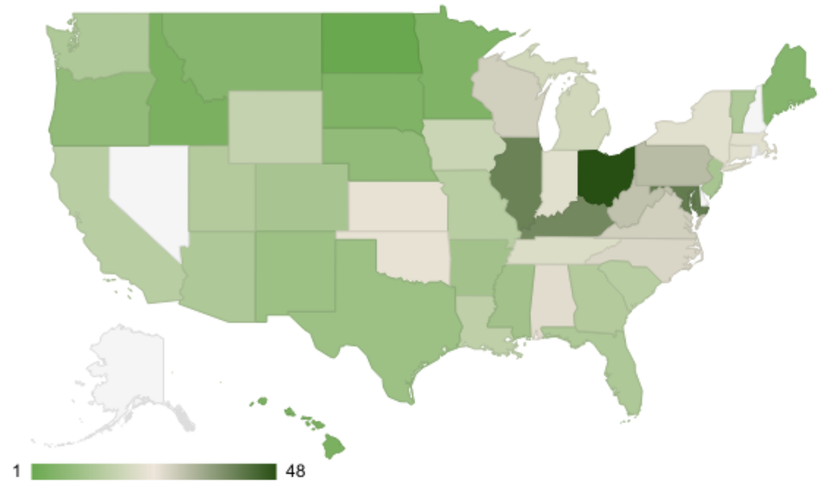



Figure 6: Percentage of Colonies Lost from January 2015 to March 2015 (National Agricultural Statistics Service, 2015) Note: Data from Alaska, Delaware, Nevada, New Hampshire and Rhode Island are not shown

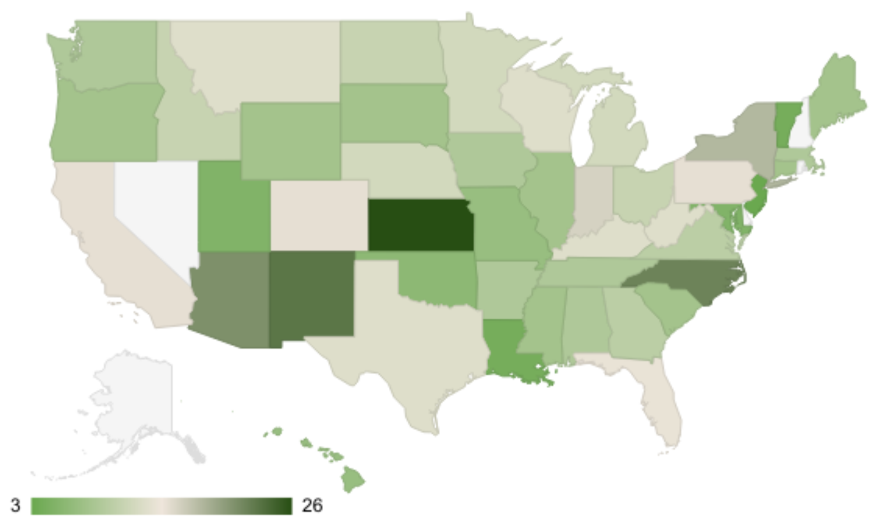



Figure 7: Percentage of Colonies Lost from October 2016 to December 2016 (National Agricultural Statistics Service, 2016) Note: Data from Alaska, Delaware, Nevada, New Hampshire and Rhode Island are not shown

Despite California having the greatest number of honeybee colonies, the state only lost 15% of their total colonies in both 2015 and 2016. By contrast, in 2015 Illinois, Ohio, and Maryland suffered the most losses, at 40%, 48%, and 41% respectively. In 2016, Kansas, New Mexico, Arizona and North Carolina lost the most colonies, at 26%, 23%, 21% and 22% respectively. What is happening in California is a result of adapting to their unique situation. One of the main major argicultural products is almonds and farmers use bees to pollunate almond groves (Sanders, 2014). However, this practice has led to the decline of honey bees, possibly due pesticide use on almonds (Sanders, 2014). As such, beekeepers need to find inventive solutions in order to protect their bees from CCD. For example, a beekeeper named Ray Olivarez moves his colonies to Montana each summer to pollinate alfalfa and clover, as well as have workers looking over bees in California and Hawaii (Fitchette, 2016). The state government has also passed laws to protect the bee population. For instance, the Pollinator Protection Act was passed in 2016 to protect bees from the dangers of pesticides (Allen, 2016). It is posible that these laws and the state's awareness to this issue is what makes the state of California more effective at dealing with colony loss than the other states.

The NASS, however, has been analyzing colonies for years. In February 2008, it was reported there were 2.44 million honey producing hives in the US, which is lower than the 4.5 million in 1980 and 5.9 million in 1947 (Vanengelsdorp et. al, 2008). In 2007, at least 24 states had reported at least one case of CCD (Sahba, 2007). Out of the 384 beekeepers from 13 states that responded, 23.8% met the criteria for CCD (Van Engelsdorp et. al, 2007). From 2006 to 2007, CCD caused losses in 45% in bee hives

(Vanengelsdorp et. al, 2008, Van Engelsdorp et. al, 2007). An overall estimated loss of 34% in 2007, 2008, 2009 and 2010 (CCD Steering Committee, 2010).

Studies for CCD exist not just in the US, but all over the world. The main source for colony analysis in Europe is the European Food Safety Authority (EFSA), which records information from all the countries in Europe. In 2007, the United Kingdom had 274,000 hives, Italy had 1,091,630, and France 1,283,810 (BBC News, 2008). In 2008, the British Beekeepers Association reported that the bee population in the United Kingdom dropped by 30% (BBC News, 2008). China also published a three year survey from 2010 to 2013 using COLOSS questionnaires that shows colony loss to be on average of 10.1% (Liu et. al, 2016). COLOSS (or Prevention of Honey bee COlony LOSSes) is a non profit organization that focuses on improving the wellbeing of bees. Their membership consists of scientific professionals that include researchers, agriculture specialists and students all over the world (COLOSS, 2016).

## Chapter III. Causes of CCD

As stated previously, CCD is theorized to be caused by a number of different factors, five of which are discussed in this paper in order of importance to the bee population themselves.

Several possible causes for CCD have been hypothesized. Some of them are human induced (loss of natural landscapes, use of pesticides) while others are related to natural phenomena (diseases, mites and parasites) (Farooqui, 2012). It is currently unclear which one of these is the leading cause of CCD. Perhaps all of them contribute simultaneously.

