NYS Beekeeper Tech Team

2021 Report

NYS BEEKEEPER TECH TEAM

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2021 NYS Beekeeper Tech Team Report

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New York State Beekeeper Tech Team

Overview

The New York State (NYS) Beekeeper Tech Team was created in 2016 in response to unsustainable colony losses across the state in recent years. The Tech Team works closely with New York beekeepers to improve honey bee health, reduce colony losses, and increase the profitability and viability of beekeeping businesses. The Tech Team meets with participating beekeepers several times a year to conduct applied research and to provide information and recommendations that address beekeeping challenges. Participants manage operations that range in size from a few backyard hives to thousands of colonies. They remain enrolled in the Tech Team program for up to three years.

The program is funded by the New York State Environmental Protection Fund. It is implemented by Cornell University in collaboration with the New York State Department of Agriculture and Markets.

Acknowledgements

The Tech Team is grateful for our close collaboration with the Bee Informed Partnership (BIP). We appreciate the support from the Executive Director Annette Meredith and the sample processing from the vanEngelsdorp Honey Bee Research Lab at the University of Maryland headed by Heather Eversole. We appreciate the work of BIP staff Anne Marie Fauvel, Ben Sallmann, and Dan Wyns, who provided assistance sampling colonies and communicating with beekeepers. We are also grateful for Nicolas Baert's, Wayne Anderson's and David Sossa's work processing pesticide samples at the Cornell Chemical Ecology Core Facility. Lastly, we are thankful for the Empire State Honey Producers Association's continued support.

Tech Team Members

Emma Walters As the Senior Honey Bee Extension Associate at Cornell University, Emma is the Senior Lead of the NYS Beekeeper Tech Team, overseeing all aspects of the program including administration, data collection, report writing, and communications. Emma is passionate about communicating scientific research to beekeepers and working with them to implement best management practices.

Connor Hinsley As the technician for the Tech Team, Connor manages logistics of Tech Team operations, including sampling honey bee colonies in the field, managing databases, and drafting reports. Connor is interested in addressing the challenges faced by both honey bees and native bees by helping beekeepers implement practical, evidence-based strategies to reduce the spread of disease and the overuse of chemical treatments.

Joan Mahoney As the NYS Apiculturist, Joan represents the Department of Agriculture and Markets on the Tech Team. She is an experienced beekeeper, horticulturalist, and program manager. She leads the NYS Apiary Inspection Program, collaborates with the APHIS National Honey Bee Disease Survey, and is key to advancing New York's apiary industry and the goals outlined in the pollinator protection plan.

Statistical Analyst

Stephen Parry conducted the statistical analyses of the Tech Team data for this report. Stephen Parry works as a statistician for the Cornell Statistical Consulting Unit. He holds a Master of Science degree in Mathematics as well as a Master of Science degree in Statistics. He enjoys helping researchers from a variety of fields to interpret their data and to communicate their findings. He has been recently published in the American Journal of Obstetrics and Gynecology, the Journal of the Endocrine Society, Agriculture MDPI, and Veterinary Ophthalmology. Before arriving at Cornell, Stephen taught mathematics and statistics courses at local colleges and universities.

Executive Summary

The Tech Team at a Glance

- We have worked with 65 beekeepers since the program started in 2016. This includes 23 commercial beekeepers, 23 sideliners, and 19 hobbyists.
- We have sampled 1,634 unique colonies from 148 apiaries. These apiaries are spread across 34 different counties.
- We have collected demographic information and details on management practices through 186 unique surveys. The beekeepers who responded to the survey managed 47,604 colonies in New York State, representing 60% of the state's estimated 80,000 colonies.
- These beekeepers reported generating a total of $7.5 million in hive products and services during their time in the program.

