THE ECONOMIC CONSEQUENCES OF HONEY BEE COLONY COLLAPSE DISORDER
FOR CALIFORNIA’S AGRICULTURE INDUSTRY

LUCAS P. DESIN
CALIFORNIA STATE UNIVERSITY SACRAMENTO
DEPARTMENT OF ENVIRONMENTAL STUDIES
SENIOR THESIS
DR. JEFFERY FORAN, CHAIR
MAY 14, 2014
## Contents

Acknowledgements..................................................2  
Abstract..............................................................3  
Introduction..........................................................4 
Background............................................................5 
  Colony Collapse...................................................5  
  Economics of Pollination.........................................6  
Analysis........................................................................7  
  The California Almond Crop......................................7  
  Other Honey Bee Pollinated Crops in California...........8  
  Declines of Native Pollinators..................................10  
  Increasing Hive Rental Prices.................................10  
  Almond and Other Crop Vulnerability.........................14  
  Interview with Dino Flor.........................................15  
Discussion..............................................................17  
  Recommendations..................................................21  
  Conclusions..........................................................22  
References.............................................................23
Acknowledgements

I would like to dedicate this paper to my loving mother Laurie Desin who gave me the inspiration to better my life through a college education, taught me to truly appreciate it and also to cherish every moment we have here on earth with the ones we love. Her life was cut short, but she touched so many people while she was here. Her love for children led her to a life helping them. She was the most selfless person I have ever known and I only wish to have half of the heart and strength that she had before I pass. She was and remains an inspiration to many people and is truly missed.

I would like to thank my father for always supporting me through difficult times and for teaching me new ways of thinking. He is a smart and hard-working man that I love and respect.

I would like to thank all of my professors in the Environmental Studies Department at California State University Sacramento. A special thanks to Dr. Michelle Stevens for always believing in me and supporting my education and well-being.

I would also like to thank Dr. James Reede, Dr. Catherine Ishikawa, and Department Chair Dr. Jeffery Foran for being great professors and supporters of my success.
Abstract

Colony Collapse Disorder (CCD) with no known single cause has been observed throughout the United States since 2006. It is a condition among honey bees (*Apis mellifera*) where worker bees fail to return to their colony. The economic implications of the disorder have been narrowly studied despite a vast amount of research into its causes. Declines in managed pollinator populations have created concern over not only the health of honey bee colonies, but the implications for agriculture, especially those crops dependent on pollination services from honey bees. This paper characterizes and quantifies the economic consequences of CCD to those involved in California’s agriculture industry, particularly for the state’s lucrative almond crop. The monetary value attributed to honey bees for their services in pollination is cited as being as high as $14.6 billion in the United States, pollination fees are increasing for various crops, and demand for bees is beginning to outweigh the supply. CCD has already led to increased costs to farmers and appreciable losses in bee colonies available to pollinate crops. A review of scholarly literature reveals vulnerability in pollinator-dependent crops facing pollinator decline and the potential for lost revenue to farmers, beekeepers and government agencies. On a broad scale, a decline or loss of pollinators is not likely to damage California’s agricultural economy as a whole, but that is not an indication that no economic consequences will occur as a result of CCD.

Introduction

Humans rely heavily on the services provided by managed honey bee (*Apis mellifera*) colonies for the pollination of important food crops. Although the exact amount contributed is debated, it has been suggested that managed honey bees contribute to higher yields in 96% of crops that rely, at least in part on pollination by some animal species (Potts *et al*, 2010). When honey bee colonies began undergoing a distinct decline around 2006, the condition was named
Colony Collapse Disorder (CCD), a condition which is characterized by the absence or loss of worker bees in a colony and has been observed worldwide since 2006 (Evans et al., 2009). Many studies have attempted to find the cause or causes of CCD but few have discussed the possible economic outcomes resulting from reduced or diminished pollination by managed honey bee colonies. The goal of this paper is to characterize and attempt to quantify the economic consequences of CCD for California’s agriculture industry. It will examine increasing costs resulting from CCD to create recommendations for some best practices which consider the consequences of reduced pollination. Reviewing research on this subject will provide evidence to answer the question of whether or not California’s agriculture industry could recover from a reduction or loss of pollination by honey bees.