*Section 3.1: History of Pesticide Use: A Cautionary Tale*

Perhaps one of the most controversial causes of CCD is pesticides. These chemicals have posed a problem for nature for decades. The concern for pesticides was first reported in the 1950's and 1960's. During that time, a large amount of pesticides were settling into streams and the soils, the most famous example is Dichlorodiphenyltrichloroethane (DDT). This chemical has been reported to be responsible for the decrease in various bird populations, including bald eagles. The pesticide results in the thinning of eggshells, making it hard for the babies to hatch, thus causing them to die in their eggs (Carson, 1962). The lack of bird calls caused various places to be oddly quiet, hence the name of the highly influential book being titled *Silent Spring*. *Silent Spring* discusses how DDT has negatively impacted the environment and the species that live there.

But birds are certainly not the only animals that are affected by pesticides. The use of pesticides is connected to the loss of bees. Known as the 'Pesticide Theory', colony loss from 1966 to 1979 appeared to be caused by pesticides (Sharpe and Heyden, 2009). The theory almost matched up with the timeline in *Silent Spring*, where DDT was used very frequently in the US during the 50s and 60s. Since DDT was not banned until 1972 (EPA, 2017), it could be possible that DDT was one of the many pesticides part of this "Pesticide Theory." There was a study that confirmed DDT was not affecting bees' ability to perform their duties (Palmer-Jones and Forster, 1958), though that might ave just been an old, outdated study. DDT and similar pesticides affected not only the eggshells of birds, but also the lives of insects as well.

Studies have shown that pesticides have had an increasingly negative effect on the mental capability of bees. There appear to be two main, different types pesticides that affect bees: neonicotinoids and formamidines (Sharpe and Heyden, 2009). Each of these pesticides has a different effect on the honey bees. Neonicotinoids are a group of pesticides commonly used for seed treatment for cereals and sugar beet, soil treatment for potted plants, treatment for turf and foliar sprays for glasshouse crops (Pesticide Action Network UK, 2017). They are widely used all over the world to deal with a number of different pests.

According to existing environmental research, neonicotinoids can cause disorientation, reduced communication, impaired learning and memory, reduced longevity and disruption of honey bee brood cycles (Sharpe and Heyden, 2009). They also act on the insect nicotinic acetylcholine receptors, affecting neural messages in bees and other insects (Sharpe and Heyden, 2009). Acute exposure to neonicotinoids usually alters nest bee behavior after 24 hours, reduces activity during the day and reduces the rate of nursing (Crall et. al, 2018). An example of a neonicotinoid is clothianidin, a chemical that upsets the bees' eating habits and disturbs their sense of direction (Warner, 2018). Neonicotinoids also affect their work behavior, such as their flower choices, the duration time for foraging and the ability to collect pollen (Raine, 2018). These impacts worsen the overall colony growth, decrease the nutrition input and lessen support for larval growth (Raine, 2018). This pesticide is extremely dangerous, so much so that it is believed to be 10,000 times more potent than DDT (Warner, 2018 and Woody, 2014). Due to this level of potency and how often the pesticides were used in many countries, neonicotinoids affect bees all over the world. For example, a study shows that Hungary and the United Kingdom that there was a 24% decline in colony size due to use of clothianidin during the winter (Woodcock et. al, 2017).

The neonicotinoids share similar structures in their compounds. For example, neonicotinoids can share a benzyl ring containing a nitrogen and a branching chlorine as seen in the structures of Imidacloprid and Acetamiprid (Figures 8-9).

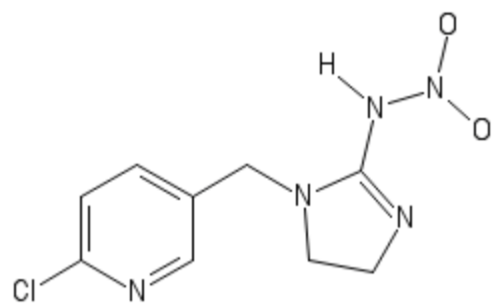



Figure 8: Imidacloprid (PubChem Sketcher Version 2.4)

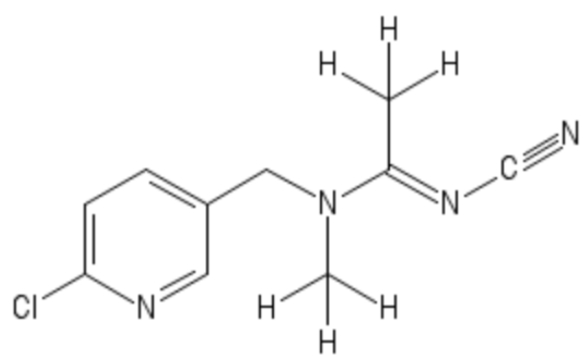



Figure 9: Acetamiprid (PubChem Sketcher Version 2.4)

Some neonicotinoids, like Clothianidin and Thiamethoxam contain a five ring chain that have a sulfur and the nitrogen with a branching chlorine (Figures 10-11).

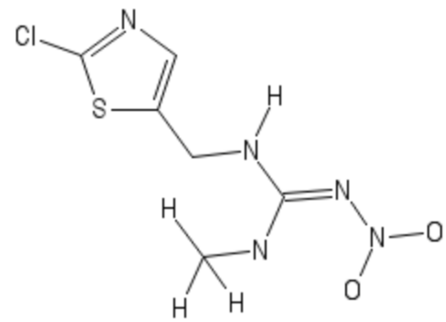



Figure 10: Clothianidin (PubChem Sketcher Version 2.4)

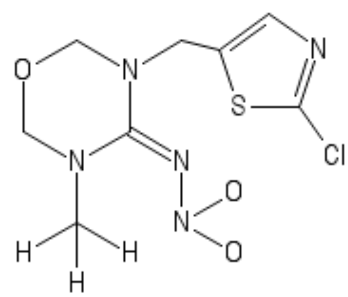



Figure 11: Thiamethoxam (PubChem Sketcher Version 2.4)

Rarely do neonicotinoids contain both types of carbon rings at the same time, yet it is possible these pesticides are grouped due to their abundance of nitrogen. The ring is not the only structural similarity. There is an abundance of nitrogen in figures 6-9, as well as a common nitrogen-two oxygen structure, as seen in figures 6, 8 and 9. Some of the figures have a nitrogen connected to a carbon by a double bond. Due to these reasons, it can be assumed that perhaps those parts of this pesticide group mean that the mechanism of action on bees are the same.

