U.S. Involvement: Decline of Honey Bee Population in the Central Valley

AP Capstone: Research

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Introduction

The honey bee, or the *Apis mellifera*, is an insect that collects pollen and nectar for its colony of approximately 60,000 worker bees. In doing so, it performs an act called cross-pollination. This assists with the fertilization of plants, which later results in the bearing of fruits and seeds. Although many plants do not require assistance in pollination, most flowering plants do. In fact, without honeybees, the world would lose one-third of its food supply (Walsh, 2013). In the US, honey bees pollinate around $15 billion worth of agricultural production annually (USDA, 2014). California uses a third of the commercial hives in America to pollinate almonds alone (Kreman et al., 2002). In recent years, beekeepers all over the world have been experiencing a certain problem that is endangering crop production.

"Colony Collapse Disorder" (CCD) is the unexplained phenomenon that is given to hives that suffered a rapid loss of adult honey bees, leaving behind the immature bees, food, and queen in the hive (Jonathan, 2010). Before settling on CCD, the syndrome took on many other names, such as May disease, spring dwindle, disappearing disease and fall dwindle disease (VanEngelsdorp, 2007). However, none of these names were appropriate with the condition for four reasons: its specific seasonal references, implication when using "dwindle", description with "disappearing", and misleading usage of "disease" (VanEngelsdorp, 2007). Therefore, the term CCD was created due to the mystery and severity of the situation.

Literature Review

CCD has been a recent concern because of the significant losses beekeepers are facing. Starting in October 2006 on the East Coast of the United States, a startling number of honey bee colonies began dying (VanEngelsdorp, 2007). VanEngelsdorp—an assistant professor of entomology at the University of Maryland—and the Pennsylvania Department of Agriculture (2007) interviewed seven experienced beekeepers who reported that their honey bee colonies suffered heavy losses (VanEngelsdorp, 2007). These beekeepers were used as a representation for every beekeeper in the states Florida, Georgia, North Carolina, and Pennsylvania (VanEngelsdorp, 2007). The colonies, however, did not only stay in those states. Being migratory beekeepers, these seven beekeepers moved their colonies to and from six more states–California, Delaware, Maine, Maryland, New York, and North Dakota (VanEngelsdorp, 2007). The amount of colonies each beekeeper manages range from 200 to over 3000. When interviewed, the beekeepers claim to have lost 30 to 90% of their colonies (VanEngelsdorp, 2007). At first, these sharp declines in colonies was called fall dwindle disease. Renaming it shortly after, this was the first official recording of CCD; however, this was not the first time beekeepers have witnessed large-scale losses.

One of the first published records of similar circumstances is the Isle of Wight incident (Bailey, 1963; Denmark et al., 2014; Hirst, 1921; Rennie, 1921). In 1906 on this small, English island, the beekeepers noticed something peculiar about their colonies. There was a notable increase of honey bee deaths and the behavior of the honey bees was also unusual (Rennie, 1921). During this time, beekeepers did not have a good explanation for this odd behavior and mysterious deaths of their honey bees so they called this Isle of Wight disease. It was not until almost a decade later when a possible cause appeared. Around the 1920s, mites were discovered on the bees infected with Isle of Wight disease. Dr. John Rennie and his associates from Aberdeen University, the first discoverers of these mites, proceeded to investigate the effect of these mites on the honey bees. At first, the group named the mites *Tarsonemus woodi,* but it was later reclassified to *Acarapis woodi* by entomologist Stanley Hirst in 1921 (Hirst, 1921). However, it was later proven by Dr. Leslie Bailey, a renowned authority on bee diseases, that the mites did not cause the Isle of Wight disease, disproving Dr. John Rennie's hypothesis (Bailey. 1963). Dr. Leslie Bailey also added that a reason why beekeepers and researchers quickly accused the mites of causing the Isle of Wight disease could be because they were desperate to find an exact answer to this problem. Given that the residents on the Isle of Wight did not have the same technology as today's, it is easy to see why the beekeepers jumped to conclusions, using the mites as a scapegoat. Although Dr. Leslie Bailey proved the mites hypothesis to be wrong, even he did not know what the root problem was. Therefore, the main contributor for this incident remains shrouded in mystery, similar to the current situation involving CCD. Although no one main contributor could be identified, there are other factors that could play a part in the CCD phenomenon, but just like the mites, it could be an early and desperate assumption for a complicated problem.

