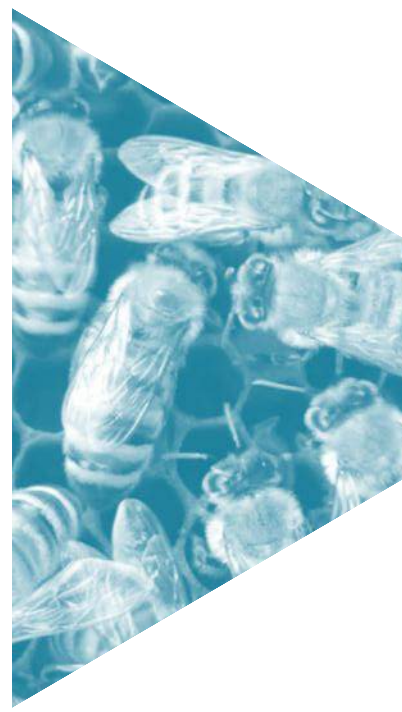
2016

NYS BEEKEEPER TECH TEAM REPORT: PESTICIDE RESIDUES



TECH TEAM

- improve honey bee
- reduce colony losses
- improve the profitability of the beekeeping industry

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Cornell CALS
College of Agriculture and Life Sciences

New York State of Opportunity. Agriculture and Markets

NYS Beekeeper Tech Team

2016 NYS Beekeeper Tech Team Report: Pesticide Residues

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Recognizing the importance of pollination services, which contribute $500 million annually to the state's agricultural economy, NYS completed a Pollinator Protection Plan in 2016. In response to this plan, the NYS Beekeeper Tech Team formed in 2016 to conduct research and extension activities benefiting beekeepers. The Tech Team identifies and promotes best management practices to improve honey bee health, reduce colony losses, and support the growth and profitability of beekeeping businesses.

Acknowledgements

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1. Overview

Concerns about declining pollinator populations have prompted extensive research on factors likely to influence the health and productivity of honey bees. Laboratory and field experiments support the scientific consensus that multiple stressors impair honey bee health and contribute to high colony loss rates. These stressors include parasites and pathogens, inadequate forage quantity or quality, suboptimal management practices, and exposure to agricultural chemicals.

New York State (NYS) is a leading producer of specialty crops, including apples, pears, cherries, strawberries, pumpkins, squash, and cucumbers, that either require or benefit from insect pollination. Pesticides are commonly used to control insects, fungal pathogens, and weeds in the production of these and other crops. Pesticide residues are nearly ubiquitous in the environment, and can enter honey bee colonies through contaminated pollen, nectar, or water that bees collect. Foraging bees that are directly exposed to pesticides on their bodies also bring those chemicals into the colony when they return and come in contact with hive materials. Moreover, some pesticides are applied directly to honey bee colonies to control parasites, particularly the *Varroa* mite. Over the past few decades, hundreds of scientific articles have explored the prevalence of various pesticides and their effects on honey bees. Existing scientific evidence suggests that pesticides are commonly found in honey bee colonies, yet little is known about pesticide residues in NYS beekeeping operations, or how different management practices are related to long-term pesticide exposure.

This report presents results from the first systematic observational study examining pesticide levels in wax from honey bee colonies in NYS. The study uses data from 198 wax samples collected by the NYS Beekeeper Tech Team in September 2016, and analyzed by the Chemical Ecology Core Facility at Cornell University. The analysis includes 41 different agricultural chemicals from five pesticide groups: miticides, insecticides, fungicides, herbicides, and synergists. It evaluates the presence and concentration of each compound, and calculates hazard quotients to indicate the relative risk to bees.

The results show that pesticide residues in NYS honey bee colonies are widespread. However, the pesticides that are most prevalent tend to be the least toxic to honey bees. The pesticide exposure risk was below the US Environmental Protection Agency (EPA) and the European Food Safety Authority (EFSA) level of concern for acute contact exposure for all 198 colonies in the study. Only two colonies exceeded the European Food Safety Authority (EFSA) level of concern for chronic exposure.

This report outlines the research methods in the following section, before presenting the results. The discussion delves deeper into the interpretation of results for each pesticide class. A section on management implications (page 14) will be of particular interest to beekeepers, as it presents a set of recommendations for reducing pesticide exposure to bees.

2. Methods

Sample design. In September 2016 the NYS Beekeeper Tech Team inspected a total of 309 honey bee colonies belonging to 60 participating beekeepers from Northern, Central, and Western New York. The sample included 30 hobbyists (1-49 colonies), 13 sideliners (50-499 colonies), and 16 commercial beekeepers (500+ colonies). Wax samples from 198 colonies, belonging to 59 beekeepers, were tested for pesticide residues. A total of 30 wax samples (15%) came from hobbyists, 48 wax samples (24%) came from sideliners, and 120 wax samples (61%) came from commercial beekeepers. A sample of three grams of the oldest available wax was collected from a frame in the brood nest. Unlike pollen, which provides a snapshot of pesticide exposure over a short period of time, wax samples provide a cumulative view of a colony's exposure to pesticides over time.

Pesticide analyses. The Cornell Chemical Ecology Core Facility analyzed the wax samples and quantified levels of 41 chemical compounds: 19 insecticides (including 6 neonicotinoids), 17 fungicides, 2 herbicides, 2 miticides and 1 pesticide synergist. The full list of these 41 compounds is provided in Appendix 1, alongside their respective levels of detection (LOD), and levels of quantification (LOQ). The LOD is the lowest concentration of a compound, in parts per billion (ppb), that can be reliably ***detected*** by the test equipment and procedure, while the LOQ is the lowest concentration of a compound that can be reliably ***measured***. The pesticides on this list include agrochemicals that are widely used across New York State, particularly in apple orchards and other cropping systems that depend upon commercial pollination. These compounds are expected to present a relatively high risk of exposure to bees, although they may not be highly toxic. The list also includes pesticides of special concern to beekeepers, due to their high acute toxicity, despite relatively low expected exposure. We also analyzed two miticides, amitraz (active ingredient in Apivar), and coumaphos (active ingredient in CheckMite+), that beekeepers may intentionally apply to their colonies to control *Varroa* mite populations and small hive beetles, respectively.