This toxicity connection might also be due to other toxic chemicals. Neonicotinoids have been connected to be chemically similar to nicotine (Insects in the

City, 2019), as nicotine contains both a benzyl ring and a 5 carbon ring, and both contained a nitrogen (Figure 12). Since nicotine is one of the most toxic chemicals known today, it would make sense that neonicotinoids would be toxic to the animals on Earth.

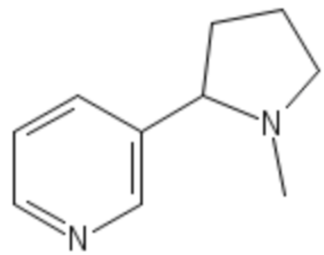


Figure 12: Nicotine (PubChem Sketcher Version 2.4)

The other main type of pesticides are Formamidines, a group of pesticides that are used to deal with cattle ticks and mites (Gupta, 2018). They are primarily manufactured by Sigma-Aldrich, but they have been commonly used all over the world.

Formamidines have a different effect on bees than neonicotinoids do. An example of a formamidine is shown below (Figure 13).

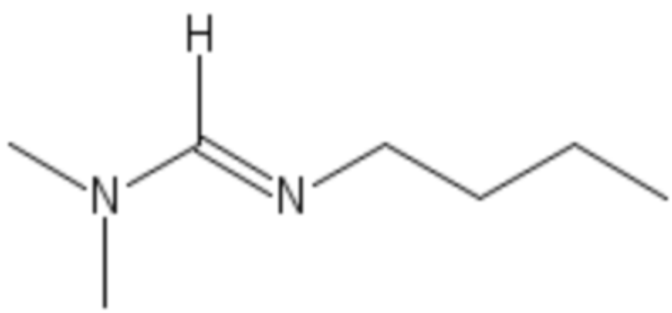
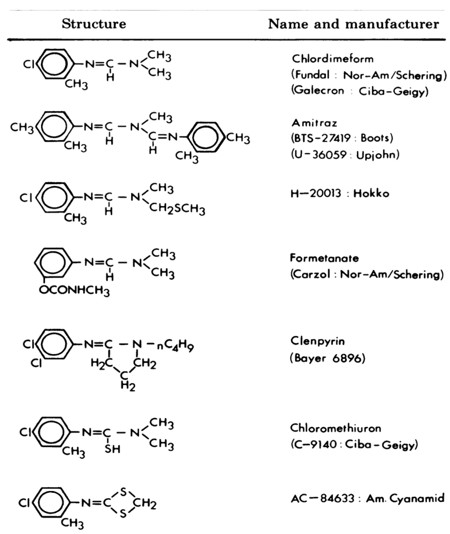


Figure 13: Formamidine 1-butyl-3,3-dimethyl (PubChem Sketcher Version 2.4)

Formamidines mostly affect the octopaminergic receptors in the brain of bees (Sharpe and Heyden, 2009). In small doses, formamindines can suppress pest mating, reproduction, feeding, and other behaviors (Sharpe and Heyden, 2009). Overall, both types of pesticides can disrupt the neural functions of bees, including their ability to learn (Sharpe and Heyden, 2009). It is clear that these pesticides negatively affect how honey bees are able to function within the hive.

Formamidines are relatively new type of pesticides discovered in the 1970’s (Hollingworth, 2019). As such, the actual mechanism of how formamindines affect the brains of honey bees is still unknown. Despite the recent discovery, several types of formamidines have been discovered (Table 2).

Table 2: List of Formamidines and their Structures (Hollingworth, 2019)



| Structure | Name and manufacturer |
|---|---|
| | Chlordimeform (Fundal : Nor-Am/Schering) (Galecron : Ciba-Geigy) |
| | Amitraz (BTS-27419 : Boots) (U-36059 : Upjohn) |
| | H—20013 : Hokko |
| | Formetanate (Carzol : Nor-Am/Schering) |
| | Clenpyrin (Bayer 6896) |
| | Chloromethiuron (C—9140 : Ciba-Geigy) |
| | AC—84633 : Am. Cyanamid |

It was initially thought that bees were not affected by formamidines, they were considered to be one of the insensitive organisms unaffected by this group of pesticides (Table 3).

Table 3: List of Organisms and Their Sensitivity to Formamidines (Hollingworth, 2019)

| Sensitive organisms | Insensitive organisms |
|---|---|
| Acarines<br>Phytophagous mites<br>Predaceous mites<br>Ticks | Invertebrates<br>Most insects, including parasites, predators and pollinators<br>Spiders |
| Insects<br>Lepidoptera<br>Hemiptera | Vertebrates<br>Fish<br>Birds<br>Mammals |

Other chemicals have proven to be dangerous to the function of honey bees. One such chemical is glyphosate, which has been used as a herbicide for weed control (Motta et al, 2018). Glyphosate is the most used herbicide in history, commonly seen in products like Roundup (Carrington, 2018). Previously, glyphosate was thought to be the least toxic herbicide in the business because most animals are unaffected by its exposure. Glyphosate blocks an enzyme called EPSP synthase in plants and microbes which is required to create amino acids like phenylalanine and tryptophan (Satyanarayana, 2018). However, untargeted animals, like bees and earthworms, appear to be negatively impacted by this herbicide. Honey bees affected by glyphosate will have their bacterial gut decrease, which negatively impact the bees' ability to forage for food (Sharpe and Heyden, 2009). It can also affect early bacteria gut production and make young bees more susceptible to *Serratia marcescens*, which is a pathogen that increases the mortality of younger bees. Glyphosate targets the microbiota that is necessary for bees to grow and fight off pathogens (Carrington, 2018). There also appears to be a contributing decline in the bee population due to the existence of glyphosate in bee guts, but more studies on the negative side effects need to be conducted (Satyanarayana, 2018).

*Section 3.2: The Effect of the Habitat Loss on the Population of Honey Bees*

Over the years, the human race has staked their claim on the planet. From learning to grow crops, to creating giant skyscrapers, they have shaped the landscape to suit their own needs. In the process, they have destroyed many natural ecosystems: rainforests, forests, canyons, and grasslands among other habitats. This destruction of ecosystems has caused negative consequences for many species. Many natural processes have been disrupted due to human inference. Temperatures are rising, coral reefs are dying, the oceans are becoming more acidic, the Arctic ice is melting, and many endemic species are becoming extinct. The overall extinction rate has increased greatly in recent decades, so much so that scientists have decided to call this age *Anthropocene*, also referred to as the Sixth Extinction (Kolbert, 2014).