Diseases and Parasites

Similar to what researchers thought was the main cause of the Isle of Wight disease, diseases and parasites are potentially a contributing factor to CCD. In this research paper, any parasites or infections affecting the larval and pupal stage of the honey bee will be disregarded because the bee would die during those stages and would not have an effect on an adult bee's behavior. Additionally, only the parasites and pathogens that are more of a threat or already a threat to California's Central Valley would be considered.

One such parasite, *Apocephalus borealis,* is a phorid fly that is native to North America (Casuso et al., 2014). This phorid fly is known to parasitize paper wasps, bumblebees, and honey bees by laying its eggs into the host. Once the eggs hatch, the larvae feed and develop in the still-living host. The parasitized bees then abandon their hives during the night and matured larvae emerge from the host. These phorid flies have been a recent concern because of the looming threat it has on crops in the US, especially California (Core et al., 2012). Not only that but parasitized bees are also infected with deformed wing virus and *Nosema ceranae*, which causes early senescence—the process of deterioration alongside aging—of adult workers (Core et al., 2012).

These conditions are similar to another parasite that is notorious in the beekeeping community, *Varroa* mites. These mites infest the brood (immature bees) cells as well as the adult stage of the honey bee by sucking out its bodily fluids. Though, just like the phorid flies, *Varroa* mites themselves are not the main concern. Rather, it is the multiple viruses, such as the ones stated before, that get transferred through the mites.(Moore, 2014). In all their annual reports on honey bee losses, the US Department of Agriculture specifically singles out the *Varroa* mites, which are consistently found in the hives that have been struck with CCD, as the main parasite that contributes to CCD (USDA, 2015). This does not mean that the USDA believes that *Varroa* mites are the sole cause of CCD, as they also mentioned other possible factors. The USDA does believe that, on the topic of parasites and pathogens, *Varroa* mites are the ones that should be considered as the most likely to cause CCD.

Although there are many more parasites and pathogens that harm the honey bee's health, they were refrained from this research paper because they are not commonly found in the California. Although, phorid flies could not be the main cause of CCD when the name CCD was first created, since phorid flies were not discovered to be a threat until around 2012. However, the phorid flies' skyrocketing population in California today is the reason why they are addressed in this research paper. *Varroa* mites have also been a threat to the honey bee's health and sort of a universal truth that *Varroa* mites are feared by beekeepers everywhere. As mentioned before, *Varroa* mites do bring many viruses, which many were not mentioned. Just like the phorid flies, deformed wing virus and *Nosema ceranae* are also transferred through *Varroa* mites; however, ones like sacbrood were not considered because they do not affect an adult honey bee's health nor do they exhibit the same results as what CCD entails.

Pesticides

Because of the deadly consequences parasites could bring, some pesticides are used in an attempt to prevent further infections and deaths of honey bees. Ironically enough, the same pesticides used to protect the honey bees could potentially be harming them. This research paper will not only focus on the common pesticides used to protect honey bees, but also the pesticides used on crops honey bees are mainly exposed to. For the purpose of this paper, spray adjuvants, which are used to improve the effectiveness of pesticides, will be considered as a pesticide.

As mentioned before, *Varroa* mites are one of the honey bee's most formidable foes, which is the reason why there are varroacides, a type of pesticide that specifically targets *Varroa* mites. In theory, varroacides sound ideal for the protection of honey bees; however, the chemicals they contain also affect the honey bee colony as a whole (FERA, 2015). Even though they do eventually kill the mites, bee products, such as honey and wax, could contain these chemicals. For example, chemicals like lactic acid and oxalic acid could get into the wax, where the brood resides, and kill them (FERA, 2015).