2021 Highlights

- **2021 marks the sixth year of the NYS Beekeeper Tech Team. This year we worked with 27 beekeepers: 9 commercial, 10 sideliner, and 8 hobby.** We expanded our geographical reach by working with two beekeepers in New York City. The 23 who responded to the annual survey managed a total of 8,714 colonies across 22 different counties.
- **New York beekeepers are important contributors to the state's agricultural economy.** The combined revenue from apiary products and services including liquid honey, cut comb honey, beeswax, queens, nucleus colonies, and paid pollination services generated an estimated production value of over $1.24 million in 2021 alone. The top three primary income sources are liquid honey, pollination services, and nucleus colonies, respectively.
- **While overall honey production was average in 2021, colony level production was the lowest since the Tech Team began.** Tech Team beekeepers produced a total of 353,000 pounds of liquid honey. Although this production exceeded the average 321,000 pounds per year since 2018, the average yield per colony was nearly 10 pounds lower than the typical average for New York at just 54 pounds per colony. Beekeepers reported little to no fall flow this year, perhaps related to the excessive rainfall in late summer and early autumn.
- **Colony losses in 2020/2021 are comparable to previous years.** Total annual losses were 43.4% (the five-year average is 43.9%), summer losses were 22.1% (the five-year average is 22.8%), and winter losses were 34.1% (the five-year average is 36.6%). Although these losses are typical for New York beekeepers, they continue to surpass what beekeepers consider acceptable (20%). Pressure from V*arroa* and its associated viruses was the most common reported cause of winter mortality and queen issues were the most common reported cause of summer mortality.
- **V*arroa* mites are a significant predictor of winter mortality.** Our models suggest that the higher the colony's fall V*arroa* levels, the lower its chance of survivorship. When fall V*arroa* loads increase by 1 mite per 100 bees, the colony's odds of survival go down by 8.5%.

- **Beekeepers who monitored and treated for *Varroa* more frequently experienced lower *Varroa* levels.** Beekeepers are encouraged to monitor their *Varroa* levels monthly as weather permits, and to treat when levels reach or exceed the treatment threshold. On average, New York beekeepers would benefit from monitoring more frequently. We recommend monitoring monthly from March to November but find the average monitoring frequency is only 2.2 times a year.
- **Colony wintering location impacts *Varroa* levels the following spring.** Many beekeepers (38% of our participants) bring their colonies to a southern state for winter. These colonies enter spring with significantly higher *Varroa* mites compared to colonies that winter in New York State. Beekeepers who winter their colonies in southern states should be vigilant about early spring monitoring and may need to prepare to apply earlier or more frequent mite treatments than beekeepers who keep their colonies in New York over winter.
- **Beekeepers increased their *Varroa* management practices after receiving extension services from the NYS Beekeeper Tech Team.** The proportion of beekeepers that monitored for *Varroa* increased from 45% to 72%, that used chemical treatments increased from 68% to 86%, and that used non-chemical control methods (e.g., culling drone brood, screened bottom board, etc.) increased from 44% to 56%.
- **Despite receiving education and training on *Varroa* management, beekeepers do not report improved control over *Varroa*.** The biggest barrier that impacts their mite management is not having enough time and/or labor, with 71% of beekeepers stating this prevents them from adequately monitoring or treating.
- **In both spring and fall of 2021, *Nosema* loads were well below the level where the parasites are considered to negatively impact colony health.** Furthermore, *Nosema* levels are not associated with winter loss in New York State.
- **In 2021, 7.4% of colonies were infected with European foulbrood.** In autumn, we found no cases. No colonies inspected by the Tech Team were infected with American foulbrood; however, NYS Dept of Ag and Markets identified 42 cases of AFB in New York State and so beekeepers should continue to be attentive when inspecting their brood nests.
- **Small hive beetles continue to be common in autumn.** Beetles were observed in 25% of the colonies we inspected. We never observed advanced stages of infestation (larvae or fermented honey) in any colonies that were occupied with bees, and so we continue to promote only non-chemical methods for small hive beetle control in New York State.
- **Queen issues are a significant predictor of winter mortality.** The presence of a laying queen is also significantly associated with fall population and fall brood pattern. Beekeepers should verify that colonies are queenright throughout the entire season and again in autumn after the fall swarm season ends to ensure they are ready to enter winter.
- **Pesticides are ubiquitous in hives and colonies contain an average of 17 different compounds in their beeswax.** The bulk of the pesticide load in 2021 comes from amitraz, a miticide applied by beekeepers.
- **Forty percent of beekeepers continue to be impacted by COVID-19**. The negative issues reported by beekeepers ranged from losses of revenue and marketing, travel restrictions, and obtaining equipment and labor.

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Introduction

New York State is home to a vibrant beekeeping industry that produces a variety of agricultural commodities and services including honey, beeswax, nucs, queens, and pollination. The total number of beekeepers in the state is unknown, but it's estimated to be between 2,500 and 3,000[1]. Of these, 65 are commercial beekeepers who manage 300 colonies or more, 126 are sideliners who manage between 50 and 299 colonies, and the rest are hobbyists who manage fewer than 50 colonies. Beekeeping is a valuable agricultural industry in New York. The most recent USDA National Agricultural Statistics Service data reported New York's beekeeping industry produced 3,248,000 pounds of honey in 2020, valued at $11,011,000[2]. Furthermore, insect pollination services is valued at roughly $308 – 439 million annually[3]. Beekeepers provide pollination services to a variety of crops both within New York and across the United States, including apple, pumpkin, peach, blueberry, raspberry, pear, cherry, cranberry, almond, melon, and squash.