The same trends in declining wildlife are true for honey bees. One study shows that a possible cause for CCD is 'nutritional stress' (Farooqui, 2012). Nutritional stress is defined as a lack of nutrients available for an organism. This is probably due to lack of resources or perhaps an infection of a mite like *Nosema ceranae* (Naug, 2009). Perhaps this stress has come from a lack of food. Most of a bee's diet comes from flowers: the nectar and the pollen (Ryan, 2018). The type of flower they need, however, varies across bee species. Typically the best flowers for honey bees are the ones that have a good supply of nectar and pollen, like sunflowers, hyssops and common yarrows (Keith, 2015). Other common examples include white clovers, apple trees, asters, borages, buckeyes and cherry trees (Chadwick et. al, 2016). In light of this, the loss of these species has profound effects on bees. It was stated in a recent online article that the loss of bee species correlates with the loss of plant species (Givetash, 2018). The native plant species have been reduced due to the expansion of urbanization and agricultural landscapes (Givetash, 2018). It also appears that the growth of agriculture has reduced the population of bees, in particular the amount of different crops that exist in fields: the less diverse the crop variety is, the fewer bees (Koh et al., 2015). As humans continue to pursue their own growth with industrialization and monocultural crop practices, they have consequently push out the bee population from pollinating, contributing to the cause of colony collapse.

This crop uniformity is having a profound effect on the amount of honey produced. Bees need honey in order to live. If the population of flowers decreases, then the worker bees' ability to create honey, and have the food needed to survive, is diminished. However, it is not just the worker bees that suffer; all different types of honey bees need honey to live. The young bees, for example, rely on the nutrients of the royal jelly to develop and grow. Royal jelly is special type of honey that is created from the glands near the head region of worker bees (Crowder, 2014). This jelly is important to the development of both the young bees and the queen bees.

It is also important to recognize how different landscapes affect the bee population as a whole. As stated before, bees are extremely helpful in growing of crops. Despite this, our monocultural customs seem to have a negative effect on the bee population. Bees appear to be highest in population in chaparral and desert shrublands, where resources are plentiful. By contrast, agricultural areas have the lowest bee population (Koh, 2015). Perhaps the reason for this is because commerical mass production of crops is ruining the natural ecosystem of the bees. The more often monoculture is practiced, the fewer bees are around to pollinate the crops.

*Section 3.3: How Diseases Affect Bees and the Connection to CCD*

Along with the human causes of colony collapse disorder, such as pesticides, climate change and habitat loss, bees can also suffer from natural causes, like diseases and mites. Bees actually do not suffer from as many pests and diseases than other insects (Caron and Connor, 2013). However, what they do suffer from is very dangerous for their survival. There are two main types of bee diseases: diseases that affect the brood and diseases that affect adult bees.

Broods that are affected by diseases look chilled and starved (Caron and Connor, 2013). One of the main brood diseases is American foulbrood (AFB). It is caused by the bacteria, *Paenibacillus larvae*, that grows in the bee larva (Caron and Connor, 2013). Known symptoms of AFB are wet and greasy surfaces, a distinctive smell, irregular and disrupted brood pattern, sunken capped cells, sickly appearance, failing the ropy test, and an optional pupal tongue. After killing one colony, *Paenibacillus larvae*, and by extension the American foulbrood disease, move on to collapse more colonies (Caron and Connor, 2013).

Another well known larval disease is the European foulbrood (EFB). This is a non-spore-forming bacterial disease caused by *Melissococcus plutonius* (Caron and Connor, 2013). It is a stress disease that mostly kills young larvae. Symptoms of this disease include larva coiled up in the cell, failing the AFB rope test, larvae gaining a yellow streak that turns brown, and a sour decay odor that is different from the AFB odor.

Chalkbrood is another important and well known disease that affects honey bees. First seen in 1972, it is caused by the fungus *Ascosphaera apis*. Larvae affected swell to the cell they inhabit (Caron and Connor, 2013). Chalkbrood is commonly seen during and damp seasons. While it does not normally kill the colony, it does render it weak and non-productive, making it more vulnerable to other diseases.

Out of all the diseases that affect bees, there are a few that are associated with CCD. These include Kashmir bee virus (KBV), acute bee paralysis virus (ABPV), Israeli acute paralysis virus (IAPV), and Deformed wing virus (DWV). All four of these diseases are caused by the presence of varroa mites in the honey bee hive. The former three diseases, KBV, ABPV, and IAPV, are closely related in the family Dicistroviridae (Miranda et. al, 2009). All three of the diseases were discovered in the exact similar manner; virus propagation in white-eyed honey bee pupae (Miranda et. al, 2009). ABPV was the first to be discovered, as an unintentional by-product during studies of chronic bee paralysis virus (CBPV) (Miranda et. al, 2009). In 1974, KBV was first discovered as a contaminant in preparation for the Apis iridescent virus for a few honey bees (Miranda et. al, 2009). IAPV was found in 2002 in Israeli after propagating the extract of a single bee in a dead cluster of dead bees (Miranda et. al, 2009). Collectively, the three of them distributed around the world by a number of hosts.

The original hosts of these three diseases vary depending on which disease is studied. Scientists have theorized the original host to be *Apis mellifera*, or the Western honey bee, but it has also been seen in five other bumble bee species as well (Miranda et. al, 2009). KBV is a bit more uncertain of its origins. Some assume it is *Apis cerana*, or Eastern honey bee, the Western honey bee, or the European wasps (Miranda et. al, 2009). As the newest find of the three, IAPV has seen as a variant of KBV. The only clear host for the disease is the Western honey bee (Miranda et. al, 2009).

From what is currently known about these diseases, there appear to be no symptoms at the individual and the colony level (Miranda et. al, 2009). Some similar symptoms are shared among them. In ABPV and IAPV, adults infected suffer from a rapid paralysis, which includes trembling, inability to fly, darkening and loss of hair on the abdomen and thorax (Miranda et. al, 2009). This paralysis rarely channels to the entire colony, though a severe infection of ABPV and KBV lead to a sharp decline in the adult bee population (Miranda et. al, 2009).