Pesticides are also used by farmers to protect their crops from getting eaten or damaged. A moderately new development of a type of pesticide used by these farmers has been shown to affect honey bee behavior (Johnson et al., 2010). Neonicotinoids are highly toxic to honey bees, and even a slight exposure to it could show signs of learning impairment as well as memory damage in honey bees (Desneux et al., 2007). Timothy J. Ciarlo and his team at Penn State (2012) were interested in the effects of spray adjuvants on honey bees (Ciarlo et al., 2012). His team decided to focus on the spray adjuvants used on the almond crops in the Central Valley of California mainly because almond pollination in the Central Valley is the "single largest pollination event in the world." (Ciarlo et al., 2012) With so many honey bees pollinating a single crop, pesticide effect on honey bees would be easier to observe. Ciarlo and his team (2012) came to the conclusion that spray adjuvants could potentially affect the honey bee's sense of smell, which heavily contributes to its navigational skills (Ciarlo et al., 2012). This would give an explanation to why worker bees might disappear since they would not be able to return to their hives.

Similar to the diseases and parasites, there are many more pesticides that are used across the globe, but because this research paper is only focusing on the Central Valley, only the most relevant were chosen. On the topic of neonicotinoids, they cannot be the sole cause of CCD since Australia uses this type of pesticide, but no cases of CCD were reported (Kluser et al., 2010). However, a very distinct difference between the hives in Australia and the hives anywhere else is that the Australian hives do not have *Varroa* mites (Kluser et al., 2010). The blaming of neonicotinoids is similar to what the blaming of the *Acarapis woodi* mites of the Isle of Wight, where people are desperate for a simple and clear answer to a very complicated problem.

Knowing this, that means that it is still too early to assume that neonicotinoids do have a detrimental problem on honey bees. Yet, this does not stop Europe from banning neonicotinoids in 2013 for two years. Depending on these results, researchers will truly see whether or not neonicotinoids are as deadly as presumed.

Climate Change

Climate change must be addressed, since it has been a prominent issue in many topics, not just CCD. Although climate change may not have been a crucial factor in the honey bee population decline in the past, it has recently emerged as a problem because most pollinators cannot adapt to temperature quick enough. Additionally, California has been in a severe drought since 2012, affecting water levels and plant life, which honey bees need to survive. Therefore in this paper, extreme weather will be assumed to be caused by climate change and the drought will be referred to as climate change. Additionally, this paper will group lack of food supply in the category of climate change and will give reasons why.

All pollinators can be directly impacted by climate change (Scaven et al., 2013). One concern for increasing temperatures is the foraging activity in pollinators. One behavioral change in the honey bees is noticed with its thermoregulation process. When honey bees want to warm up, they bask in the sun; in contrast, they seek shade or return to their hives to cool down. However, when temperatures are too extreme, honey bees ceases to carry out its pollinating processes (Kjøhl et al., 2011). With already increasing temperatures, the pollination time is already declining, as honey bees try not to overheat. What results in this would be the different times of the day honey bees would go out to forage (Scaven et al., 2013). The consequence of foraging early or later in the day is the shift in pollen flow. For example, to avoid overheating in the middle of the day, bees could forage earlier in the day, which puts plants that flower later in the day in trouble. This would limit the honey bee's options for a diversity plants to pollinate since unintentional selection causes certain plants to be more reproductively successful than others.

In terms of lack of food supply, there are many factors that result in no plants but a prevalent cause is the temporal mismatch between plants and bees. As winter ends and spring begins, the blooming of flowers is usually synchronized with the honey bee's emergence from winter; however, climate change has been causing the times to begin differently (Memmot et al., 2007). Jessica Forrest (2015), the assistant professor at the University of Ottawa, reviews the research on plant-pollinator mismatch. After analyzing the experiments, she concluded that the plant-pollinator mismatch impairs the production of seeds in plants (Forrest, 2015). This would most likely be caused by the different response times to seasonal cues, such as the increase of temperature during the transition from winter to spring. If honey bees go out to forage with no blooming flowers, the honey bees would eventually starve. In contrast, flowers could bloom, but with no pollinators, seeds would not be able to be made. However, Forrest (2015) did mention that all these experimented that were conducted could not emulate climate change in a large-scale area (Forrest, 2015). Even so, this still provides evidence that lack of food supply for pollinators are affected by the temporal shifts.