Hazard quotients. To estimate pesticide risk from residues in the wax, we computed a wax hazard quotient (WHQ)[1]. The WHQ is constructed by summing the quotient of each pesticide residue (ng/g wax) divided by its respective honey bee LD_{50} (ug/bee). Higher values reflect a relatively higher risk of an acute pesticide poisoning event. The LD_{50} is a measure of acute toxicity, or short-term poisoning potential. LD stands for "lethal dose," and the LD_{50} is the amount of a compound that, given all at once to a sample of bees, causes half the bees to die within a short period of time (either 24, 48, 72, or 96 hrs). The contact LD_{50} measures toxicity from physical contact with a compound, while the oral LD_{50} measures the toxicity from ingestion of a compound. The contact and oral LD_{50} values used in this study are listed in Appendix 1.

3. Results

We tested 41 compounds in 198 samples, for a total of 8,118 tests, out of which there were 1,000 positive residue detections. Figure 1 illustrates the percentage of positive detections from each of the five pesticide categories that we evaluated (Table 1 lists the specific pesticides in each category). Overall, ***fungicides were the most commonly detected pesticides in our sample***, accounting for 42% of positive detections.

Figure 1. Distribution of positive detections by category

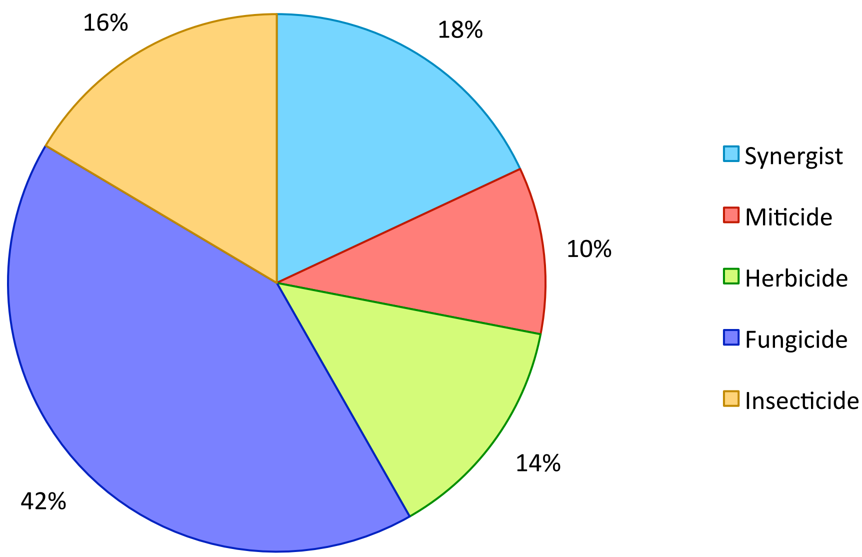


Figure 2 is a frequency histogram illustrating the distribution of wax samples according to the number of pesticides detected. Each bar represents the number of colonies (out of 198) in which we found the corresponding number of different pesticides. The three colors indicate whether the samples came from hobbyist, sideliner, or commercial operations. ***More than half of colonies had at least 5 different pesticides***. The total number of pesticides per sample ranged from 0 to 18, with a mean of 5.5.

Figure 2: Histogram of the number of pesticides detected per colony

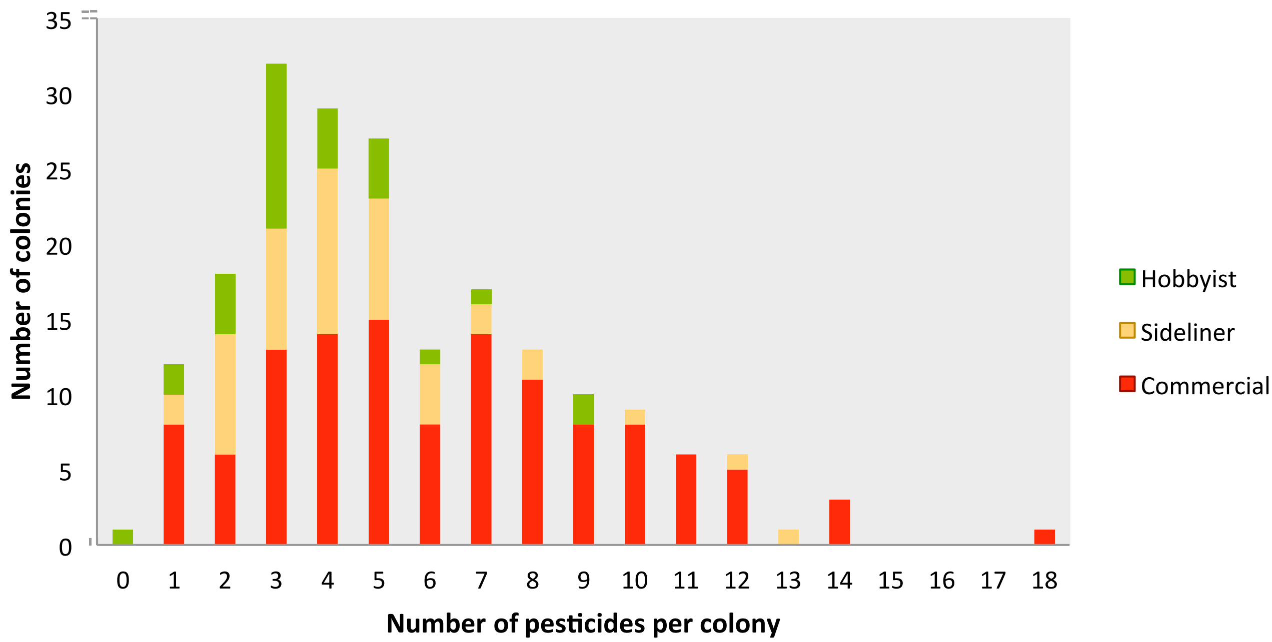


Figure 3 illustrates the average pesticide count per colony (mean +/- standard error) for hobbyists, sideliners and commercial beekeepers. With an average of 5.9 different pesticides per colony, commercial beekeepers had the highest pesticide counts. ***Wax samples from commercial beekeepers had significantly more pesticides per sample, on average, compared to wax samples from hobbyists.*** Hobbyists had an average of 3.3 pesticides per colony. The average number of different pesticides per colony for sideliners, 4.2, was not significantly different from hobbyists or commercial beekeepers.