While both ABPV and KBV are transmitted via varroa mites, the actual transmission for IAPV is unknown. Since it is thought that IAPV is a strand of KBV, it is possible that it might be transmitted the same way as KBV. There is a serious conditions where 80% of bees infected with IAPV die within a week (Miranda et. al, 2009).

All three of these diseases share symptoms with CCD. The three diseases cause the honey bee colony to decrease in activity as the adult bees leave or die off.

ABPV builds up in the brain and hypopharyngeal glands in adult bees and can be detected in faeces (Miranda et. al, 2009). KBV can also be detected in faeces (Miranda et. al, 2009). ABPV has also been seen in semen, larval and pupal tissues and is the most common out of three to be found in the brood (Miranda et. al, 2009). KBV can be seen in surface-sterilised eggs, along with larval and pupal tissues (Miranda et. al, 2009).

DWV first appeared in the 1990s after it killed large numbers of colonies. Symptoms of DWV include unhealthy, underweight and discolored honey bees, bees living for only a few days and deformed wings (Caron and Connor, 2013). It is important to note that the wing deformation caused by DWV are different from those caused by the K-wing virus.

*Section 3.4: The Presence of Mites and How They Transmit CCD*

Mites are considered pests in the human world and nature at large. They affect a large number of species on the planet, including humans, dogs and honey bees. There are a few types of dangerous mites that cause terrible problems for honey bees. The most problematic ones are the tracheal mite and the varroa mite. The tracheal mite, *Acarapis woodi*, arrived from Mexico and is known to have caused depopulation in the honey bee population (Caron and Connor, 2013). Tracheal mites are able to spread from hive to hive by the drifting of bees, beekeepers combining or diving colonies and beekeepers moving colonies from place to place (Honey Flow, 2019). The mites attack the bee population by living in the tracheal system of bees (Caron and Connor, 2013). Bees that suffer from a tracheal mite infection will be impacted by weak bee crawling and K-wing adults (Caron and Connor, 2013). It is believed that tracheal mites cause Isle of Wright disease (Caron and Connor, 2013). This disease was first seen in the early 1900s where it destroyed colonies in the UK. Symptoms include wing deformation, similar to that caused by the K-wing virus, and hives that are characterized by confused and disoriented bees clustering near one another.

The other main mite that affects the honey bees is the varroa mite. They appear on the pupae of bees, and rarely on adults (Caron and Connor, 2013). Varroa mites are known to transfer two known diseases, ABPV and KBV, to the entire bee populations, resulting in disease colony losses. The disease transfers to adult bees and pupae with 50-80% efficiently (Miranda et. al, 2009). Once a varoa mite is in a hive, it affects every bee in the colony. Once the entire hive is infected, they can spread to other hives in a number of different ways: hitchhiking infested honey bee to contact healthy bees, contacting healthy bees when they rob honey from weaker colonies, hitchhiking on other insects, or by the movement of the hives or beekeeping equipment (Plant Industry Divison, 2019).

The USDA has analyzed the effect of varroa mites on the US (Figure 12).

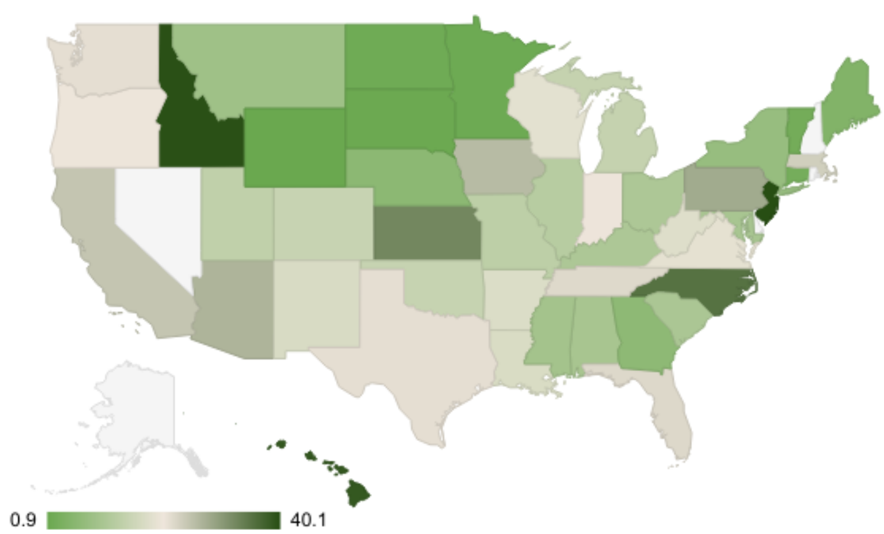


Figure 14: Percentage of Honeybee Colonies Affect by Varroa Mites from January 2015 to March 2015 (National Agricultural Statistics Service, 2015) Note: Data from Alaska, Delaware,Nevada, New Hampshire and Rhode Island are not shown

All of the states (with the exceptions of the states with no data recorded) have reports of varroa mites. There does not appear to be any pattern to the varroa mite infestation, though the majority of the worse cases are on the west coast. The worst cases of varroa mites are in New Jersey, Idaho, and North Carolina.

One of the main diseases to arise from mites is Parasitic Mite Syndrome (PMS). There are high mite infestations in the fall and while bees are able to survive in the winter, they die off in the spring (Caron and Connor, 2013). The disease can affect both the adult bees and the brood of the hive. Adult bees tend to be affected by varroa mites and sometimes even tracheal mites, though they are not as common (Caron and Connor, 2013). It also reduces the adult bee population, killing the colony. Even in a dead colony, some bees can seen in the hive, either dead or alive (Caron and Connor, 2013). There can even be some unhealthy crawling bees around the hive (Caron and Connor, 2013). Because of the small amount of adult bees, the broods usually become unhealthy, 'snot' and 'cruddy' (Caron and Connor, 2013). Queen supersedure is another known symptom, in which the queen bees dies off and the colony needs to have a new queen to overthrow her so the colony can thrive. Multiple supersedure cells will be made at the same time so there is a greater chance of the healthy queen being made. The brood, on the other hand, suffer from PMS as well. Varroa mites are present, the brood pattern is spotty, and the brood soon dies (Caron and Connor, 2013). It is also important to note that PMS for broods develop symptoms of both AFB and EFB.