In the end, beekeepers and bee experts could all agree that extreme temperature shifts do play in as a factor of CCD. But as said before, this is up to discussion, because of the assumption that extreme weather is due to climate change. While the issue of climate change only emerged in recent years, the effects of it have become too noticeable to ignore. Although, the effects climate change has on individual honey bees may be problematic, it could not possibly cause the rapid declines seen in the past few years. Instead, the plant-pollinator mismatch is the frightening concern, since it leads to the loss of both the plant and the pollinator.

Present Study

CCD does not only mean the deaths of honey bees, rather it means the decline of bee population. One possible cause could not be isolated because there is no evidence of one single factor that would support every possible case of CCD. Most of the research that was conducted for parasites and diseases generally believe that the parasite itself is not what contributes to CCD. In fact, the diseases that get transferred through the parasite are the real concern. While beekeepers are thinking of a plan to limit the infestation of parasites, beekeepers would also have to worry about where the honey bees are getting their food supply because of the potential risks pesticides could cause. The chemicals inside the pesticides could hurt the honey bees individually or the colony as a whole. While those are subject to location, climate change is less restricted since it is a global concern. Extreme weather patterns causes the emergence of plants and bees to be at different times, which becomes a problem since one cannot survive and reproduce without the other. These studies and findings are important since these are the main factors this research paper would focus on in attempting to address.

However, there are still gaps in this field. One would be the other factors that contribute to CCD, such as malnutrition, lack of genetic diversity, and beekeeping techniques. These problems are not too similar to each other, so if a method were to be made, then the solution would be very vague and imprecise since it is impossible to address all these factors. Another gap in this research is the location. CCD is a worldwide phenomenon, but research from different countries–and even cities–could have environmental differences. French beekeepers would say that pesticides killed their bees while Spanish beekeepers would say it is a gut parasite that is killing their bees. (Lovell, 2012).

For being one of the most important states in the US, surprisingly, there are very little studies on CCD in California, and even less in the Central Valley. Almonds, California's second largest cash crop, are worth $3.8 billion alone (Leschin-Hoar, 2013). Almonds also rely heavily on pollinators, which is why beekeepers from all over the country bring their colonies to California so their honey bees could pollinate these trees. Therefore, with the current knowledge and technology, this research paper will address this question: What measures should the US take to combat the decline of honey bee population in the Central Valley?

Method

As of now, it is hard to personally conduct an experiment that actually results in a usable solution of saving the honey bees. Setbacks such as the ethics behind experimenting on live honey bees, the different locations, the time constraints, and the lack of materials make it almost impossible to begin an experiment with useful results given the current situation. Therefore, this research paper will focus on other research that has been conducted on ways to solve the decline of the honey bee population. However, because there is not a consensus over what the main cause of CCD is, there are different solutions to different problems depending on the presumed cause. The solutions will be split up into three parts: pesticide alternatives, diseases and pathogens approach, and addressing climate change.

The easiest approach to make sure pesticides are not harming the honey bees is to simply remove all pesticides from crops. In short, farmers would have to grow their crops organically.

Although this solution will most likely help pollinators everywhere, there are multiple problems that go along with organic farming, which is why the complete removal of all pesticides will not be looked into in this research paper. However, what would be analyzed is the removal of bee-harming pesticides, which is exactly what Europe has done: the banning of three neonicotinoids for two years. Ideally, this would be the perfect study to analyze, but the official published results of the ban will be finished at the end of January 2017. Instead, an opinion article titled *Maintaining the Restriction on Neonicotinoids in the European Union – Benefits and Risks to Bees and Pollination Services*, written by professors at Lund University, will be examined. Professor Björn K. Klatt and his colleagues (2016) are experts in environmental science and recently have been placing their focus on honey bee health, and Lund University is centered in Europe so they could have examined the effects of the pesticide ban firsthand.

In terms of diseases and parasites, getting rid of the parasites would result in a decline of diseases in honey bees because there will be fewer mediums to transmit the diseases. Between *Varroa* mites and phorid flies, *Varroa* mites will be focused on in this method. Phorid flies are a concern in California, but there has not been any recent news about these parasites, and they are easier to manage. On the other hand, *Varroa* mites have always been a problem to the honey bee population and they can quickly adapt to their environment. The best way to get rid of these mites is still in question. Therefore, this research paper will utilize a leaflet titled *Managing Varroa* by the National Bee Unit. The National Bee Unit is a recognized center of excellence in Europe that provides advice and research in bee health. As the title explicitly states, the leaflet provides methods to control *Varroa* infestation. This leaflet was chosen not only because it was edited and revised recently, but also because it has an unbiased opinion about the potentially deadly varroacides.