Figure 3. Pesticide count by operation scale

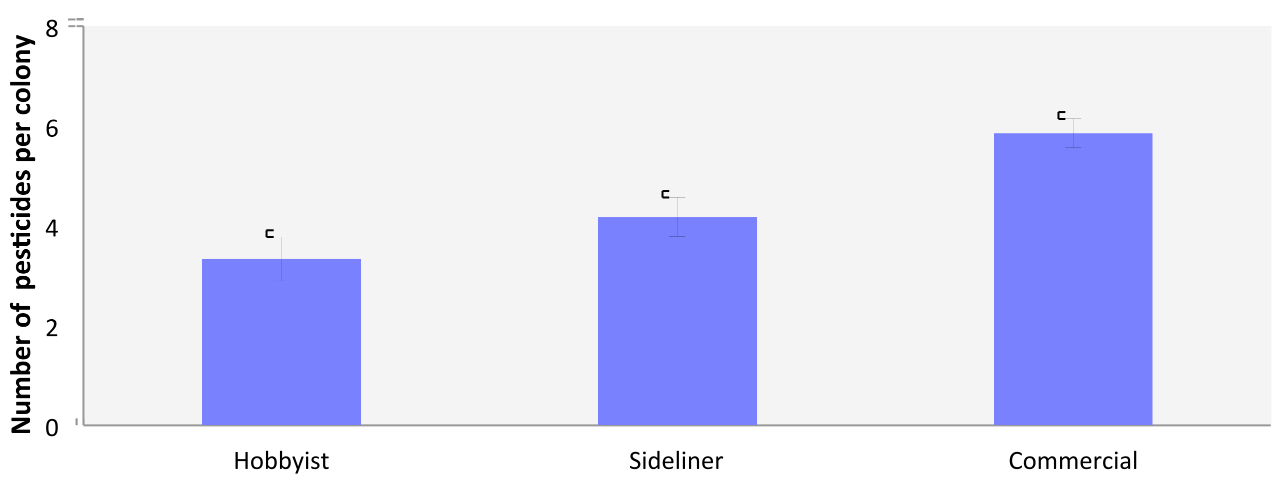


Table 1. Prevalence of positive detections and average pesticide levels from 198 wax samples.

Compound	Compound Type	# Positive Detections	% Positive Detections	Mean residue (ppb)	Mean Contact WHQ	Mean Oral WHQ
Piperonyl butoxide	Synergist	196	99%	6.44	0.379	-
Fenpyroximate	Insecticide	120	61%	7.52	0.683	0.063
Metolachlor	Herbicide	115	58%	2.84	0.026	0.026
Azoxystrobin	Fungicide	104	53%	5.39	0.027	0.215
Coumaphos	Miticide	100	51%	80.95	4.047	17.597
Pyraclostrobin	Fungicide	76	38%	10.49	0.105	0.144
Cyprodinil	Fungicide	59	30%	8.68	0.087	0.087
Trifloxystrobin	Fungicide	51	26%	3.40	0.017	0.017
Fluopyram	Fungicide	36	18%	8.41	0.084	0.082
Atrazine	Herbicide	34	17%	10.83	0.112	-
Pyrimethanil	Fungicide	27	14%	23.88	0.239	0.239
Difenoconazole	Fungicide	22	11%	13.97	0.138	0.079
Propiconazole	Fungicide	20	10%	41.36	0.827	0.537
Propamocarb	Fungicide	16	8%	1.24	0.012	0.013
Chlorantraniliprole	Insecticide	16	8%	3.19	0.798	0.031
Fenbuconazole	Fungicide	15	8%	251.95	0.869	-
Spinetoram J	Insecticide	15	8%	0.53	22.083	3.786
Penthiopyrad	Fungicide	11	6%	27.08	0.087	0.070
Amitraz	Miticide	9	5%	0.09	0.002	-
Spinetoram L	Insecticide	8	4%	0.28	11.458	1.964
Penconazole	Fungicide	7	4%	2.34	0.197	0.098
Myclobutanil	Fungicide	4	2%	27.09	0.684	0.797
Thiophanate-Me	Fungicide	4	2%	8.55	0.086	0.086
Spinosyn A	Insecticide	4	2%	0.47	158.33	8.333
Acetamiprid*	Insecticide	3	2%	19.65	2.494	1.407
Fluxapyroxad	Fungicide	2	1%	-	-	-
Avermectin B1a	Insecticide	2	1%	3.94	131.67	-
Carbaryl	Insecticide	2	1%	18.78	22.381	125.33
Emamectin B1a	Insecticide	2	1%	0.04	25.000	-
Spinosyn D	Insecticide	2	1%	0.06	33.333	1.754
Thiamethoxam*	Insecticide	2	1%	13.59	566.67	2720.00
Emamectin B1b	Insecticide	1	1%	-	-	-
Indoxacarb	Insecticide	1	1%	25.06	212.71	96.538
Thiacloprid*	Insecticide	1	1%	-	-	-

Note: There were no positive detections for fungicides boscalid and cyflufenamid, or for insecticides clothianidin*, cyantraniliprole, imidacloprid*, nitenpyram* and phosmet, in any of the wax samples that we tested. Asterisk (*) denotes neonicotinoids.