**Background**

*Colony Collapse*

In 2006, managed honey bee colonies experienced a marked decline in worker bee numbers, the phenomenon was reported by beekeepers up and down the east coast of the United States, and due to its gravity was named Colony Collapse Disorder as honey bee colonies experienced losses of 35.8% in the winter of 2007/2008, 31.8% in 2006/2007, and 28.6% in 2008/2009 (Johnson, 2011). It was not long before reports of similar losses were reported around the country. These declines hold the potential to affect not only crop productivity in California but also the economic benefits provided by abundant harvests. Observations reveal that honey bee colonies in the U.S. declined in abundance for many years prior to and after CCD (*Figure 1*).
There is no single cause of CCD, but there are likely several interacting drivers, including habitat fragmentation, increasing pesticide usage, reduced biodiversity, pollution, increasing non-native species, pests, pathogens and climate change (Potts et al, 2010). These make the problem far more complex and difficult to mitigate. It has been suggested that certain drivers are increasing the intensity of other drivers and leading to more significant declines in honey bee abundance (Potts et al, 2010). The complex nature of interacting drivers and the inability to pinpoint specific causes make this issue difficult to solve and could threaten economic prosperity from agricultural practices worldwide (Figure 2).
Economics of Pollination

The worldwide economic value of pollination is estimated to be €153 billion (~$200 billion U.S.), 9.5% of the total value of agricultural food production in 2005 and the leading crop categories for insect pollination are fruits and vegetables, edible oil producing crops, stimulants, and nuts and spices respectively (Gallai et al, 2009). This makes the total value of agricultural food production for 2005 over $1.6 trillion. These numbers, however, are based on all pollinators including native bees, birds, bats, moths and other animals. A more specific value is the value of pollination by managed honey bees alone. The value of pollination services provided by managed honey bees alone is estimated to be $14.6 billion in the United States, a figure that includes indirect, or livestock feed values and direct crop values (Bauer and Wing, 2010). These numbers reinforce the idea that managed pollinators bring much value to the economy and are something worth concern.
Analysis

*The California Almond Crop*

The California almond industry is fast-expanding and remains a profitable industry for the state (Morse & Calderone, 2000). In 2010 around 80% of the world’s almond supply came from California and about 70% of California almonds are exported, making almonds the state’s largest value agricultural exports, and as of 2008, there was estimated to be 1,725,070 hives pollinating California crops, 79% of which were used to pollinate almonds (Carman, 2011). Honey bees are critically important to the success of the almond crop in California and elsewhere. There are three times as many honey bee colony rentals for pollinating the almond crop as there are for the next most important crop (Morse & Calderone, 2000) and an annual cost increase of $83 million dollars for almond production is attributed to CCD related consequences (Carman, 2011). The dependency of the California almond industry on pollination by managed honey bee colonies for its economic benefit makes the industry vulnerable to reduced yields or failure with the reduction or disappearance of honey bees. The cost of almond production in California is clearly increasing. Increasing costs associated with almond production can be seen from 2006 to 2011 (*Figure 3*).
Figure 3. The cost increase from year 2006 to year 2011 for almond production/acre in California  
Source: Klonsky (2012)

Other Honey Bee-Pollinated Crops in California

Other important honey bee pollinated crops in California are seen here, along with the percentage of total U.S. production supplied by California. Cantaloupes represent 61% of U.S. production from California, honeydews 76%, avocados 84%, kiwis 100%, plums and prunes 54%, pears 32%, alfalfa seed 33%, watermelon 18%, fresh cucumbers 16%, along with others such as citrus fruits, broccoli and carrots (Morse & Calderone, 2000). The high proportions of total U.S. production coming from California for bee pollinated crops may suggest that California will sustain an economic setback with reduced pollination. The dependence of many of these crops on honey bee pollination services as well as the economic value attributable to
honey bees has been documented (Table 1). The trends observed are that California produces the majority of the U.S. supply in several crop categories, that these crops are highly dependent on honey bees for pollination, and that the economic value provided by honey bees in the U.S. appears appreciable.