*Section 3.5: Climate Change and How the Rising Temperature is Impacting Bees*

One of the biggest issues plaguing the planet is the reality of climate change. Climate change is when the overall temperature increases, which has terrible consequences for the people and species of the planet. This is caused by excess $CO_2$ emissions in the atmosphere from humans using their cars, factories, and chopping down trees. The increase in temperature causes more dangerous natural disasters, acidic oceans, and rising water levels. The higher temperatures can negatively impact the livelihoods of plants and animals. They have evolved over millions of years to adapt to their current environment. However, climate change is occuring at a more rapid rate, faster than plants and animals are able to adapt. Therefore, being unable to change, plants and animals usually die.

Honey bees are very susceptible to temperature. Raising bees is extremely difficult due the changing seasons. The average temperature for bees to forage is 46 to 50$^{o}$F (Caron and Connor, 2013). They cannot forage in environments too cold or too hot. Bees cannot live in the cold seasons (like fall and winter), so freezing weather will kill the workers and the colony. However, the other extreme is just as bad. If the temperature is too warm, it can lead bees to wander the wilderness, unable to return to their hive. Due to the constantly increasing temperatures in the world around them, it is becoming more likely more bees to leave their hives to die. This is not unlike the symptoms of CCD, and perhaps the increasing temperature is an additional cause of the bees' decline.

Flowers and other vegatation are also impacted by temperature just as severely as insects. Flowers live under extremely specific conditions; they need the right amount of water, sunlight, and of course the right temperature to grow. It can not be too warm or too cold. As the temperatures increases, flowers, unable to move from their rooted spot, cannot adapt quickly to the rising temperatures and die off. This, coupled with the effect of temperatures on honey bees, might impact CCD in honey bees.

In addition to analyzing varroa mite, the USDA have explored other causes of colony losses. The USDA has released graphs detaling the effects of other and unknown causes of CCD. What other and unknown causes mean is not explained. Perhaps it could be pesticides, CCD, or but still the effect is devastating (Figure 13-14).

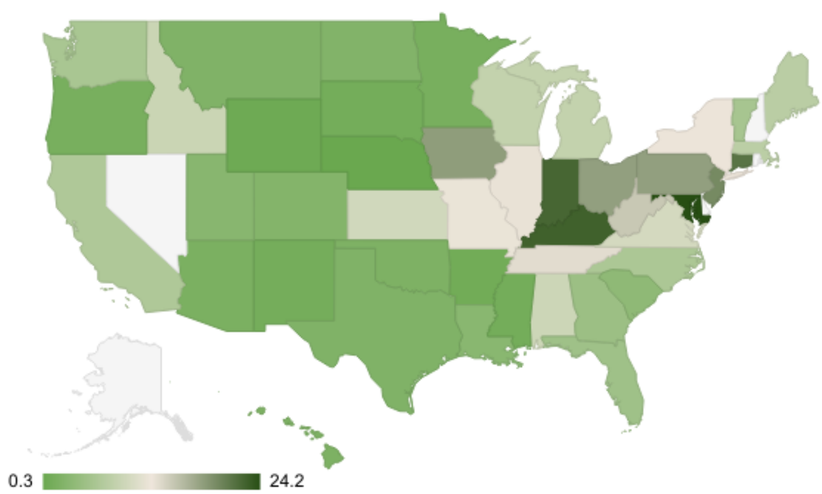



Figure 15: Percentage of Honeybee Colonies Affected by Other Causes from January 2015 to March 2015 (National Agricultural Statistics Service, 2015) Note: Data from Alaska, Delaware, Nevada, New Hampshire and Rhode Island are not shown

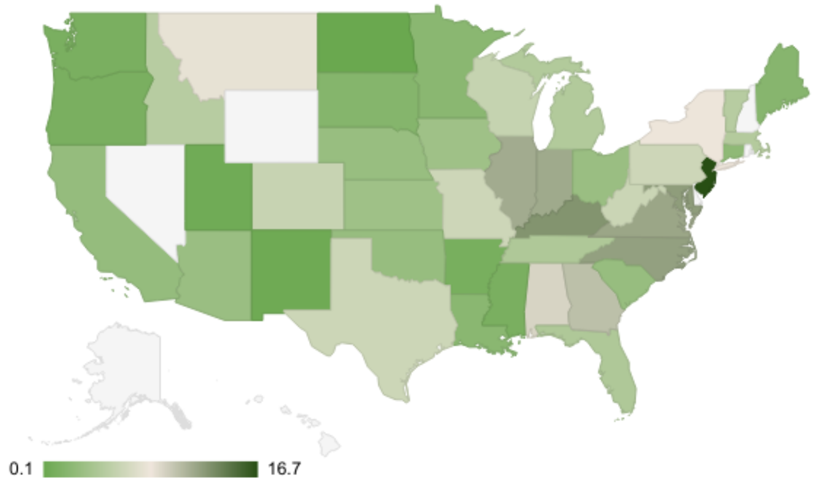



Figure 16: Percentage of Honeybee Colonies Affected by Unknown Causes from January 2015 to March 2015 (National Agricultural Statistics Service, 2015) Note: Data from Alaska, Delaware, Hawaii, Nevada, New Hampshire Rhode Island and Wyoming are not shown

In both Figures 13-14, the most losses occur on the East coast. Other states with similarly worse cases are in North Carolina, Virginia, Illinois and Indiana.

## Chapter IV. Political Assistance: A Survey of Policies Designed to Protect and Support Honey Bee Populations

CCD is a mystery to the scientific community due to the concern it brings to the world at large, making it a huge issue to try to solve. As such, there are ways to combat CCD in the hopes of restoring the honey bee population to its former status.

### *Section 4.1: Curbing our Pesticide Use*

After *Silent Spring* was published, it took some time before the US government listened to Rachel Carson's words. In 1972, the EPA put a ban on DDT from future use in order to protect the bird population of various raptors (EPA, 2017). This was a successful effort as several previously endangered species, such as the bald eagle, were able to make a comeback so vigorous that, in the summer of 2007, the species was removed from the Endangered Species List (U.S. Fish & Wildlife Service, 2011). This is an example of how laws can save various species from extinction by banning dangerous chemicals from the environment. This story was not just for pesticide use in the United States. Other countries have also utilized this method to curve pesticide use.