Of the 41 compounds that were analyzed, 34 were present in colonies from our sample, while two fungicides and five insecticides were not detected at all. Table 1 reports the prevalence of positive detections and the average concentration of quantified detections, in parts per billion (ppb), for each individual pesticide. The ***pesticide synergist piperonyl butoxide (PBO) was ubiquitous***, showing up in 99% of wax samples. After PBO, four other pesticides were present in more than half the samples, including the insecticide fenpyroximate, the herbicide metolachlor, the fungicide azoystrobin, and the miticide coumaphos. The pesticides with the highest average concentrations included the miticide coumaphos (81 ppb) and the fungicides fenbuconazole (252 ppb), propiconazole (41 ppb), myclobutanil (27 ppb), and penthiopyrad (27 ppb). Table 2 briefly summarizes each of the top 10 most prevalent pesticides found in this study.

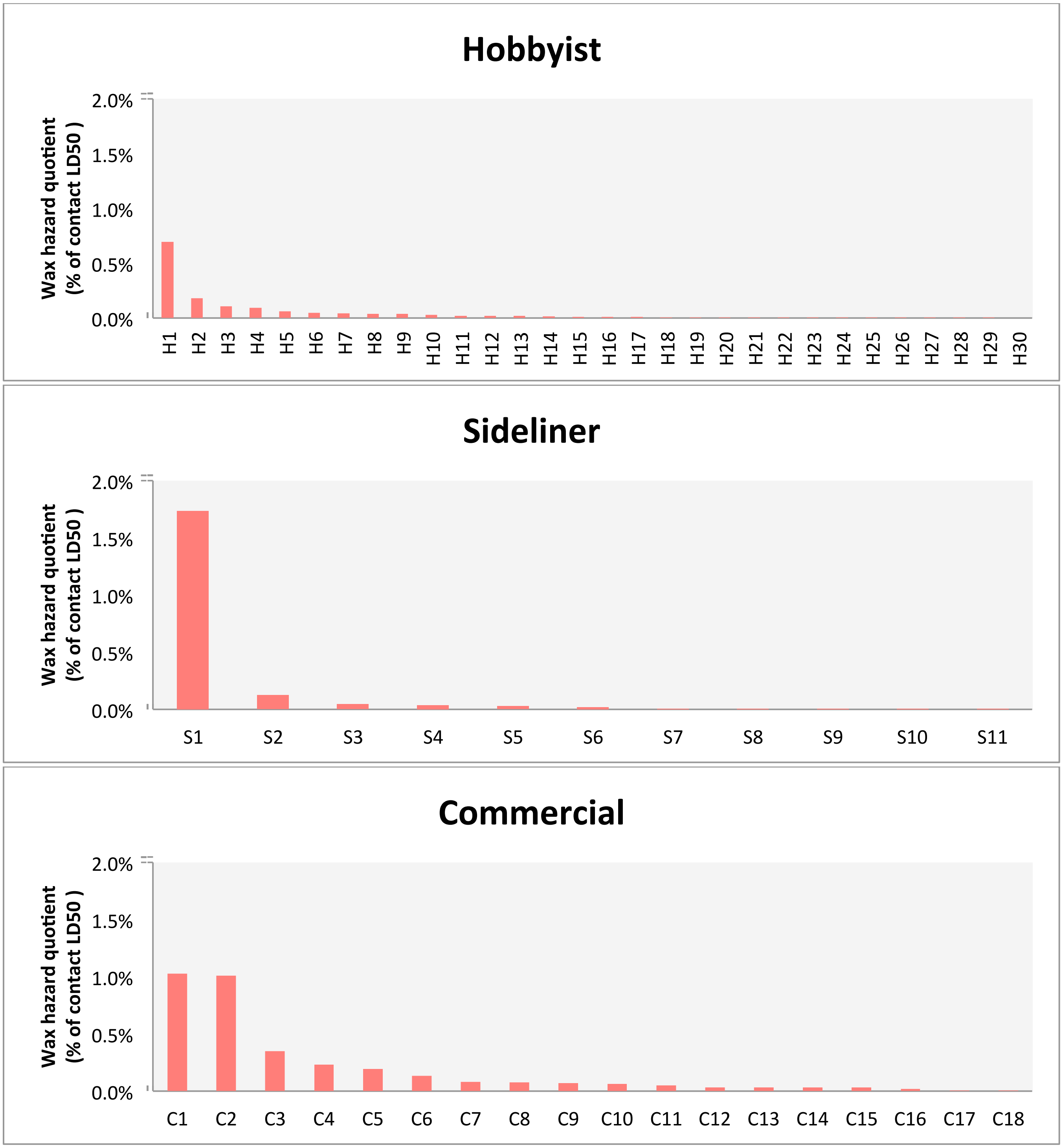
Table 1 also shows the average contact and oral wax hazard quotients for each pesticide. ***The pesticides with the highest hazard quotients were insecticides that were present in relatively few colonies.*** Coumaphos also has moderately high contact and oral hazard quotient values, and was much more prevalent than the insecticides with higher hazard quotients. The remaining pesticides that were quantified in our study, including 14 fungicides, two insecticides, two herbicides and the one synergist, had small contact and oral hazard quotients.

To understand the ***acute*** risk to honey bees of the residues present in each colony, we present the contact hazard quotient as a percentage of the LD_{50} value. For reference, a hazard quotient of 100% would equal the contact LD_{50} value, which represents the level of a compound that, given all at once to a sample of bees, is expected to kill half the bees within a short time period (either 24, 48, 72, or 96 hrs). The US Environmental Protection Agency (EPA) uses a risk quotient threshold of 40% to represent a level of concern for acute contact exposure, while the European Food Safety Authority (EFSA) uses a more conservative threshold of 20%.

