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Colony Collapse Disorder: Macdonald Campus Apiary

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Categories

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Colony Collapse Disorder: Summary

Bees' services reach far beyond honey production. They provide a vital link in ecosystems and agriculture through pollination. Pollination is the movement of pollen grains from male to female parts of plants, ensuring successful fruit production. Plants either self-pollinate or do so through wind or insects (University of Arizona). Bees, among beetles, butterflies, hummingbirds, and bats all pollinate plants. In North America, native bees pollinate 130,000 species of flowering plants, an important dimension in ecosystems and agriculture (Schacker p. 11, 2008).

Apiculture is the maintenance of honeybee colonies. In recent history, honeybees have been suddenly disappearing without clear reasons; this phenomenon is called Colony Collapse Disorder and has severe economic and ecologic implications. This project allowed for the study of apiculture, a topic currently not offered at McGill, and aimed to identify the causes of Colony Collapse Disorder (CDD) at the McGill Apiculture Association's (M.A.A.) apiary at Macdonald Campus. Research was conducted through reading primary literature, participating in the M.A.A.'s summer apprenticeship program, and interviewing local beekeepers and farmers. The results of this literature review and interviews indicate that the primary cause of CCD here is Clothianidin, a type of systemic pesticide used on the McGill Farm's cornfields.

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Abstract:

Apiculture is the maintenance of honeybee colonies. In recent history, honeybees have been suddenly disappearing without clear reasons; this phenomenon is called Colony Collapse Disorder and has severe economic and ecologic implications. This project allowed for the study of apiculture, a topic currently not offered at McGill, and aimed to identify the causes of Colony Collapse Disorder (CDD) at the McGill Apiculture Association's (M.A.A.) apiary at Macdonald Campus. Research was conducted through reading primary literature, participating in the M.A.A.'s summer apprenticeship program, and interviewing local beekeepers and farmers. The results of this literature review and interviews indicate that the primary cause of CCD here is Clothianidin, a type of systemic pesticide used on the McGill Farm's cornfields.

Background and Context:

Bees' services reach far beyond honey production. They provide a vital link in ecosystems and agriculture through pollination. Pollination is the movement of pollen grains from male to female parts of plants, ensuring successful fruit production. Plants either self-pollinate or do so through wind or insects (University of Arizona). Bees, among beetles, butterflies, hummingbirds, and bats all pollinate plants. In North America, native bees pollinate 130,000 species of flowering plants, an important dimension in ecosystems and agriculture (Schacker p. 11, 2008).

The species *Apis mellifera*, or commonly the honeybee, is the species used in beekeeping. Beekeeping plays a major in role agriculture, approximately one third of all crops in the United States depend on pollination, a value of more than $15 billion (Schacker p. 11, 2008), and $215 billion worldwide (Cox-Foster, vanEngelsdorp 2009). Honey alone contributed $256.5 million to the United States economy in 2011 (National Honey Board 2012). An example of this keystone like relationship honeybees have with agriculture is the almond crop in California. California produces 82 percent of the world's almonds (Jacobsen, p 123 2008); in 2006 the state sold $1.5 billion dollars worth (Schacker p. 11, 2008). Almond pollination takes place in February, and during this time hundreds of commercial beekeepers migrate approximately 48 billion bees to pollinate the crop (Lifsher, 2012). Without bees, the almond industry could not operate at this level, and have grave effects on many aspects of the food industry. (See Appendix I of list of bee pollinated crops)

The McGill Apiculture Association is facing CCD as well. At Macdonald campus, the apiary tended twenty hives as of fall 2011, but 50 percent of the hives were lost due to CCD (See Apnnedix II). From an economics perspective, The Horticultural Center, the fruit and vegetable farm on campus, depends on these bees for pollination and subsequent sales. At one point in the 1990s, there were upwards of one hundred hives at the horticultural center. Now, with a smaller, unstable population of bees, what is causing Colony Collapse Disorder?