In recent years, various countries have banned selected pesticides implicated in colony loss. In 1993, imidacloprid, a pesticide in the neonicotinoid family, was first used in France on sunflower and corn seeds to protect them from pests (Farooqui, 2012). However, when imidacloprid was used, there was a decline of the honey bee population. Farmers believed the pesticide imidacloprid was responsible for decline, and the pesticide was banned from use on sunflowers in 1999 and then from use on corn five years later (Farooqui, 2012). In Germany, imidacloprid was used in the production of rapeseed, sugar beets and corn, and farmers there experienced a similar decline in the honey bee population (Farooqui, 2012). This resulted in the pesticide being banned in the country due to the decline in rapeseed, apples and pears (Farooqui, 2012). Overall, the use of neonicotinoids, including imidacloprid, has now been banned for use on seeds in France, Germany and Italy until further notice (Farooqui, 2012).

Further bans on neonicotinoids continue to this day. As a matter of fact, earlier this year, France banned the use of all neonicotinoid pesticides from outdoor use on any plant (Dupraz-Dobias, 2018). The main pesticides banned were imidacloprid, clothianidin and thiamethoxam. The other main neonicotinoids thiacloprid and acetamiprid were included in the French ban, but not the European ban overall (Dupraz-Dobias, 2018).

Geographical location and political standing have proven to be important factors in whether or not honey bees live or die. While the many parts of the world seems to be taking a hit from the loss of bees, Cuba has seen a sharp increase in the bee population. Cuba is a communist nation, which has impoverished farmers in the country (The Economist, 2018). They do not have money to afford pesticides, modern equipment, and have litte economic incentive to industrialize the land (The Economist, 2018). As a result, farm and livestock were postitively affected by the lack of pesticides in the area. and the lack of desire to grow their farms to match increases in demand for livestock or crops (The Economist, 2018). This means that bees are able to grow in a safe environment without the threat of pesticides or losing their homes. In fact, the bee population in Cuba has been growing an average of 7,000 hives per year (The Economist, 2018). It appears that the lack of pesticides increases the bee population.

*Section 4.2: Dealing with Habitat Loss*

There are a number of different ways to ensure honey bees can survive in these new industrial environments. Policies have existed in order to ensure that the bees have enough resources to continue to grow. In Amsterdam, Netherlands, various industries have installed ‘green roofs’ (which have been called ‘insect hotels’), which contain native plants for the bees to grow (Givetash, 2018). These roofs not only provide natural resources for the bees, but also a way for humans to relax and enjoy the beauties of nature without leaving their homes. By planting different types of flowers, bees are able to pollinate, have enough nutrients to survive and due to this effort, the bee population in Amsterdam has increased by 45% since 2000 (Givetash, 2018). If this method worked for the people of Amsterdam, then it could work for other urban areas around the world. The High Line in New York City uses a similar style to that of Amsterdam. This attraction is a 1.45 mile long park on the roofs of NYC that contains multiple gardens and plants to support pollination (High Line, 2000).

In addition, the small country of Slovenia has established laws to protect bees, which has resulted in no colony collapse being present in cell counting (Hruby, 2019). In Slovenia, there are a recorded estimate of 10,000 beekeepers out of a total population of over 2 million, which is about five beekeepers for every 1,000 people (Hruby, 2019). By contrast, the United States has an estimated 125,000 beekeepers out of a population 327 million people, which is about 0.4 per 1,000 people (Hruby, 2019). So how did Slovenia keep the bee population healthy despite the smaller population? Many believe it is because of the Slovenian people's ingrained love of bees and honey, the country's historic ties to beekeeping, and a government that recognizes its benefits to the economy. Because of these factors, CCD is never seen in that small country. Perhaps other nations can learn from Slovenia and incorporate those characteristics into beekeeping.

In a similar vein to green rooftops, various other political efforts can be achieved to preserve the bee population. In the US, there have been a number of nature reserves created in order to maintain the natural landscape and prevent any industrial development. Famous examples of these include The Grand Canyon, The Redwood forests of California, the Everglades, Death Valley, Yellowstone Park and Yosemite

Park. These reserves can exist on a smaller scale, such as local reserves. At Drew University, there are two natural reserves, the Zuck Arboretum and the Hepburn Woods, which exist to restore the natural plant life in New Jersey. Drew University also has a meadow in order to support pollination. There have been multiple environmental science professors that work to maintain the invasive species population, and ensure the native plant species will grow. A similar idea can be used for bee populations all over the world. Perhaps people can create reserves full of suitable flowers that the bees can pollinate, and possibly include certain fruit trees. That way people can benefit from helping out the environment with more fruits for nourishment and the bee population can continue to grow.

*Section 4.3: Curing Diseases*

There are a number of different cures for AFB, most of which involve various chemicals. Terramycin is one chemical that is capable of stopping AFB, however it does not kill the spores of AFB and the bacteria that carry the disease have been resistance to Terramycin since the 1990's (Caron and Connor, 2013). Ethylene oxide is also used to kill the spore stage of AFB. This sterilant gas, however, may cause cancer in honey bees.

Diseases have been a recent point of study and research instead of action. Many diseases, such as IAPV, KBV and ABPV, are unknown at the moment and further research is needed to learn about their transmission, diagnosis, incidence and characterization (Miranda et. al, 2009). Today, cures for these diseases are not well known or documented. Tylan and Lincomix are commonly used. If the hive is heavily infected, the solution is to burn the bees, combs and the equipment. This is usually done in the evening and in a landfill (Caron and Connor, 2013).

Another possible cure includes a lye bath, where beekeepers boil the wooden pieces of the manmade hive or coat it in boiled paraffin. While this may deal with diseases, colonies still run the risk of being re-infested (Caron and Connor, 2013). There is also gamma radiation, which cleans bee equipment of disease pathogen contamination.

Quite recently, there has been some promising news about curing diseases for honeybees with vaccines. Scientists have been working on a vaccine to target microbial diseases that kill honeybees (Jacob, 2018). Currently it is in the development phase, and it will take years before it hits the market, but the news that a working vaccine is in development is an amazing step forward to protect bees. It was previously thought to be impossible to use vaccines because to bees lack an antibody system like humans do (Jacob, 2018).

There is, however, not much in the way of treatment for many diseases (such as Sacbrood, and Deformed Wing Virus) (Chadwick et. al, 2016). Further studies are required to see if any treatments can be found.