Despite their critical importance for agriculture, honey bees in New York State face more challenges than ever before, and colony losses continue to occur at high rates. The Bee Informed Partnership loss surveys document between 33% and 68% of New York's colonies have died each year since 2010[4]. Parasites, viruses, pesticides, nutrition, and management practices all shape honey bee health outcomes. The complexity of factors that influence colony health and productivity makes it difficult for beekeepers to diagnose specific health problems in their colonies and respond appropriately. As a result of consistent high losses, it's become difficult for many beekeepers to run their operations in an economically sustainable way.

Reliable information on colony health and performance empowers beekeepers to make informed management decisions. Knowing *Varroa* mite levels, *Nosema* spore counts, and pesticide residues takes the guesswork out of identifying issues with incomplete information. Coupling these data with resources and expert recommendations allows beekeepers to proactively manage their operations using effective, evidence-based practices. The NYS Beekeeper Tech Team was founded to foster this approach.

The Tech Team works with beekeepers across New York State, inspecting a sample of colonies from each participating operation. Tech Team technicians train beekeepers in the field in identifying and monitoring health issues. In the process of sampling, the Tech Team documents parasite infestations, pathogen levels, pesticide residues, and management practices of individual hobbyist, sideliner, and commercial beekeepers. Each beekeeper receives a detailed colony health snapshot of their own operation, along with values from similar operations for comparison. Recommendations based on individual test results inform production decisions and support proactive planning for improved pest, disease, and pesticide management. Sharing this information with beekeepers is critical to mitigating colony losses and enhancing the stability and profitability of the New York State beekeeping industry.

The year 2021 marks the sixth of the program, and so this report provides the opportunity to share lessons learned and progress made over the past six years. Additionally, this report presents results from data collected in 2021 and presents evidence-based Best Management Practices to support decision making for improved colony health.

Methods

The Tech Team visits New York State beekeeping operations twice annually, in June and September, to inspect and sample colonies from diverse operations. Surveys are sent each October to collect information on operation demographics and management practices. The data collected through hive sampling and beekeeper surveys enables the Tech Team to track trends in the status of honey bee health in New York and to identify effective management practices that improve colony health and productivity.

Beekeeper Participants

Twenty-seven beekeepers participated in the Tech Team program in 2021. Of those beekeepers, eight were hobbyists (managing fewer than 50 colonies), ten were sideliners (50–299 colonies), and nine were commercial (300 or more colonies). Two beekeepers graduated from the program and six new beekeepers were enrolled this year.

Tech Team participants maintain colonies in New York State and must generate at least $1,000 in annual revenue from beekeeping. The Tech Team aims for one third of participants to be commercial beekeepers. Priority is given to those who are seeking help to overcome disease and parasite issues in their operation. Any remaining slots are filled on a first-come, first-served basis.

Participation in the Tech Team program is completely voluntary, and all information gathered from beekeepers is confidential. Beekeepers who receive Tech Team services are expected to permit the team to visit their operation and sample their colonies, to attend the one-on-one annual meetings, and to complete an annual survey that documents operation characteristics and management practices.

Beekeepers can remain enrolled in the program for three years. Participation in subsequent years is conditional on the beekeeper completing their annual management practices survey and annual one-on-one meeting.

Colony Inspections

The Tech Team inspected a total of 294 colonies in 2021. Four colonies from a single apiary were sampled for hobby and sideliner operations, and ten colonies per apiary from two apiaries were sampled for each commercial operation. Whenever possible, colonies that were sampled previously were sampled again in 2021. In both June and September, each colony was inspected to assess the queen status, population strength, brood pattern, and brood health. At least four brood frames were inspected in each colony during each inspection. In addition, *Varroa*, *Nosema*, and pesticide samples were taken.

The Tech Team aims to sample a representation of the apiary, selecting colonies of varying sizes and strengths. Every colony sampled is given a unique alphanumeric colony ID. In the event a colony dies or is lost between sampling periods, the ID of the colony is recorded along with its estimated time and cause of death, and a new queenright colony is sampled in its place.

We recognize the floral resource availability, weather, and other factors beyond beekeepers' control vary between counties and region, and as such, we attempt to sample colonies across the state. The 294 colonies sampled in 2021 were spread across 9 regions and 22 counties of New York State. This year, we expanded our representation by enrolling two beekeepers in the NYC area. The geographical distribution of beekeepers sampled in 2021, as illustrated in Figure 1, is categorized by region as defined by the New York State Department of Economic Development.