Literature Review:

Colony Collapse Disorder:

Colony Collapse Disorder (CCD) has one prevalent symptom, a sudden absence of worker bees with only the queen and young remaining in the colony with few or no dead bees around the hive (EPA, 2012). This phenomenon was first observed in the 2006/2007 winter, when 32% of all colonies were lost in the U.S.A., and since then have lost on average 32.2% yearly (ARS USDA, 2011). However, widespread colony losses are not unheard of, there have been 18 documented cases of large-scale bee mortality since 1869 (Underwood, vanEngelsdorp 2007). A cause or cure has not been discovered, but rates of CCD plateaued since 2007. The sudden disappearance of worker bees, the characteristic of CCD, is surprising because it contradicts honeybees' strong and complex social orientation. Honeybees operate in a caste system of communicated directions and food sources through dance and trophallixis, and follow orders from the queen bee, which lays every egg in the hive. Proposed causes have included malnutrition, migratory beekeeping, environmental stressors, parasites, and pesticides but no single cause has been found and CCD often has different causes case-by-case (EPA, 2012). Next, the possible causes of CCD will be examined through a literature review

Malnutrition and Migratory Beekeeping

Workers, queens, drones, and larva development all have the same food requirements: nectar and pollen. Nectar, ranging from 5 to 80 percent sugar, provides carbohydrates, and pollen, necessary for plant reproduction but also evolved to attract bees, provides protein, lipids, vitamins, and minerals (Winston p 56, 1987). Therefore, because of the large variability in nutrient content between species' pollen and nectar, it is essential for honeybees to collect from a wide range of plants; honeybees cannot subsist on one food source alone.

The economics of pollination largely determines migratory beekeeping; a sizable part of commercial beekeepers' income comes from hive rentals for pollination, thus migration. Migratory beekeeping jeopardizes honeybees with malnutrition. A study by Aizen and Harder shows that the population of domesticated honeybees is growing slower than the agricultural demand for pollination. In the past fifty years there has been an "almost 4-fold rise in agriculture production that requires animal pollination" (Aizen, Harder, 2009). As a result, commercial apiculture is forced into migratory beekeeping to attempt to counterbalance this inequality. Additionally, honeybees are an invasive species in most areas where they are presented, and often steal pollen without pollinating the plant or pollinating inefficiently, reducing seed production (Hargreaves, Harder, Johnson, 2009). This opens the door to potential ecological harm.

Several aspects of migratory beekeeping harm honeybees that can force them into colony collapse. To illustrate, let's reexamine, the case of the almond industry in California again, which poses several threats to beekeepers nationwide (Jacobsen 123, 2008). Almonds bloom in February, so beekeepers deceive their bees out of winter semi-hibernation into productivity months in advance and thereby risk exposing bees to prolonged colder temperatures (Jacobsen 126, 2008). The confinement, temperature fluctuations, shocks and vibrations that bees endure during transportation also stresses out the bees (Kevan et al, 2007). Furthermore, honeybees have regular daily rhythms of activity and sleep (Kaiser 1988), so this fast movement across time zones could further provoke honeybees. On top of transport problems, malnutrition, disorientation, and mass conglomeration, bees are vulnerable to any disease or parasite in the area (Jacobsen 128, 2008). The McGill Apiculture Association does not do any migratory beekeeping; this is not a possible cause of CCD at McGill.

<u>Role of Systemic Pesticides in Colony Collapse Disorder</u>

A recent type of systemic pesticide called neonicotinoids, that coats the seeds and is manifested through the plant's tissue, nectar, and pollen, has been linked to CCD. It is a neurotoxin that mimics nicotine, an insecticide that plants produce naturally. For example, tomatoes, potatoes, and green peppers produce small amounts (Jacobsen 84, 2008). Neonicotinoids have risen to popularity because they are designed to negatively affect insects while remaining relatively harmless to vertebrates (Jacobsen 95, 2008). Physiologically, neonicotinoids target the cholinergic system in insects, which control the olfactory pathways that link to sensory neurons, binding with receptors inhibiting acetylcholine (Devillers, Pham-Delegue 85, 2002). Honeybees are exposed to neonicotinoids through contact and ingestion of pollen and nectar. It is also possible for honeybees to contaminate other colony members because nectar and pollen are stored and shared within the hive (Henry et al. 2012). Furthermore, the honeybees' nicotinic receptor in the nervous system contains eleven subunits, more than the fruit fly and mosquito, which makes honeybees even more susceptible to neonicotinoids compared to other insects (Schacker 53, 2008). However, the United State's Environmental Protection Agency's Fate and Effects Division does not explore the effects of non-target insects