<table>
<thead>
<tr>
<th>Crop Category (ranked by share of honey bee pollinator value)</th>
<th>Dependence on Insect Pollination</th>
<th>Proportion of Pollinators That Are Honey Bees</th>
<th>Value Attributed to Honey Bees ($ millions)</th>
<th>Major Producing States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa, hay &amp; seed</td>
<td>100%</td>
<td>60%</td>
<td>4,654.2</td>
<td>CA, SD, ID, WI</td>
</tr>
<tr>
<td>Apples</td>
<td>100%</td>
<td>90%</td>
<td>1,352.3</td>
<td>WA, NY, MI, PA</td>
</tr>
<tr>
<td>Almonds</td>
<td>100%</td>
<td>100%</td>
<td>959.2</td>
<td>CA</td>
</tr>
<tr>
<td>Citrus</td>
<td>20-80%</td>
<td>10-90%</td>
<td>834.1</td>
<td>CA, FL, AZ, TX</td>
</tr>
<tr>
<td>Cotton</td>
<td>20%</td>
<td>80%</td>
<td>857.7</td>
<td>TX, AR, GA, MS</td>
</tr>
<tr>
<td>Soybeans</td>
<td>10%</td>
<td>50%</td>
<td>824.5</td>
<td>IA, IL, MN, IN</td>
</tr>
<tr>
<td>Onions</td>
<td>100%</td>
<td>90%</td>
<td>661.7</td>
<td>TX, GA, CA, AZ</td>
</tr>
<tr>
<td>Broccoli</td>
<td>100%</td>
<td>90%</td>
<td>435.4</td>
<td>CA</td>
</tr>
<tr>
<td>Carrots</td>
<td>100%</td>
<td>90%</td>
<td>420.7</td>
<td>CA, TX</td>
</tr>
<tr>
<td>Sunflower</td>
<td>100%</td>
<td>90%</td>
<td>409.9</td>
<td>ND, SD</td>
</tr>
<tr>
<td>Cantaloupe/honeydew</td>
<td>80%</td>
<td>90%</td>
<td>350.9</td>
<td>CA, WI, MN, WA</td>
</tr>
<tr>
<td>Other fruits &amp; nuts</td>
<td>10-90%</td>
<td>10-90%</td>
<td>1,633.4</td>
<td>—</td>
</tr>
<tr>
<td>Other vegetables/melons</td>
<td>70-100%</td>
<td>10-90%</td>
<td>1,099.2</td>
<td>—</td>
</tr>
<tr>
<td>Other field crops</td>
<td>10-100%</td>
<td>20-90%</td>
<td>70.4</td>
<td>—</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>—</td>
<td>—</td>
<td><strong>$14,563.6</strong></td>
<td>—</td>
</tr>
</tbody>
</table>

*Table 1.* The estimated value of honey bees to U.S. crop production in 2000 and crop dependence on pollinators.

Source: Johnson (2007)
Declines of Native Pollinators

The importance of native insects and other animal pollinators and their contributions to the enhancement of crops cannot be overlooked. Accumulating data suggests that the cultivation of crops dependent on pollinators is increasing while native and non-native pollinator abundance is decreasing (Calderone, 2012). This suggests that both native and managed pollinators are important to agricultural crops and that their yields are at least somewhat dependent on animal pollination services. The economic value of crops directly dependent on pollinators other than honey bees is suggested to be $3.44 billion in the United States in 2009 (Calderone, 2012). Existing evidence confirms population declines in wild bees that are likely decreasing pollination of agricultural crops and likely increasing pressures on managed honey bees for their pollination services (Sinnathamby et al, 2013). These recent declines in pollinator populations may be a sign that pollinator dependent crops could decline in productivity in the future.