All of the colonies in our sample had wax hazard quotients well below both the EPA and the EFSA thresholds of concern for acute contact exposure. The highest hazard quotient was 10.2% of the contact LD_{50}, and the vast majority of colonies (97.5%) had wax hazard quotients below 1.0%. These results imply that, although pesticide residues are commonly found in beeswax, they are present at concentrations far below the levels that would cause an acute poisoning event.

To approximate the ***chronic*** risk to honey bees of the residues present in each colony, we calculate the oral hazard quotient as a percentage of the LD_{50} value. The EFSA recommends a threshold of 3% to represent a level of concern for chronic oral exposure. Two out of 198 colonies in our sample exceeded this EFSA threshold, with oral hazard quotients of 49.0% and 5.4%, respectively. These were the two colonies in which thiamethoxam, a neonicotinoid, was present. All of the remaining colonies (99.0%) had oral hazard quotients below the EFSA threshold of concern for chronic exposure.

Figure 4. Average contact hazard quotients for individual beekeepers.



4. Discussion

This observational study analyzed levels of 41 pesticides in 198 honey bee colonies across New York State. We detected at least one agricultural chemical in virtually all (99.5%) of the colonies, and our samples contained 5.5 different pesticides, on average. These findings corroborate the existing scientific evidence that pesticide residues are widespread and commonly found in honey bee colonies. While it is common to find pesticides in bee hives, the concentrations that were detected in the wax samples were all very low. There were no colonies that experienced pesticide levels close to the doses that cause mortality, and only two of 198 colonies experienced pesticide levels that exceeded the EFSA threshold of concern for chronic oral exposure. Below we discuss findings and implications for each pesticide class.

Miticides

The miticides coumaphos and amitraz were both were found in some of the wax samples. Miticides are among the most common pesticides present in honey bee hives in North America[2], which is not surprising because they are applied directly to colonies by beekeepers. Beekeepers historically used coumaphos, the active ingredient in CheckMite+ strips, as a *Varroa* treatment. However, this miticide is no longer recommended as *Varroa* mite populations are now largely resistant to coumaphos, and it is known to negatively affect honey bee health. None of the beekeepers in our sample applied this product to their colonies in 2016, yet 51% of the colonies that we sampled contained coumaphos residues.

Beekeepers should be concerned about coumaphos concentrations in their hives. Coumaphos has been shown to interfere with queen and drone reproduction at levels below those found in CheckMite+ strips[3-6]. Queens that are raised in cells that contain coumaphos experience low birth weight, increased mortality, and physical abnormalities during development. Coumaphos also reduces sperm counts in queens' spermatheca and in drones' testes.

It is well known that coumaphos is highly persistent in wax[7]. With a half-life of 115 to 346 days, it can take several years for the pesticide to breakdown completely[8]. Moreover, coumaphos does not break down during the heating and processing of wax to create foundation[8]. Even if beekeepers *never* treated their colonies with coumaphos, they may unknowingly introduce it when adding new wax foundation.

Amitraz is a popular *Varroa* mite treatment in use today, yet it was present in just 5% of colonies in the study. Compared to coumaphos, Amitraz is less harmful to bees, and it breaks down quickly in wax and honey. To date, there is no evidence that Amitraz has any sublethal impacts on honey bee health, although some acute toxicity can be experienced by workers when the miticide is first applied. Amitraz residues cannot be detected after several weeks, though its breakdown chemicals can be present in honey for up to two months.

Insecticides

There are many different classes of insecticides growers use in NYS. Among the most common are organophosphates, pyrethroids, carbamates, and neonicotinoids. Neonicotinoids are currently the most studied pesticide with regards to honey bee health[9], and there is much controversy surrounding the risk they pose to bees. While neonicotinoids are the most used insecticide worldwide, it is not common for them to be present at acutely toxic levels in bee hives. However, low levels of these pesticides can cause sublethal impacts, such as impaired learning and memory, locomotion, and foraging. Acetamiprid concentrations of 5,000 ppb, imidacloprid concentrations of 75 ppb, and clothianidin concentrations of 25 ppb have been shown to cause sublethal effects in honey bees[10]. Furthermore, chronic exposure (over more than four days) to acetamiprid concentrations of 5,000 ppb, thiamethoxam concentrations of 5.31 ppb, clothianidin concentrations of 2.05 ppb, or imidacloprid concentrations of 0.25 ppb can impair honey bee health[10]. One commercial honey bee colony in this study had thiamethoxam levels of 24.5 ppb, high enough to potentially cause chronic injury to honey bees. All other colonies in this study had neonicotinoid levels lower than those known to cause sublethal and chronic impacts.

This study evaluated the levels of six different neonicotinoids (denoted with an asterisk in Table 1). No colonies had detectable levels of clothianidin, imidacloprid, or nitenpyram. Thiacloprid was detected in one colony, at a level too low to be quantified. Acetamiprid was detected in three colonies, but only quantifiable in one, at a concentration of 19.7 ppb. Two colonies contained thiamethoxam at concentrations of 24.5 ppb and 2.7 ppb, respectively. Neonicotinoids were not present in any of the colonies at levels known to cause sublethal effects. However, the two colonies containing thiamethoxam had oral hazard quotients greater than 3% of the contact LD50, and therefore exceeded the European Food Safety Agency (EFSA) threshold of concern for chronic oral exposure.

Fenpyroximate, the most prevalent insecticide among colonies in this study, was found in 61% of the colonies sampled. Few papers have investigated its impact on bee health, but one study demonstrated that, at levels of 54,000 ppb, fenpyroximate reduces the lifespan of queens[11]. The levels that were found in wax samples in this study were below 10 ppb. Other insecticides detected in these colonies were uncommon (found in less than 9% of all colonies) and were at levels well below the LD_{50} values known to cause acute toxicity to bees. There is very little research exploring the concentrations known to cause sublethal impacts for these insecticides.