(Johnson, 2010). In Quebec, almost 100% of corn is treated with the neonicotinoid Clothianidin, made by Syngenta, since 2008 (Chagnon, Boily, 2011). Since neonicotinoids are accepted as a standard pesticide in North America, it is important to continue monitoring its impact on bees.

The subject of Neonicotinoids has been disputed amongst apiculturists throughout the world, chiefly by the difficult nature of studying and quantifying bees. Controlling variables such as exposure to pesticides, food sources, isolating specific aspects, creating replicable conditions are all challenges that can compromise the validity of any given study. Tests in laboratories can produce precise results, but they cannot be seen in apiaries due to these variables. Despite these complications, neonicotinoids are being brought into question. In the fall of 2012, the Environmental Protection Agency will create a panel addressing risk assessment of pesticides for bees (Stokstad, 2012). Also, on June 12th of 2012, Health Canada released a re-evaluation notice of neonicotinoids on pollinators, examining their adverse effect. (Pest Management Regulatory Agency, 2012). Neonicotinoids also cause problems for honeybees in European countries; in 2008, Germany banned the use of Clothianidin on rapeseed and corn (Benjamin, 2012). Italy banned neonicotinoids in 2009 due to their adverse effects on honeybees also, as has France and Slovenia (Ban on Neonicotinoid Seed Coating to save Bees in Italy, 2009).

Case studies and lab experiments show the adverse effects of neonicotinoid pesticides have on honeybees, and sub-lethal levels have causal relationships to CCD. One study tested imidacloprid's, a common neonicotinoid, effects on honeybees' habituation, locomotion, and taste threshold by feeding bees different concentrations of imidacloprid and measured the effects after three time periods, 15 minutes, 30 minutes, and 60 minutes (Devillers, Pham-Delègue 93, 2002). A loss of sensitivity was noticed after 60 minutes from a dose of 5 nanograms (ng) of imidacloprid, but also a dose of 20ng induced the same loss 15 minutes after application (Devillers, Pham-Delegue 91, 2002). Locomotion tests showed that doses of as little as 2.5ng caused a loss of motor coordination; bees fell on their backs shaking, and additional observations up to two hours after showered that they had not recovered by that time. Imidacloprid doses of 2.5ng caused motor displacements and slower brain metabolism.

In 2001 Italy's National Institute of Apiculture conducted research on the effects of imidacloprid on honeybees, tagging bees and feeding them various quantities of imidacloprid: 0 parts per billion (ppb), 100 ppb, 500 ppb, and 1000 ppb. After 2 hours, about 80% of bees who fed on 0 ppb imidacloprid returned to the hive, but only 57% of those that fed on 100 ppb imidacloprid returned to the hive (Jacobsen 88, 2008). The bees that fed on higher concentrations of imidacloprid disappeared completely within 24 hours (Jacobsen 89, 2008). In addition, the control bees flew away from the feeder immediately after feeding, but it took nearly 75 minutes for the bees who fed on 1000 ppb imidacloprid to leave. Imidacloprid is one of the most studied neonicotinoids, which gives an indication of the dangers of neonicotinoids as a whole, but does not specifically relate to the Apiary at Macdonald Campus, because Clothianidin is the neonicotinoid primarily used in Quebec.