As stated about climate change, the most prevalent issue is the lack of food from the plant-pollinator mismatch. However, because the drought has been a significant factor in the plant life in California, one of the best methods should involve in the increasing of wildflowers. Therefore, a testimonial article from *Western Farm Press* will be analyzed, specifically how much the cover crop helped with the honey bees. Cover crop is a plant that is usually used to improve the soil, but in this case, it is used as an additional food source for honey bees. This article was written about the 2014 spring pollination in San Joaquin Valley, which is an area of the Central Valley. This article was mainly chosen based on its location.

Findings

Klatt and his colleagues (2016) first reviewed the current understanding of neonicotinoids and how most of the research on the effects the chemical has on honey bees are an inaccurate representation of the actual effects because lab results are not the same as field results. (Klatt, 2016) This would mean that neonicotinoids may actually be less harmless than perceived by most research studies. Klatt and his colleagues (2016) also said that the ban on neonicotinoids will most likely result in the use of other insecticides, potentially even more harming. (Klatt, 2016) Their conclusion is to continue the use of neonicotinoids since they are less toxic to honey bees than any other pesticide.

Currently, every control method for managing *Varroa* could be split into two categories: varroacides and biotechnical methods, which are methods that resort to physical means to reduce the mite population. (Managing Varroa, 2015) Varrocides are then split into authorized (medicinal products tested and approved for efficacy and safety) and unauthorized (natural substances that are non-approved). (Managing Varroa, 2015) The leaflet provided the advantages and disadvantages of using biotechnical methods and varroacides, such as how expensive they are and repercussions. Additionally, four commonly used biotechnical methods and twelve varroacides were examined.

In this article, Grewal Brothers Farming used cover crop as a food supply for the bees during the spring. The cover crop that Grewal used was from the Seeds for Bees project through Project *Apis m.*, a non-profit company whose goal is to improve honey bee health. The purpose for the Seeds for Bees project is to increase forage and improve bee health by providing free seeds to almond growers. Migratory beekeeper Brett Adee (2014) described the cover crop as a wonderful solution since it helped with the strengthening of his bees' health and with the improvement of the soil. (Baker, 2014)

Analysis

In the end, the solutions from all three methods turned out to have an evident variation from each other. For pesticides, the continual use of neonicotinoids may be the best method to use when compared to some other pesticides and their side effects. For *Varroa* mites, two types of solutions were proposed, one that includes the use of chemicals (which can result in residues of it in bee products) and one that is very time and labor intensive. As for an approach for climate change, cover crops seem like the best option. Each method, however, has its limitations and implications.

Neonicotinoids may still be a viable option since there have not been any appropriate research for how exactly neonicotinoids affect honey bees outside of the lab and what the long term effects are. In addition, the two-year ban was in Europe, and as mentioned earlier, CCD varies with location. The Central Valley could have an entirely different effect than Europe, but until more studies are done, the research paper can only assume that Europe will have the same environmental effects of the Central Valley. In the article, Klatt and his colleagues (2016) did mention that there needed to be more studies on other alternatives for pesticides. Alternatives that were not mentioned in the article that would be interesting to research upon would be genetically modified crops and organic farming.

In the case of farmers in the Central Valley, using biotechnical methods may not be the best choice to address the *Varroa* mite problem. One reason is because of how time-consuming it would be to check all the hives on an agricultural plot. Even if a beekeeper were to hire workers to check, some biotechnical methods do require a high level of beekeeping knowledge. Not only that but multiple methods may need to be used since just one method may not be sufficient if used alone. However, varroacides are not perfect either. Authorized varroacides may be approved to be useful and safe, they are usually expensive to buy. Also, *Varroa* mites adapt very quickly, so they can soon develop resistance to the varroacides. This leads to unauthorized varroacides, which is what this research paper is leaning towards. Unauthorized varroacides may not have approval and enough research performed on them, but since it uses natural substances and it is relatively cheap, the benefits may outweigh the drawbacks. However, more research is definitely needed for unauthorized varroacides and other solutions.