Fungicides

While many insecticide labels prohibit their application while flowers are blooming and bees are foraging, most fungicides can be applied during this time. For this reason, it is common for foraging bees to come in contact with fungicides and bring them back to the hive. In this study, fungicides were more prevalent than any other pesticide in wax, comprising 5 of the top 10 most commonly detected. While many fungicides appear to be largely nontoxic to honey bees, one emerging class of fungicides has been shown to be potentially harmful. Ergosterol-biosynthesis-inhibiting (EBI) fungicides impair bees' ability to detoxify chemicals. When an EBI fungicide is present in combination with certain pyrethroid or neonicotinoid insecticides, the fungicide can increase the insecticides' toxicity[12-16]. This study detected five EBI fungicides in honey bee colonies (myclobutanil, penconazole, fenbuconazole, propiconazole, and difenoconazole). While their concentrations were low, the degree to which they harm honey bees may be higher depending on what other insecticides were also present in the colony. With the frequency of tank mixes used by growers, it is critical that these interactions be explored more thoroughly with regards to bee health. Cornell University has prioritized researching the impacts of fungicide interactions on honey bees in the future.

Herbicides

Two herbicides were tested and detected in honey bee colonies. Atrazine and metolachlor were present in 17% and 58% of colonies, respectively. These herbicides are very commonly used by growers and pesticide applicators, and were found at very low levels in colonies that do not usually cause acute toxicity in honey bees. Very little work has been done to investigate the chronic and sublethal impact of these herbicides on honey bee health, and neither have been investigated to the point where solid conclusions can be made.

The Cornell Chemical Ecology Core Facility is not yet able to detect glyphosate or other herbicides in wax.

Synergists

The synergist piperonyl butoxide (PBO) was the most common chemical in honey bee wax, found in 99% of samples. The levels that it occurred in the hive are well below the doses required to kill honey bees, but this synergist can interact with other chemicals. When found in combination with certain pyrethrin, pyrethroid, neonicotinoid, and carbamate insecticides, PBO inhibits a bee's ability to detoxify these pesticides[17,18]. Besides reducing their ability to efficiently break down pesticides, virtually nothing is known about how these interactions between PBO and other chemicals impair honey bee health in real world settings.

Study Limitations & Areas of Future Research

Our analysis was limited to 41 chemical compounds that the Cornell Chemical Ecology Core Facility currently has the capability to analyze. These compounds were chosen carefully by the research team, yet they represent only a subset of hundreds of pesticides that honey bees may encounter in the environment. Furthermore, the limit of detection and quantification for some pesticides – including neonicotinoids – was relatively high. Other studies have found neonicotinoids in bee hives at concentrations below the facility's levels of detection. The Cornell Chemical Ecology Core Facility will be expanding the number of compounds it can detect and improving the sensitivity of its detections for future rounds of pesticide sampling.

This study analyzes pesticide residues in wax samples, yet wax is not the only medium through which bees are exposed to pesticides. Honey bees may encounter pesticide residues as they collect and consume contaminated pollen, nectar and water, or through direct body contact with pesticides applied recently to plants and soil. This study shows that pesticides are widespread in beeswax in NYS, yet it also provides a conservative estimate of the full scope of honey bee exposure to pesticides.

Some pesticides may exert behavioral, physiological, or molecular effects on honey bees, without causing mortality. Yet chronic and sub-lethal pesticide concentrations are largely unexplored. This report uses contact hazard quotients as a reliable indicator of the risk of ***acute toxicity*** to bees. It also examines oral hazard quotients as a plausible indicator of ***chronic or sublethal effects***, however, the LD_{50} values used to calculate hazard quotients are based on short-term exposure, so the long-term effects are less certain. Furthermore, some pesticides are known to magnify the toxicity of other compounds, leading to synergistic effects that are not captured by the standard LD_{50} values. Because of these gaps in the scientific literature, this study emphasizes risks of acute toxicity to honey bees. More research is needed to better understand synergistic and sublethal effects of agricultural pesticides.

5. Implications for Management

Pesticide exposure is a difficult challenge for beekeepers to manage because many of the factors that determine exposure to agrochemicals are outside of a beekeeper's control. Effectively mitigating risk to pollinators involves many groups working together: pesticide applicators, growers, policy makers, the public, and beekeepers must communicate and collaborate to find solutions. Some beekeepers may feel at a loss when it comes to reducing pesticide exposure in their own colonies. Sending bees into pollination, or keeping bees in agricultural areas, may increase the risk of exposure to certain pesticides. Yet for many beekeepers these practices are central to their operations. Here we present a few ways that beekeepers at any scale can be proactive in minimizing pesticide risk.

Frames & Foundation

- Replace frames on a regular basis. Cornell University recommends rotating out two of your oldest frames from each hive body every year to reduce contaminants in your hives.
- Consider using plastic foundation, as it contains less recycled wax than wax foundation. If you wish to paint additional wax onto your plastic foundation, use light-colored wax that you have collected from your own colonies.

***Varroa* Mite Management**

- Develop a *Varroa* management plan that includes regular monitoring for mites, and only apply a chemical treatment when your mite level meets or exceeds the treatment threshold. We recommend a treatment threshold of 2 mites per 100 bees in the spring, and 3 mites per 100 bees in the summer and fall[19,20].
- Use only registered mite treatments. Read the instructions before using a miticide, and carefully follow all treatment guidelines on the label. It is dangerous and unlawful to introduce non-registered or homemade miticides into a honey bee colony.
- Do not apply unnecessary *Varroa* mite treatments. Introducing unnecessary chemicals into a hive poses a risk to honey bee health. It may also increase the chance of Varroa mites in your operation becoming resistant to treatment.

Communication with Landowners

- Develop friendly relationships with landowners and other neighbors who apply pesticides to their land. Foster open communication about where hives are located in relation to their land and when pesticide applications will occur.
- If you provide commercial pollination services, consider using a written contract to specify your expectations regarding pesticide application before and during the pollination window. If you are able to move your colonies out of the field during pesticide application, do so. Determine the minimum amount of time you require in advance of pesticide application. See Appendix 3 for an example pollination contract.