Increasing Hive Rental Prices

There was increasing demand for honey bees as well as an observable decline in supply even before CCD was officially named, and in 2000 there are estimated to be 2.9 million honey bee colonies in the United States, of which around 2 million are rented to farmers in need of additional pollination for their crops (Morse & Calderone, 2000). An increase in the cost of bee rentals in the Pacific Northwest in recent years has been documented (Table 2). Data from 1992-2009 reveals an average rental price increase from $19.25 per colony to $89.90 per colony (Bauer & Wing, 2010). The supply of bees in the Pacific Northwest versus the demand from the almond industry for pollination reveals shortages of bee colonies (Figure 4) and trends show increasing hive rental prices for individual crops cultivated in California (Figure 5).
The expanding California almond industry is named as a driver of increasing demand for honey bee rentals, bringing an increase in demand by 300,000 colonies in addition to the increasing human population in the United States, which is growing honey bee demand more than 200,000 colonies (Morse & Calderone, 2000). An increase in honey bee rental costs in the Pacific Northwest of 210% was documented between 2001 and 2010 from $33.65 per colony to $70.85 per colony and the California almond crop used 27% of all rental colonies in the Pacific Northwest in 2010, representing 52% of total bee rental income (Burgett, 2009). Hypothetical figures from Burgett (2009) suggest that the California almond crop contributes around $25 million to Pacific Northwest beekeepers who have a total potential gross rental income of $75 million for their pollination services, and cites observed rental prices of bees used for the almond crop being $150.25 per hive in 2009 and 137.20 per hive in 2010. A slight decrease may indicate a certain level of regular variability between years or possibly a new trend of improvement in colony survival. Many California crops and their economic benefits are, dependent, at least in part, on pollination provided by managed honey bee colonies. Despite some level of annual variation, trends of increasing costs and reduced supply from CCD and other drivers appear to be increasing economic strain.

Carman (2011) finds that the supply of pollination services is decreasing and the cost of beekeeping is rising from CCD related losses. Farmers are known for signing contracts with beekeepers. When the beekeepers experience lost colonies from CCD they are forced to replace the lost bees at around $100 per hive and this is one of the causes of rising prices for bee rentals and the estimated $83 million in annual losses from CCD (Carman, 2011). Beekeepers regularly migrate around the U.S. and pollinate more than one crop with their hives (Carman, 2011), but when there is simply not enough bee colonies to sustain the crops dependent on them, we may
begin to see the economic consequences become intensified from reduced yields via inadequate pollination. With increasing demands from the expanding almond industry in California, it is easy imagine honey bee pollination services failing to keep pace with demand.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Honey Crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blueberries</td>
<td>23</td>
<td>33.18</td>
<td>21.34</td>
<td>43.44</td>
</tr>
<tr>
<td>Crimson</td>
<td>21</td>
<td>8.95</td>
<td>0.00</td>
<td>36.84</td>
</tr>
<tr>
<td>Clover</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radishes</td>
<td>23</td>
<td>31.42</td>
<td>15.92</td>
<td>49.23</td>
</tr>
<tr>
<td>Red Clover</td>
<td>22</td>
<td>27.07</td>
<td>9.93</td>
<td>46.47</td>
</tr>
<tr>
<td>Vetch</td>
<td>15</td>
<td>3.11</td>
<td>0.00</td>
<td>11.86</td>
</tr>
<tr>
<td>Group statistics</td>
<td>104</td>
<td>22.27</td>
<td>0.00</td>
<td>49.23</td>
</tr>
<tr>
<td><strong>Non-honey crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apples</td>
<td>23</td>
<td>38.80</td>
<td>22.67</td>
<td>49.68</td>
</tr>
<tr>
<td>Cherries</td>
<td>23</td>
<td>38.70</td>
<td>27.08</td>
<td>53.71</td>
</tr>
<tr>
<td>Cranberries</td>
<td>20</td>
<td>45.48</td>
<td>29.05</td>
<td>60.00</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>21</td>
<td>39.46</td>
<td>23.47</td>
<td>71.04</td>
</tr>
<tr>
<td>Pears</td>
<td>23</td>
<td>38.23</td>
<td>24.01</td>
<td>51.41</td>
</tr>
<tr>
<td>Squash</td>
<td>21</td>
<td>40.64</td>
<td>26.20</td>
<td>60.78</td>
</tr>
<tr>
<td>Group statistics</td>
<td>131</td>
<td>40.10</td>
<td>22.67</td>
<td>71.04</td>
</tr>
<tr>
<td><strong>Almonds</strong></td>
<td>17</td>
<td>75.61</td>
<td>46.94</td>
<td>150.27</td>
</tr>
<tr>
<td><strong>All crops</strong></td>
<td>252</td>
<td>35.14</td>
<td>0.00</td>
<td>150.27</td>
</tr>
</tbody>
</table>