One study by Schneider et al., in 2012, about the sub-lethal effects of Clothianidin on honeybees designed an experimental feeder 7 meters away from the hive, tagged the honeybees, and measured the times foraging trips and the percentage of bees that returned to the hive in a three hour period using a radio frequency identification tag. The control trial measured the effects of different doses of Imidacloprid, and at a dose of 1.5 nanograms, 100% of the bees returned to the hive; with a 3ng dose 95% returned to the hive; and only 25% returned with a 6ng dose. In the trials conducted with Clothianidin, 94.4% of the .5ng bees returned to the hive; 73.8% of the bees treated with 1ng; and 20.6% returned treated with 2ng. The observed bees treated with Clothianidin moved awkwardly, lay on their backs and moved their legs in a paddling motion and flew with an arched back. In addition, the bees did not return to the hive anytime after the three-hour period. Clothianidin treatment also changed the amount of visits to the feeder. Bees treated with 6ng did not visit the feeder until after 24 hours after the first time. Clothianidin proved to cause similar sub-lethal effects on bees to imidacloprid, but at lower doses, indicating Clothianidin to have a stronger impact. Approximately 1.5ng is about 115parts per billion in nectar, and even higher levels are present in guttation. (Schneider et al, 2012).

In 2012, Krupke et al., explored the several ways honeybees are exposed to levels of neonicotinoids living near agricultural fields. In addition to the maize fields, soil collected from areas nearby the cornfields contained Clothianidin in all the samples tested. Furthermore, dandelion flowers in nearby areas contained Clothianidin. This demonstrates that honeybees are exposed to Clothianidin through several mechanisms in addition to collecting pollen from maize, the origin of the pesticide. As the Macdonald campus apiary is located near the cornfields of the Macdonald Farm, the honeybees may be foraging more pollen with Clothianidin than expected. Also, maize pollen comprised 50% of the pollen collected by bees, by volume. They also analyzed the dead bees, and found traces of Clothianidin in all the dead and dying bees sampled, while not detecting any levels of Clothianidin on the healthy bees (Kruple et al, 2012).

Girolami et al. , 2009,found through lab experiments that humidity can exacerbate the effects of both Clothianidin and Imidacloprid to honeybees. In this experiment, groups of 24 honeybees were exposed to Clothianidin and captured on the feeder, then brought into the lab and either placed in high humidity, close to 95% or low humidity, and the difference in fatalities were noted 15, 30, 45, and 60 minutes afterwards. More than twenty bees were dead after every time interval in the high humidity, and in the lab humidity there were never more than 6 bees dead. However, these findings were less evident in the field due to the capriciousness of relative humidity and its reactions to wind, temperature, etc (Girolami et al, 2009). The significance of this study to the apiary at Macdonald campus is this; being located close to the St. Lawrence and Ottawa rivers increases the area's humidity, raising the honeybees' vulnerability to Clothianidin.

Varroa Mite and Colony Collapse Disorder

The *Varroa destructor* mite has been a perpetual problem for beekeepers since the 1980s; the mite attaches onto the abdomen of the honeybee and acts as a vector in transmitting different diseases (Schacker 35, 2008). At the hive level, infested colonies can die in between 6 months to 2 years, depending on population growth rates, strength of hive, and time infestation during the year. A *Varroa* infestation prior to wintering causes the hive to die faster. However, *Varroa* as the cause of CCD seems improbable; there are no dead bees present in the hive from CCD, and *Varroa* causes bees to die in the hive (Schacker 39, 2008). Also, *Varroa* is not a new phenomenon; *Varroa* mites have been around for decades yet there was not CCD, *Varroa* therefore cannot be the cause.

In a descriptive study, vanEngelsdorp et al (2009) found no difference in mean abundance of *Varroa* mites between CCD apiaries and control apiaries (vanEngelsdorp et al, 2009). Despite not being responsible for causing CCD alone, *Varroa* mites can be symptom of a weakened hive by CCD along with other synergistic factors, like malnutrition (Le Conte et al, 2010, Schacker 39, 2008). At the Macdonald campus apiary, the first *Varroa* mite was found in the hive, on August 19th, 2012. Presence of *Varroa* in the apiary aligns with this hypothesis, because the Clothianidin treated corn started tasseling last month, allowing enough time for the nicotinic pollen to affect the honeybees, allowing the *Varroa* infest the hive.