Lastly, cover crops may seem like a viable solution, but only temporarily. Since climate change is a new topic, there has not been much research about it. To address the lack of food supply, cover crops are not enough to have a substantial impact on the bee population. What this article did not mention were any limitations to cover crops, which is not surprising since *Western Farm Press* is for solutions for common problems, so it is expected to promote this solution. What also would have been helpful is if Project *Apis m.* posted any results for how much the Seeds for Bees project actually helped.

Conclusion

In the final analysis, it seems that one solution could not possibly be made that would address the three problems. The first step the U.S. should take is to fund more research to kill *Varroa* mites. But for farmers, unauthorized varroacides are the best option to kill the mites. Although there has not been enough research for these types of varroacides, the authorized ones are costly. However, if the U.S. were to subsidize authorized varroacides, then those might be the best option. In terms of pesticides, the use of neonicotinoids should still be implemented until the European report comes out at the end of this year. But along with that, the long-term effects of neonicotinoids on honey bees should be researched alongside the usage of it. For climate change, the best option, for now, is to find ways to increase the wildflower population. That way, the bees would always have some sort of food supply. If that is not enough, a structure that is based on Oslo’s bee highway should be built in the Central Valley. Honey bees would be able to go farther away from their hives to collect pollen and nectar, and they will never run out of food. Additionally, there should be classes given out to the general public to spread the awareness of the honey bee decline as well as classes that teach how to manage a beehive in one’s own backyard. The honey bee population is still declining so the more knowledgeable ordinary people are about this, the more likely honey bees will become healthier and rise in numbers.

There are some limitations in this research paper. One problem is with the data. The problem with the sources used is that it provided no quantitative data and no comparison to show how much these solutions would have helped. In fact, a difficult part of this research was to actually find any recorded data of the number of bees before and after a method was used. It was even harder to find any research conducted in the Central Valley. Therefore, the results found in this research paper were not very helpful to the combating of honey bee decline. Most importantly though, the right research question was asked at the wrong time. Because the current CCD is still quite recent, there are not many researches for certain topics like climate change. Most sources were similar to the research with the Isle of Wight: once one potential cause of CCD appeared, every researcher and beekeeper jumps in and blames it as the main cause. If time and resources were not a problem, an actual experiment or an interview with a beekeeper in the Central Valley would have been useful. The experiment would try to capture the effects of each potential method mentioned in the research paper. Although an interview does provide insight about the Central Valley, one beekeeper may not be a good representation of the whole Central Valley. But, if this same research were to be conducted again, it should be done in 2017, when the results for the two-year pesticide ban would be done.

References

Bailey, L. (1963). *The" Isle of Wight disease": The origin and significance of the myth.* Ilford, Essex: The Central Association of Bee-keepers.

Baker, P. (2014, July). *Planting bee forage cover crops in San Joaquin Valley*. Retrieved from http://westernfarmpress.com/orchard-crops/planting-bee-forage-cover-crops-san-joaquin-valley

Casuso, N. A., Mortensen, A. N., Ellis, J. D. (2014, October). *zombie fly - Apocephalus borealis Brues.* Retrieved from http://entnemdept.ufl.edu/creatures/MISC/BEES/Apocephalus_borealis.htm.

Ciarlo, T. J., Mullin, C. A., Frazier, J. L., & Schmehl, D. R. (2012). Learning Impairment in Honey Bees Caused by Agricultural Spray Adjuvants. *Plos ONE*, *7*(7), 1-12. doi:10.1371/journal.pone.0040848

Core, A., Runckel, C., Ivers, J., Quock, C., Siapno, T., et al. (2012) A New Threat to Honey Bees, the Parasitic Phorid Fly Apocephalus borealis. *PLoS ONE* 7(1): e29639. doi:10.1371/journal.pone.0029639

Denmark, H. A., Cromroy H. L., Sanford, M. T. (2014, July). *honey bee tracheal mite - Acarapis woodi.* Retrieved from http://entnemdept.ufl.edu/creatures/misc/bees/tracheal_mite.htm.