*Table 2. Honey bee rental fees for the Pacific Northwest 1987-2009*

*Source: Rucker et al (2012)*
Thousands of colonies required for almond pollination (Demand)

Thousands of CA colonies available for pollination (at 90% Supply)

Thousands of CA, OR & WA colonies available for pollination (at 90% Supply)

Figure 4. The relationship between bees required for almond crops and a 90% supply of Pacific Northwest bee colonies
The total value of honey bees based on their contributions to production in the U.S. is estimated to be around $14.6 billion (Bauer & Wing, 2010) and the growth rate of the economic value of honey bees attributable to the almond crop has increased from 1.9% in 1945-1969 to 15.6% in 1990-2010, the dollar value increase estimated in the period between 1990 and 2010 for the almond crop being $1.47 billion (Sinnathamby et al, 2013). This is an appreciable sum of money and is important for California’s economy. If pollination becomes more limited or non-existent, California’s economic benefit from agricultural exports would surely be diminished.
Fears of economic consequences from CCD can be realized when one considers the dependency of the almond crop on pollination services by managed honey bee colonies.

The most vulnerable crops appear to be those which are most dependent on honey bee pollination. Among the different crop categories in various regions on earth, nuts are the most vulnerable followed by fruits and stimulants and the regions that grow nuts are a far more vulnerable category as compared to the overall value for the world (Gallai et al, 2009). Economic benefits from almond production can therefore be characterized as highly vulnerable based on these criteria. This is significant because almonds are an important nut crop benefitting California’s economy. California becomes exceedingly susceptible as it faces a declining supply of pollination services by honey bees and increasing almond acreage (Carman, 2011).

Several agricultural crops are listed as being 90%-100% dependent on pollination from honey bees including almonds, apples, avocados, cherries, asparagus, broccoli, carrots and many more (Johnson, 2007). Also important is the dependency of the alfalfa crop on honey bee pollination. Although not a crop for direct human consumption, alfalfa feeds much of the livestock that humans eventually consume, about one third of the value of honey bees as pollinators is due to the production of alfalfa, and the annual value attributable to honey bees for the alfalfa, hay and seed crop in 2000 is over $4.6 billion (Johnson, 2007). Although the value attributable to secondary products like livestock from honey bees would be extremely difficult to extrapolate, it must be remembered when considering possible economic effects. It will be important to consider how far those effects may reach.

An interview with long-time Central Valley farmer Dino Flor provides insight on the topic of CCD from a farmer’s point of view. He is now working in distribution and deals with
many of the crops cultivated in California. Flor has witnessed firsthand a flourishing demand for almonds in recent years. He described a fast-expanding and also, highly productive almond crop this year and sees no signs of a slow-down in the near future. He expresses his concern with the losses of bees being reported and says that growers need to be stewards of the land they work so it remains productive. Farmers cannot afford to lose the productivity of their crops by being careless with their land and Flor says this helps promote more sustainable practices among growers. He believes that a majority of farmers want to be stewards of the land and are willing to make changes such as using the least amount of pesticides necessary, notifying neighbors when crops will be sprayed, spraying when bees are least active, planting pollen-rich vegetation between crops to improve bee habitat, and providing the bees with clean water. These, he says, are things he once practiced and are things growers should still be doing today.

Flor goes on to say that he does not believe a shortage of bees could slow down a strong industry like that of almonds in California. He says that when this amount of money is involved, it is hard to imagine that a solution cannot be bought by way of research funding, importing more bees, or breeding programs producing pest-resistant bee varieties. The question then arises if he believes there are other crops farmers could transition into growing if there was a total loss of bees. He says that farmers often switch to different crops for various reasons and that he cannot foresee a situation where the agricultural economy could be irreparably damaged from a loss of managed pollinators. Flor also says he has rented honey bees in the past for his cucumber, peach and cherry crops and bees are necessary to maximize yields. He believes that growers would not be able to be profitable growing certain crops if honey bees disappeared but does not foresee that happening in reality. Flor describes his feelings on the subject of CCD as hopeful because he
believes modern scientific advancements only hold the potential to improve crops and yields and
to improve honey bee health.