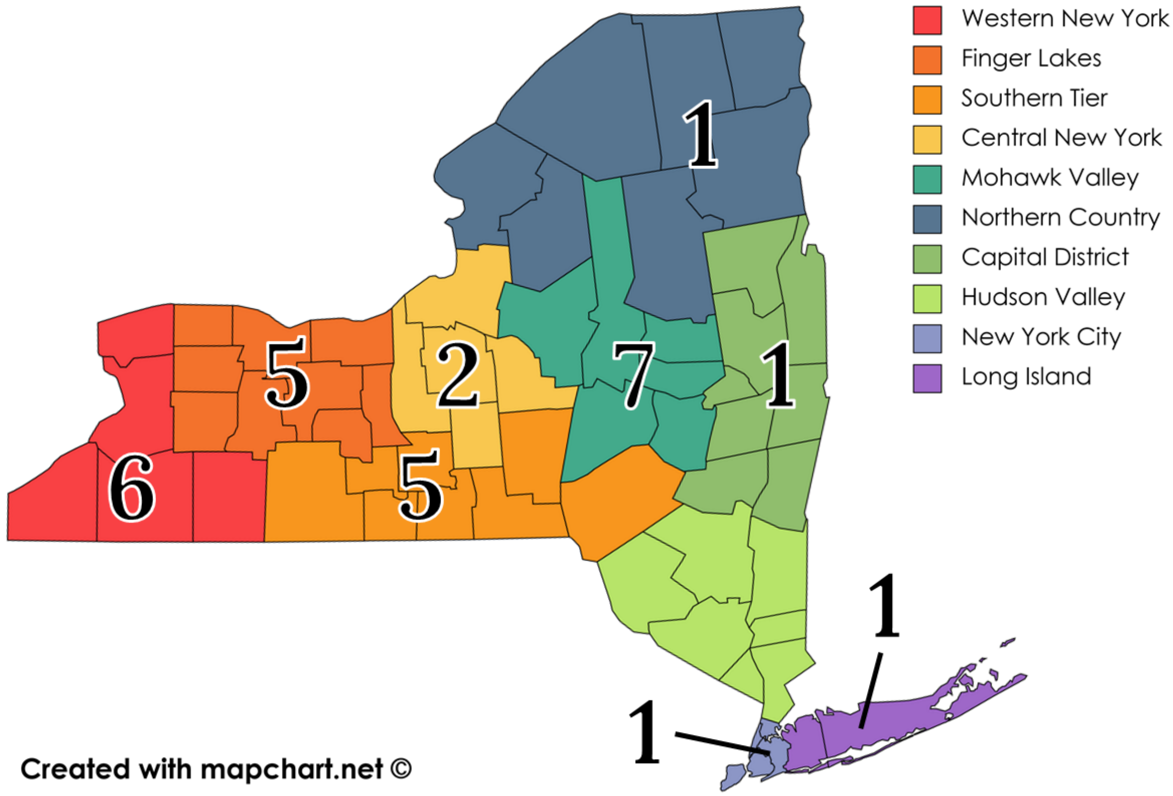

Figure 1. *The number of beekeepers we sampled in each region in 2021. Created with mapchart.net*

Of the 294 colonies we sampled in 2021, 109 (37.1%) were in the Mohawk Valley, 78 (26.5%) were in the Finger Lakes, 34 (11.6%) were in Western New York, 29 (9.9%) were in the Southern Tier, 23 (7.8%) were in the Capital District, 9 (3.1%) were in Central New York, 4 (1.4%) were in the Northern Country, 4 (1.4%) were in Long Island, and 4 (1.4%) were in NYC. This representation reflects the concentration of commercial beekeeping located across the central belt of the state.

Sampling Parasites and Identifying Diseases

To assess for *Varroa* and *Nosema* levels, the Tech Team collected approximately 300 bees from brood frames in every colony and shipped them to the University of Maryland Bee Lab. The bees and *Varroa* mites in the sample were counted to calculate the mite population as a percentage of the honey bee population in that colony. From this sample, 100 worker bee abdomens were removed, and the gut contents were viewed through a microscope on a hemocytometer to estimate the average number of *Nosema* spores per bee.

If American or European foulbrood signs were observed, a Vita® test kit was used to verify the infection. If the colony tested positive for American foulbrood, Joan Mahoney, the state apiculturist, would be contacted immediately in compliance with New York State apiary laws, and the Tech Team mailed a brood sample to the USDA Beltsville Bee Lab.