Nosema Parasite and Colony Collapse Disorder

The *Nosema ceranae* parasite has been correlated with CCD, but is not considered to be a causal factor, like *Varroa*. Originally afflicting the Asian honeybee, the fungus infects the bees' digestive tracts and targets their epithelial cells (Jacobsen 80, 2008). The fungus then multiplies hundreds of times, rupturing the cell and releasing fungi into the lumen, preventing the nutrient absorption (Schacker 41, 2008). Unable to absorb nutrients, the bee dies (Jacobsen 80, 2008). Another result of *Nosema cerenae* is in-hive dysentery that infects and inadvertently spreads the parasite to other bees throughout the hive (Schacker 41). Honeybees usually succumb to *Nosema* from facing other problems. As Dr. Jeff Pettis of the United States Department of Agriculture puts it, "We think of *Nosema* as a stress disorder of honey bees" (Schacker 41, 2008). In one study, Pettis found that one of the sub-lethal effects of Imidacloprid exposure led to an increase of *Nosema ceranae* in adult bees (Pettis et al, 2012). Furthermore, one study found that the combined effects of Imidacloprid and *Nosema ceranae* increased mortality more than Imidacloprid exposure or *Nosema ceranae* infection could alone (Alaux et al 2010). CCD correlates with *Nosema ceranae* but Nosema can enter the hive independently too. However, in the context of Colony Collapse Disorder, *Nosema ceranae* can be an indicator. Nosema is not present in the M.A.A. hive currently, but the parasite's physical manifestation, dysentery, was seen in last year's collapsed hives, signaling that *Nosema* affected the hives in last season.

Conclusions

Colony Collapse Disorder has affected honeybee hives worldwide. Now after several years of attention, research, and economic consequences, causes have been identified as various types of stress on the honeybees, which lead to other problems and eventually collapse. Also the cause of colony collapse disorder can be unique to each case. Additionally, one dimension can affect all honeybees: loss of genetic diversity. In the United States, less that 500 breeder queens produce millions of queen bees (Schacker 42, 2008), and additionally each queen gives birth to the thousands of bees in each hive. Essentially, the honeybee is becoming a monoculture, which by nature is highly susceptible to diseases and pests (Schacker 42, 2008). This genetic bottleneck of sorts could aid Colony Collapse Disorder, but the extent that it does is undeterminable. The M.A.A. has bred some of their own, but also bought some too, so it is unknown how severely this affects CCD at the apiary.

Several scientific (Devillers, Pham-Delegue 2002, Schneider et al, 2012, Jacobsen, 2008), papers demonstrate how neonicotinoids, the type of systemic pesticide used on corn and other crops, affect honeybees acetylcholine neurotransmitter through lethal and sub-lethal doses causing disorientation, increases stress and mortality, abnormal movements The sub-lethal effects seem to weaken the individual hive, and can explain the loss of adult bees. From here, the problem can worsen and lead to in hive mite and parasite infestations, like the *Varroa destructor* mite and *Nosema cearena* parasite (Le Conte et al, 2010, Alaux et al 2010, Pettis et al, 2012).

Based on these findings, it is advised to discontinue using Clothianidin, the neonicotinoid used in 98% of corn in Quebec, on the Macdonald Campus Farm to protect the honeybees. Furthermore, the use of the pesticide may be a breach of the Environmental Policy for McGill University, which states, "the McGill University community shall make every reasonable effort to: Prevent the overconsumption of energy and other resources and reduce the production of waste and the release of substances harmful to the biosphere" (Environmental Policy for McGill University, 2002).

Managing honeybees and their livelihood is critical to protecting our own livelihood. Honeybees play a vital yet sensitive role in agricultural ecosystem that has underappreciated impact on our lives. While governments around the world have put policies into place to protect honeybees from Neonicotinoids, it is critical that additional research is conducted to continue protect the honeybee. As this paper illustrates, discontinuing the use of Clothianidin is one immediate step that should be taken to protect the honeybee and our community.