Discussion

Analysis of literature provides an indication that there is vulnerability in California’s
tagriculture industry when considering the current and possible effects of CCD. There is a clear
dependency of certain California crops on pollination services provided by honey bees. The
decline of bee colonies observed thus far has impacted hive rental costs and led to financial
losses. The dependency of the almond industry on pollination by honey bees makes California’s
highest value agricultural export extremely vulnerable. Crops cultivated in the state which are
totally or mostly dependent on honey bee pollination can be equally vulnerable. At stake is a
multi-billion dollar loss for California’s agriculture industry.

The total loss of honey bees for pollination in California may be more economically
significant than observed by other states, growing crops less dependent on these pollination
services. States growing mostly grain, for example, would not feel the economic constraints felt
by those states such as California because their crops do not require pollination by honey bees.
Bee declines in the U.S. between 1986 and 2010 are estimated at $1.8 billion dollars in monetary
losses (Sinnathamby et al, 2013) and this number would likely be greatly inflated with a total
loss of pollination from honey bees. This again raises the question as to whether or not farmers
of almonds in California might be able to convert to alternative crops if the decline grew so
severe.

This is a difficult question to answer because a great number of California growers have
recently converted their crops to almonds due to the growing demand for the product, the high
prices they bring, and the losses they may have been experiencing with previous crops. Evidence of increasing almond acreage in California (Carman, 2011) supports this idea. There is always a possibility that another crop which is easily cultivated in California may experience higher demand and provide farmers with new opportunities, but it is also possible that some farmers might be without alternatives and would be unable to continue growing. The interview with Flor reveals that some farmers do not believe that alternatives to the almond crop are impossible to implement. It does not appear to be true that nothing can be done to improve the economic benefits from honey bee pollinated crops in the state. The estimated $14.6 billion annual value attributed to honey bees in the U.S. may provide incentive for some to take action against future losses. This agrees with the opinion of Flor that the amount of money involved is too much for the almond industry to risk and will be an incentive for protecting managed pollinators in the future.

The importance of all pollinators for the economic benefits they provide by pollinating food crops is high. The ~200 billion dollar annual value attributed to pollinators on earth is important for food supplies and revenue around the globe. Crops dependent on native pollinators are worth over $3.44 billion annually in the U.S. and mitigating bee losses for agricultural benefit should always consider both native and managed species. The decline of native pollinators may be increasing demand for managed pollinators and intensifying pollination shortages at hand. With decreasing contributions from native pollinators, growers may begin to experience things like lower yields and a reduced fruit set. With the decreases in honey bee health from CCD in combination with the loss of native pollinators, farmers have cause for concern, but may begin to find solutions or better practices to counter reduced pollination on their own. Farmers working with beekeepers to innovate new practices are a viable option for
preventing further losses of bees. The effects of reduced pollination will first affect the farmer, which in turn could be a call to action for them to work toward safeguarding their harvests.

One of the most economically important and also most vulnerable of California crops are almonds. The suggested 83 million dollar annual loss for the production of almonds in California currently, appears to be a small fraction of the economic consequences almond growers could face if symptoms of CCD worsen in the coming years. The value that honey bees bring to almond and other crops in California is appreciable and the dependency of many of these crops on pollination by honey bees is critically important to their survival. Many crops in the state are 90-100% dependent on managed pollinators so these crops must be characterized as vulnerable economically, at very least. Without managed honey bee colonies the almond crop in California could no longer remain productive. However, the opportunities to change practices, import bees, breed pest-resistant varieties, and restore habitat offers options for farmers and beekeepers to improve honey bee health and safeguard pollination services for economically significant crops like almonds.

Honey bee colony declines in the Pacific Northwest are increasing the prices of rental hives for all dependent crops in the region. The almond industry in California has seen a huge rise in pollination fees due to high demand for almonds and for pollinators of almonds in combination with a reduced supply of bees from colony declines. The estimated annual revenue of $75 million to Pacific Northwest beekeepers is a sign that beekeeping is a big business in the region. Many of these beekeepers transport their bees to California for pollination of the almond crop so they stand to lose a large portion of their income if CCD increases and they are no longer able to provide services. Pollination fees increased from 2001 to 2010 in the Pacific Northwest
by 210%, which is undoubtedly related to the reduced supply and increasing demand from the growing California almond industry.