Reporting Pesticide Kills

- Report acute pesticide kills as soon as symptoms are observed to two places:
    - The NYS Apiculturist, Paul Cappy: (518)-485-8760
    - The Department of Environmental Conservation (518) 402-8727
    - Symptoms of acute pesticide kills include a pile of dead bees at the entrance, bees that are twitching or disoriented, and bees that have their tongues sticking out.

Support Ongoing Research

- Participate in Dyce Lab research projects that advertise beekeeper participation. These opportunities are advertised as they become available on the Dyce Lab facebook page (accessed at facebook.com/DyceLab) and the Cornell Pollinator Network website (accessed at www.pollinator.cals.cornell.edu).

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Appendix 1. List of 41 pesticides tested for in wax samples.

Compound	Compound Type	LOD (ppb)	LOQ (ppb)	Contact LD50 (ug/bee)	Oral LD50 (ug/bee)
Piperonyl butoxide	Synergist	0.038	0.124	17	NA
Amitraz	Miticide	0.004	0.012	50	NA
Coumaphos	Miticide	1.500	4.950	20	4.6
Acetamiprid*	Insecticide	0.930	3.069	7.9	14
Avermectin B1a	Insecticide	0.300	0.990	0.03	NA
Carbaryl	Insecticide	3.750	12.375	0.84	0.15
Chlorantraniliprole	Insecticide	0.030	0.099	4	104
Clothianidin*	Insecticide	12.00	39.60	0.044	0.004
Cyantraniliprole	Insecticide	0.128	0.421	0.09	0.11
Emamectin B1a	Insecticide	0.003	0.011	0.004	NA
Emamectin B1b	Insecticide	0.150	0.495	0.004	NA
Fenpyroximate	Insecticide	0.038	0.124	11	118.5
Imidacloprid*	Insecticide	1.350	4.455	0.044	0.004
Indoxacarb	Insecticide	1.500	4.950	0.118	0.26
Nitenpyram*	Insecticide	1.590	5.247	0.138	NA
Phosmet	Insecticide	1.500	4.950	0.62	0.37
Spinetoram J	Insecticide	0.006	0.019	0.024	0.14
Spinetoram L	Insecticide	0.019	0.062	0.024	0.14
Spinosyn A	Insecticide	0.016	0.053	0.003	0.057
Spinosyn D	Insecticide	0.011	0.037	0.003	0.057
Thiacloprid*	Insecticide	0.960	3.168	37.83	17.32
Thiamethoxam*	Insecticide	0.353	1.163	0.024	0.005
Atrazine	Herbicide	0.375	1.238	97	NA
Metolachlor	Herbicide	0.150	0.495	110	110
Azoxystrobin	Fungicide	0.004	0.012	200	25
Boscalid	Fungicide	3.750	12.38	200	166
Cyflufenamid	Fungicide	1.530	5.049	100	100
Cyprodinil	Fungicide	0.150	0.495	100	100
Difenoconazole	Fungicide	0.375	1.238	101	177
Fenbuconazole	Fungicide	1.500	4.950	290	NA
Fluopyram	Fungicide	0.150	0.495	100	102.3
Fluxapyroxad	Fungicide	1.500	4.950	100	110.9
Myclobutanil	Fungicide	0.375	1.238	39.6	34
Penconazole	Fungicide	0.375	1.238	12	24
Penthiopyrad	Fungicide	0.375	1.238	312	385
Propamocarb	Fungicide	0.038	0.124	100	99
Propiconazole	Fungicide	1.830	6.039	50	77
Pyraclostrobin	Fungicide	0.150	0.495	100	73
Pyrimethanil	Fungicide	0.375	1.238	100	100
Thiophanate-Me	Fungicide	1.500	4.950	100	100
Trifloxystrobin	Fungicide	0.150	0.495	200	200

Note: The asterisk (*) indicates neonicotinoids. The level of detection (LOD) is the lowest concentration of a compound, in parts per billion (ppb) that can be reliably detected by our test procedure, while the level of quantitation (LOQ) is the lowest concentration of a compound that can be reliably measured. The LD_{50} is a measure of acute toxicity (short-term poisoning potential). LD stands for "lethal dose," and the LD_{50} is the amount of a compound that, given all at once to a sample of bees, causes half the bees to die. LD_{50} values were calculated from a variety of sources[1,21,22].

Appendix 2. Top 10 Most Common Pesticides[23-26]