Appendix I: List of Crops Pollinated by Honeybees

The list of crops pollinated be bees from the Univeristy of Delaware's College of Agriculture and Natural Resources (Caron, 1999):

Crops Pollinated by Bees

Some of the crops that require, or at least benefit from, bee pollination are listed below. The list is grouped for convenience and is limited to plants that contribute to our food supply. Trees, shrubs, and plants useful for other purposes are not included. Crops marked with an asterisk are often grown on large acreage and the fields are stocked with honeybee colonies to provide adequate pollination for maximum yields and optimum quality.

Forage and Legume Crops

*Alfalfa; buckwheat; clover (alsike, berseem, crimson, Egyptian, *Ladino, *red, rose, strawberry, and white); *crown vetch; sweet clover (*Hubam, *white, *yellow); lespedeza (bush); *trefoil; vetch (*hairy and purple).

Fruit Crops
*Apple; apricot; *avocado; berry (blackberry, *blueberry, *cranberry, gooseberry, raspberry, and *strawberry); carambola; *cherry; citrus (*grapefruit, lemon, *mandarin, nectarine, *tangelo, and *tangerine) *kiwi, mango, passion fruit, *peach; *pear; persimmon, *plum, and prune.

Nut Crops
*Almond, cashew, chestnut, coconut, and *macadamia.

Oilseed Crops
.*Cotton, flax, *rape, *safflower, soybeans, *sunflower, tung.

Vegetable Seed Crops
Asparagus, *broccoli, *brussel sprouts, *carrots, *cauliflower, celery, Chinese cabbage, collard, cucumber, dill, eggplant, garlic, kale, kohlrabi, leek, *lima beans, mustard, *onion, parsley, *pepper, pumpkin, *radish, rutabaga, *squash, and *turnip.

Vegetable Crops
Beans, *cucurbits (cantaloupe, cucumbers, muskmelon, pumpkin, squash and watermelon), eggplant, lima beans, and peppers

Appendix II: Colony Collapse Disorder Data of Local Apiaries

	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
MAA			20% of hives were lost	3/7 hives were lost	40% of hives were lost	50% of hives were lost
MAA Community Apiary				72% of hives were lost	16.67% of hives were lost	25% of hives were lost
Dennis Hatcher's Hives					Lost 100% except 1 hive	0% loss*

There is little data available, but this chart will be updated when it is found.

* In these hives, Fumagilin-B was sprayed to control the Nosema. The MAA subscribes to organic beekeeping practices, which involves not introducing anything into the hive that the bees would not bring in own their own. In addition to spraying the hives, he started with new hives this year, so their populations were lower, and thus had less foraging honeybees. Because there were less bees foraging, there were less bees bringing in Clothianidin contaminated pollen and survived by virtue of a smaller population of foraging bees. However, this is just a theory and needs to be validated.