It is clear that many crops in California are vulnerable with the reduced pollination threatening them and that agricultural revenues have become more dependent on managed pollinators in recent years. This increased economic dependence is likely due to the expansion of honey bee dependent crops in California and elsewhere. The human population is rising and therefore creating demand for more agricultural products, but this does not explain the increasing proportion of bee-dependent crops in California and throughout the U.S. The interview with Distribution Specialist Dino Flor indicates that the worldwide demand for nuts, particularly almonds, is exploding and leading to more farmers than ever before converting land for almond cultivation. This helps explain the higher proportions of bee-dependent crops in recent years, especially in California. It also helps explain how agriculture as a whole in the state has grown into a position of increased vulnerability concerning pollination. As the agricultural economy in California becomes more dependent on pollination services, its revenue also becomes more vulnerable. The literature seems to suggest that pollination supply in California is not, and likely will not, be able to keep pace with demand from the almond industry for pollination services, unless there is an improvement in colony declines. Economic losses are likely to follow but are these losses significant when compared to the revenue from the sum of all agricultural exports from California?

It appears that the answer to this question is no. California is home to a diversity of crops with a monetary value far greater that the value attributed by honey bees. On fertile lands like those in California, agricultural exports can likely bring hundreds of billions of dollars annually, numbers that surely far exceed the ~15 billion dollar value attributed to honey bees over the
entire country. The most likely victims of the economic consequences will be farmers, beekeepers and distributors involved with pollinator dependent crops in California.

**Recommendations**

Careful planning to manage honey bee populations is needed to prevent the economic consequences associated with CCD in California. An attempt must be made to improve colony health and mitigate losses to improve the economic benefits gained from honey bee pollination services. Current viable recommendations include improving habitat heterogeneity to provide more pollen as a food source, actively managing other pollinator species for improved pollination, switching usage of honey producing bees to utilize them as crop pollinators, increasing honey bee culture practices with more diverse populations, improving agricultural policy, and compensating farmers who use the best agricultural practices (Sinnathamby et al, 2013). Efforts like these have potential to decrease the economic and ecological losses observed from symptoms of CCD by improving habitat resources for bees and increasing diversity among bee populations and subsequent genetic resistance to pathogens and pests. Habitat restorations might also be increased to improve altered habitat conditions and resource availability. It has also been suggested that some of the recent improvements in colony numbers can be attributed to an increase in honey bee imports to supplement losses (Sinnathamby et al, 2013). Practices like these will be necessary if CCD continues impacting bee colonies as reported since 2006. Agricultural policy may also need to be adapted or modified to compensate for colony losses and to better suit changing needs based on recent data. Farmers collaborating with beekeepers to minimize colony declines will likely prove helpful in adopting new strategies. Both together, working with government agencies to create a practical plan of action for farmers and beekeepers, may work best.
It is difficult to manage an issue like CCD without knowing with certainty the cause or causes of the decline. The only option remaining is to manage all of the suspected drivers of this disorder. This is not a simple task and will likely require working with and rewarding farmers for using those best practices with their crops and utilizing a huge amount of inter-agency communication and coordination. Recording and sharing data effectively will help mitigate the effects of the disorder by building an accurate base of knowledge to work from.

Conclusions

The answer to whether or not California’s agriculture industry could recover from the reduction or loss of pollination services by honey bees is yes. It would likely recover. Most growers of pollinator dependent crops would be able transition into a crop less dependent on honey bee pollination and over time the economic effects on a broad scale would fade. The recent almond acreage increase in California, however, suggests that there are many almond farmers that could suffer smaller-scale economic losses at the level of cultivation and beekeepers or the entire hive rental industry could be damaged. The loss or reduction of honey bees likely does not pose a significant threat to California’s agricultural economy as a whole, but there are certainly economic consequences associated with CCD related honey bee declines. Billions of dollars are at stake, but that may work in favor of bee colony health due to the idea that the almond industry is so large and almonds in such high demand that there is ample money available for funding research and to explore options to work toward solutions. Losing this revenue may not be an option for those who profit from these valuable bee pollinated crops. Optimistically, more research might then be funded and Californians can work toward a solution which benefits California’s agricultural economy, food production, and the well-being of the environment for a sustainable agricultural future in the state.
References