*Section 4.4: Tackling the Threat of Mites*

There are many ways to tackle the various mites and the diseases they cause. Beekeepers and scientists have found a number of solutions to combat tracheal and varroa mites, as they continue to be a threat to their jobs. For one, scientists have looked for honey bees that are resistant to mites. Some honey bees already are more resistant than others (Caron and Connor, 2013). Scientists have been performing tests to make most, if not all bees more resistant to mites. There has been some studies of genetic control and selection in certain honey bees to make them more mite resistance and tolerant. Scientists have also been looking into speeding up the development of the honeybees. Since mites appear to commonly affect the young larvae than adults (Caron and Connor, 2013), perhaps there is a way to allow young bees to grow into adults much quicker.

Perhaps one the most effectively implemented solutions to tackling mites is chemical treatment. There are many different chemicals that have been used, Mavrik, Mite Away II (which contains Formic Acid) Oxalic acid, HopGuard, and Acetic acid (Caron and Connor, 2013). However, certain chemicals, like miticides, are considered controversial.

A recent study has pointed to mushrooms to be the answer to mites. The Wood Conk mushroom contains extracts that are shown to have antiviral properties that reduced viruses in honey bees (Stamets, 2018). Two types of the wood conk mushrooms tested: the red reishi and the amadou (Stamets, 2018). The current theory is these mushroom extracts strengthens the immunity to viruses, but further study is needed to see if this is truly accurate.

There are also a number of other chemicals that are currently being tested on for effectiveness against mites. Many of these methods have and continued to be analyzed and studied. Chemicals like sucrocide, mineral oil, coconut oil, propolis and cattle feed have all been considered to kill mites. New methods have continued to be discovered as well.

*Section 4.5: Tackling Climate Change*

While the connection between honey bee health and climate change is clear, trying to protect bees from climate change's effects is more difficult. Due to the constantly increasing temperature, conservation proves to be more difficult (Boehm, 2017). In spite of such conservational challenges, there seems to still exist some hope for bees living in warmer environments. In Panama, studies reveal that bees are capable of thriving in increasingly warming temperatures (Landers, 2017). This is possibly due to Panama position proximate to the Equator, where countries encounter much warmer temperatures. Other bees may not be so lucky, as they are much more adapted to living in cooler temperatures. Trying to come up with a solution though is a difficult problem given how rapidly the climate is changing.

The best possible solution might be to limit the effects of climate change through the use of global climate accords, like the Paris Climate Accord. The spirit of collabation needs to be felt by all the nations to improve their carbon footprint. By working together, the countries from around the world can lower their greenhouse emissions to lessen their impact not only on the honey bee population, but have a greater positive effect on a global scale.

## Chapter V. Conclusion

This paper discussed the phenomenon known as Colony Collapse Disorder, which is offered as the chief cause of the recent honey bee decline all around the world. This paper went over the history of CCD and its effect on honeybees, the possible causes of CCD, and what countries have done to prevent these causes. In spite of all the recent studies, there are still many things that remain unknown about CCD, the consequences of which have yet to be determined. Bees, however, have a very obvious connection to the world at large. Colony Collapse Disorder has opened up a slew of new discussions about honey bees. Without bees, the planet would have less vegetation, crops and flowers, to sustain people around the world (BBC News, 2014). Already though, the human race has caused many issues to arise. Climate change, pesticides, habitat loss, along with all the natural causes, pile up on each other as they also continue to happen simultaneously.

So, what then are the principle causes of CCD? The theories that were explored to explain CCD are very relevent to major losses across all insects. Pesticides affect the brains of honey bees, which alters how they function in the hive. Diseases and mites severely weaken the defenses of bees. Habitat loss and the concept of monoculture has decreased the population of honey bees. Climate change has increased the overall temperature of the planet. The hotter climate is not suitable for honey bees, and might have influenced CCD infected honey bees and their colonies.

That is, of course, not the only question that needs to be asked. Are these truly the chief causes of CCD? Possibly. The more likely causes seems to be those that affect bees outside the hive rather than those inside the hive, such as pesticides and habitat loss. Pesticides are released into the environment and can be absorbed into the atmosphere, soil and water. This exposure may have killed honey bees outside of the hive, causing CCD like symptoms. In a similar vein, nutritional stress caused by habitat loss happens outside of the hive. Due to the lack of available flowers, bees will fly around to search for food and die due to lack of proper nourishment. This could be an explaination for the missing bees in the hive. Diseases and mites, on the other hand, might be less likely to be a cause of CCD. Both of these have only been observed inside of honeybee hives. Because of this, it is a little harder to tell if they have killed bees. Climate change is also difficult to pin down as a cause, since it has so many wide effects on the world at large that do that relate back to CCD.

It is also likely that these associations could just be unrelated. The effects of CCD on honey bees are similar to the effects of pesticides, habitat loss, increased temperature. As it is likely for climate change, pesticides, etc. to be the causes of CCD, it might just be a coincidence. It is important to understand that CCD might not be the biggest threat to honeybees. CCD symptoms are actually not as common as once believed, so it might be possible that efforts to stop CCD should not be top priority. Perhaps investing time in the aforementioed causes of CCD should be top priority.

Does this mean that the topics discussed are not worth exploring and tackling within the field of Environmental Studies? No. Regardless of whether the connection is real or not, these issues discussed in the paper are still problems that are plaguing the planet. They are responsible for killing honey bees, as well as other animals all over the world. Perhaps, if the causes for CCD are the same as the causes addressed, taking care of one of these dangers might also impact the progress made on CCD.

If the history of these issues proves anything, there are always proposed solutions to our problems, old and new. The human race has found a number of different answers, from policy to environmental and chemical cures and everything in between. There is a possibility that CCD losses can be reduced if not eliminated entirely due to the abundance of known solutions and possible future solutions. There is a shared desire to solve these issues within the scientific community and like-minded nations. Nations all over the world have created laws, new scientific solutions, and other methods to ensure sustainable practices are present for future generations. The existence of honey bees ultimately helps to build that future and cab be used as a thermometer to incidate the health of the environment. Bees thus can and should be seen as vital to that future. We need to find any means necessary to protect both the bee population and the future state of produce. For the future of CCD research, the nations of the world should come together to create multinational accords not unlike the Paris Climate Accords. If all the nations work collaboratively together in support of scientific research to not only understand CCD but manage the other influencers to the honey bee population, then the honey bee population will continue to thrive. As the honey bees thrive, so does the rest of the planet.

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