Appendix III: Significance to the Horticultural Center

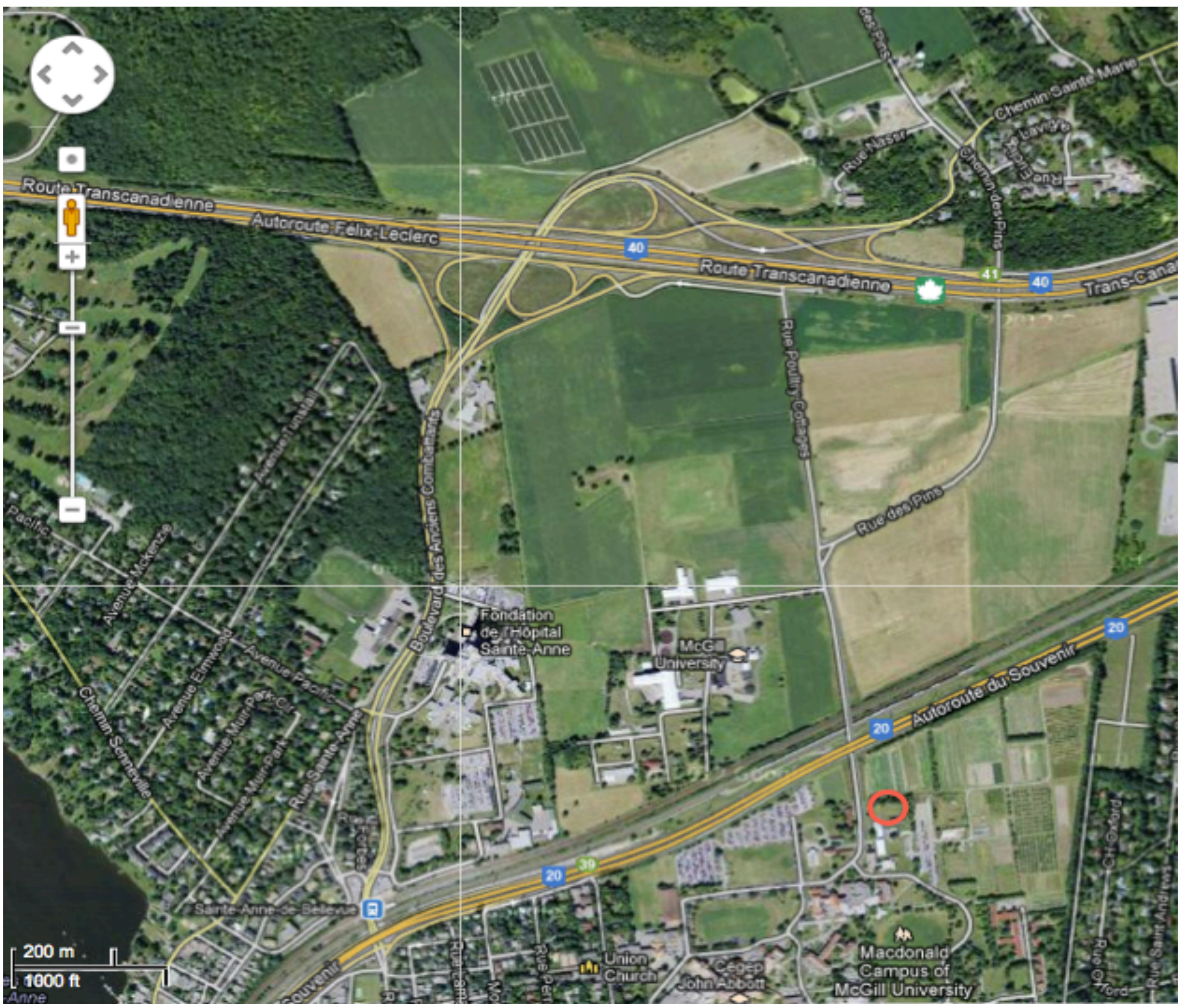
The Horticultural Center relies on the honeybees to ensure successful pollination of their crops. Because of this, to the best of their knowledge, they use no pesticides that harm honeybees. Additionally, the apply pesticides in the evening, after the bees have returned to the hive from foraging, to avoid the honeybees (Bleho 2012). Additionally Mike Bleho, the manager of the Horticultural Center, said the Hort. Center used to keep over 80 hives in the 1990's, and back then used much more toxic pesticides, but never had comparable hive losses.

Appendix IV: Area of Apiary and Corn Fields

Honeybees have been observed to fly as far away as 9 kilometers away from the hive; in this study monitoring foraging trips, Beekman and Ratnieks found that more that 50% of the hive went more than 6 km away from the hive (Beekman and Ratnieks, 2000). In a more recent study addressing the question "How far do honeybees fly", Traynor observed honeybees' flight distance and its effects on average change of hive weight over 18 days. He found that honeybees could still survive on food sources 4 miles away (See chart). Given the numerous variables determining foraging distance, Traynor concluded that honeybees would fly as far as necessary find sources of food (Traynor, 2002).

Distances Honeybees Will Forage

Average change in Hive Weight over 18 days in pounds	
0.0 miles	25.3
0.5 miles	31.6
1.0 miles	23.3
1.5 miles	21.3
2.0 miles	18.1
3.0 miles	13.8
4.0 miles	5.1
5.0 miles	-3.0
6.0 miles	-6.2
7.0 miles	-8.6



The red circle indicates the location of the MAA, and shows its distance to the farm. As the distance scale shows, the fields are well within a four-mile range of the apiary.

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