1	**Piperonyl butoxide** - *Found in 99% of colonies* As a pesticide synergist, piperonyl butoxide (PBO) has little or no direct effect on insects by itself. Rather, it is used in combination with insecticides to magnify their toxicity. It is most commonly used with pyrethrins, pyrethroids, and carbamates. PBO inhibits natural enzymes that insects produce in their bodies to detoxify other pesticides. Without these enzymes, insecticides remain in the insects' bodies for a longer period of time. Unlike adjuvants, pesticide synergists are included on a pesticide product's active ingredient label.
2	**Fenpyroximate** - *Found in 61% of colonies* This insecticide is used to control spider mites and other plant-infesting mites, leafhoppers, mealybugs, whiteflies and psylla. In some areas outside of NYS, this pesticide is used to kill the *Varroa* mite. Fenpyroximate is applied to greenhouse vegetables, ornamental plants, nursery crops and non-bearing fruit trees to inhibit feeding and reproduction of target insects.
3	**Metolachlor** - *Found in 58% of colonies* Farmers and pesticide applicators commonly use this herbicide use to control weeds in various cropping systems, including field corn and soy. Metolachlor inhibits protein synthesis in plants, and is highly effective against grasses. Both metolachlor and atrazine are active ingredients in the top two herbicide products applied in NYS, by volume, in 2013.
4	**Azoxystrobin** - *Found in 53% of colonies* This broad spectrum fungicide is widely used to control many different fungal diseases in agriculture, especially in grain, vegetable and fruit crops. It is also used on commercial and residential turf, athletic fields and golf courses.
5	**Coumaphos** - *Found in 51% of colonies* This insecticide/miticide was first registered with the EPA in 1958 as a treatment for livestock, primarily cattle. Coumaphos is the active ingredient in CheckMite+, which was approved in NYS in 1999 as a treatment for *Varroa* mites, and later for small hive beetles. Today, coumaphos is rarely used as a treatment for *Varroa* due widespread resistance. It is highly persistent in wax, and does not break down when wax is melted. Studies show coumaphos can harm the development and reproductive ability of queens and drones.
6	**Pyraclostrobin** - *Found in 38% of colonies* Since 2004, this broad-spectrum fungicide has been used in NYS to control fungal diseases across a wide range of crops, including fruits, vegetables and grains. Pyraclostrobin is also widely used on golf courses, recreational areas and residential lawns.
7	**Cyprodinil -** *Found in 30% of colonies* This broad-spectrum fungicide was first registered with the EPA in 1998 to control scab, blossom blight and brown rot on almonds, apples, grapes and stone fruit. Today cyprodinil is used as a foliar spray to treat a variety of fungal diseases on many different fruit and vegetable crops in temperate and tropical climates.
8	**Trifloxystrobin** - *Found in 26% of colonies* Since 1999, trifloxystrobin has been used in the U.S. to control fungal pathogens on apple, grape, squash, turf grass, and ornamental plants. This broad-spectrum fungicide inhibits fungal spore germination and mycelial growth.
9	**Fluopyram** - *Found in 18% of colonies* This fungicide was first registered in New York State in 2014 to treat scab and powdery mildew in apple. It is an active ingredient in the product Luna Tranquility, which also contains pyrimethanil, a fungicide that we detected in 14% of our wax samples. Fluopyram is also approved for use on turf grass, ornamental plants, and nursery plants.
10	**Atrazine** - *Found in 17% of colonies* Atrazine is the second most widely used herbicide in the U.S., after glyphosate. It is commonly used to control broadleaf weeds in corn, and it is also approved for use on turf grass, including golf courses, recreational fields, and residential and commercial lawns.

Appendix 3. Example Pollination Services Contract

This contract is made between the following parties:

Beekeeper's name: ____________________________________

Grower's name: _____________________________________

CONTACT INFORMATION		
	Beekeeper	Grower
Mailing address:		
Phone number(s):		
Email address:		

The parties agree to the following terms

CROP AND COLONY OVERVIEW			
This agreement involves the 20___ growing season			
Crop to be pollinated by honey bee colonies			
Address and/or GPS coordinates of orchard/field where the hives will be placed			
Date of colony placement*		Date of colony removal*	
* If actual flowering dates differ from dates above, the grower will provide 48 hours notice to the beekeeper regarding when colonies should be placed and removed			
No. of hives rented		Price of a standard hive rental	$
Total anticipated rental price	$	Date(s) on which the rental fee is payable to the beekeeper	
Describe in detail or illustrate the colony placement in the orchard			
The grower will provide right of entry to beekeepers visiting the property whenever necessary so that s/he can manage colonies	☐ Yes ☐ No		
A water source will be provided to the honey bee colonies by the following party	☐ Beekeeper ☐ Grower ☐ No water will be provided		
The beekeeper is not responsible and will be held harmless for bee stings to animals or people			

The **beekeeper** agrees to provide colonies of the following standards:

COLONY STATUS OF A STANDARD HIVE	
Colony configuration (2 deeps, 1 deep, etc.)	
Minimum frames of bees in each hive	
Minimum frames of brood in each hive	
Pounds of food stores	lbs
Presence of a laying queen	
Colonies are free of American Foulbrood	
The beekeeper agrees to open and demonstrate the health and status of colonies randomly selected by the grower	
The beekeeper will maintain colonies in good pollinating condition by providing feed, medication, and mite treatments as needed	

The **grower** agrees to the following responsibilities:

GENERAL RESPONSIBILITIES
The grower will provide a suitable place for the hives that are accessible by truck or other vehicles
The grower assumes all responsibility for field or crop damage or loss resulting from the use of the beekeeper's vehicle(s)

MINIMIZING RISK OF PESTICIDE EXPOSURE	
No insecticides will be applied to the crop within ______ weeks of hive entry	
No insecticides will be applied to the crop while honey bee colonies are in place for pollination services	
The following pesticides or agricultural chemicals are mutually agreed to be used while the bees are on the crop:	
1.	2.
3.	4.
5.	6.
7.	8.
9.	10.
The number of hours notice the grower agrees to give the beekeeper if pesticides not listed above need to be applied to the crop while the colonies are in place for pollination (e.g., 48 hrs)	hrs
The cost of moving colonies out of a crop if a potentially hazardous pesticide will be applied during pollination. The grower shall assume the costs to move the colonies away from and back to the crop.	$
The grower will compensate the beekeeper for any colonies that died from acute pesticide poisoning events while present or within one month of pollinating this crop. Cause of death must be verified by the State Apiculturist or Department of Environmental Conservation. The cost of compensation per colony:	$
The grower will dispose of all pesticide products in a manner that bees will not be able to contact it while searching for a source of water.	

Additional agreements:

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ADDITIONAL CONSIDERATIONS
Prior to placing colonies for pollination, either party can be excused from his or her responsibilities of this contract should events occur beyond their control that prevent him or her from fulfilling the obligations as outlined
In the event that disputes arise, they will be settled by arbitration. Within 10 days each party will select one arbitrator and the two arbitrators will select a third. After reviewing the case, the decision of any two arbitrators will be binding. Cost of arbitration will be equally divided between the two parties.

Signature of beekeeper: ___________________________________ Date: _______________

Signature of grower: ______________________________________ Date: _______________

Signature of witness: ______________________________________ Date: _______________