Desneux, N., Decourtye, A., & Delpuech, J. (2007). The sublethal effects of pesticides on beneficial arthropods. *Annu. Rev. Entomol.*, *52*, 81-106.

The Food and Environment Research Agency, (2015, October) *Managing Varroa* [Brochure]

Forrest, J. R. (2015). Plant–pollinator interactions and phenological change: what can we learn about climate impacts from experiments and observations?. *Oikos*, *124*(1), 4-13.

Hirst, S. (1921). LIX.—On the mite (Acarapis woodi, Rennie) associated with Isle of Wight Bee disease. *Journal of Natural History*, *7*(42), 509-519.

Johnson, R. (2010, January 7). *Honey bee colony collapse disorder* (pp. 7-5700). Washington: Congressional Research Service.

Johnson, R. M., Ellis, M. D., Mullin, C. A., & Frazier, M. (2010). Pesticides and honey bee toxicity–USA. *Apidologie*, *41*(3), 312-331.

Kjøhl, M., Nielsen, A., & Stenseth, N. C. (2011). *Potential effects of climate change on crop pollination.Potential effects of climate change on crop pollination*. Food and Agriculture Organization of the United Nations (FAO).

Klatt, B. K., Rundlöf, M., & Smith, H. G. (2016). Maintaining the restriction on neonicotinoids in the European Union–benefits and risks to bees and pollination services. *Frontiers in Ecology and Evolution*, *4*, 4.

Kluser, S., Neumann, P., Chauzat, M., Pettis, J. (2010). "Global honey bee colony disorders and other threats to insect pollinators."

Kremen, C., Bugg, R. L., Nicola, N., Smith, S. A., Thorp, R. W., & Williams, N. M. (2002). Native bees, native plants and crop pollination in California. *Fremontia*, *30*(3-4), 41-49.

Leschin-Hoar, C. (2013, February 12). Why California Is in Desperate Need of Bees [Web log post]. Retrieved from http://www.takepart.com/article/2013/02/12/bee-decline-could-hurt-almond-growers-signs-things-come

Lovell, J. (2012). Beekeepers Abuzz Over Climate Change and Hive Losses. *Scientific American*. Retrieved from http://www.scientificamerican.com/article/beekeepers-abuzz-over-climate-change-and-hive-losses/

Managing Varroa [Leaflet]. (2015) York, England: Crown

Memmott, J., Craze, P. G., Waser, N. M., & Price, M. V. (2007). Global warming and the disruption of plant–pollinator interactions. *Ecology letters*, *10*(8), 710-717.

Moore, P. A., Wilson, M. E., & Skinner, J. A. (2014). Honey Bee Viruses, the Deadly Varroa Mite Associates.

Rennie, J. (1921). (4) Isle of Wight Disease in Hive Bees—Acarine Disease: The Organism associated with the Disease—Tarsonemus woodi, n. sp. *Transactions of the Royal Society of Edinburgh*, *52*(04), 768-779.

Scaven, V. L., & Rafferty, N. E. (2013). Physiological effects of climate warming on flowering plants and insect pollinators and potential consequences for their interactions. *Current zoology*, *59*(3), 418.

United States Department of Agriculture. (2014). Agriculture Secretary announces $3 million for a new program to improve pollinator health [Press release]. Retrieved from http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/newsroom/releases/?cid=STELPRDB1246681.

United States Department of Agriculture. (n.d.). *Honey Bee Health and Colony Collapse Disorder.* United States Department of Agriculture website. http://www.ars.usda.gov/News/docs.htm?docid=15572

VanEngelsdorp, D., Foster, D. C., Frazier, M., Ostiguy, N., & Hayes, J. (2007). *" Fall-dwindle Disease": Investigations Into the Causes of Sudden and Alarming Colony Losses Experience by Beekeepers in the Fall of 2006*. Florida Department of Agriculture.

Walsh, B. (2013, August 19). The Plight of the Honeybee. *Time*, 182(8), 24. Retrieved from http://time.com/559/the-plight-of-the-honeybee/