Pesticide Sampling and Risk Assessment

In this report, we summarize pesticide results of beeswax samples taken from 613 colonies during the period of 2016–2021. Each fall, a sample of 3 grams of wax is collected from the brood nest of two colonies per apiary. The oldest (darkest) wax is sampled when possible. The Tech Team samples wax because this substrate provides a cumulative view of a colony's exposure to pesticides. Many pesticides are lipophilic, so they leach into the wax and accumulate over time. Many are also slow to breakdown in beeswax. Beekeepers have the option to submit a fresh pollen sample from a pollen trap for pesticide analysis. A fresh pollen sample provides a snapshot of pesticide exposure over a short period of time, permitting beekeepers to identify the time and locations where their bees are exposed to specific pesticides. This report only presents wax results because the Tech Team did not receive any pollen samples in 2021.

In 2021, the Cornell Chemical Ecology Core Facility analyzed 72 new wax samples using Liquid Chromatography Mass Spectrometry and quantified levels of 92 unique pesticides. These included 33 insecticides, 22 herbicides, 34 fungicides, two miticides (amitraz and coumaphos), and one synergist (a chemical that increases the toxicity of the pesticides with which it is combined). The pesticide load present in the wax is reported in parts per billion (ppb).

Currently, the best approach to estimate a colony's pesticide risk is to determine its wax hazard quotient (WHQ). The WHQ for each pesticide is calculated by dividing the amount of the pesticide residue (ng/g wax) by its respective LD_{50} value (ug/bee).

$$Wax\ Hazard\ Quotient = \frac{Amount\ of\ pesticide\ (ppb)}{Pesticide\ toxicity\ (LD_{50})}$$

The LD_{50} value 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 (usually 48 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 LD_{50} values used in this study are listed in Appendix 1. The LD_{50} values for five compounds outlined in Appendix 1 are not publicly documented, and so those pesticides do not contribute to the WHQ risk analysis.

The risk for an entire colony is the summation of these values for each pesticide present in the wax. Higher values reflect a relatively higher risk of an acute pesticide poisoning event.

- The United States Environmental Protection Agency recognizes a WHQ of 40% to be the level of concern for *acute* exposure and 100% to be the level of concern for *chronic* exposure[5].
- The European Food Safety Authority recognizes a WHQ of 20% to be the level of concern for *acute* exposure and 3% to be the level of concern for *chronic* exposure[6].

This method of reporting pesticide risk only relates to mortality. At low levels, some pesticides can cause sublethal impacts (i.e., those that do not result in death). Sublethal impacts include learning and memory issues, reproductive and development issues, or changes in behavior. Additionally, two pesticides can interact synergistically, meaning they are more toxic when occurring together than the sum of both pesticide's toxicity levels on their own. The risk of sublethal and synergistic impacts is not captured in this analysis.

Management Survey

All participating beekeepers received a comprehensive survey covering production, management practices, colony losses, and operation characteristics. At the time of printing this report, a total of 23 beekeepers completed the survey, resulting in an 85% response rate. Several beekeepers reported COVID-19 impacted their ability to complete the survey this year. Surveys from 2016 through 2021 were included for comparison where appropriate. Responses help explain trends in colony health outcomes documented by technicians in the spring and fall. They also allow beekeepers to evaluate how their colony health, product prices, gross production, and disease management practices compare to state averages.

2021 Industry Overview

The 23 respondents to the 2021 survey managed a total of 8,714 colonies, representing 11% of the estimated 80,000 colonies kept in New York[7]. The combined revenue from apiary products and services including liquid honey, cut comb honey, beeswax, queens, nucleus colonies, and paid pollination services generated an estimated production value of over $1.24 million in 2021 alone.

Honey Production

In 2021, beekeepers reported harvesting more than 353,000 pounds of liquid honey, generating roughly $616,000 in gross revenue. This overall production is on par with previous years, but the average honey yield per colony was the lowest reported to date at 54 pounds per hive (Table 1). Many participating beekeepers shared with us that their bees were producing honey in spring and early summer, but the fall flow was poor or nonexistent. These reports were consistent with our observations in the field. When we drove across the state to sample hives in September, we observed goldenrod and knotweed (major fall nectar-yielding plants) had finished blooming by mid-September and robbing activity was extreme in several apiaries. It was common for us to find colonies light on honey stores compared to what we would normally expect for autumn.

In contrast, spring arrived suddenly in 2021, with nectar flows and swarm reports starting about two weeks earlier than normal in central New York. But from July onward, New York State received above-average precipitation, with most areas obtaining between 4 and 16 additional inches of rain compared to the historical average (Figure 2). This wet period from late summer through fall may have contributed to the poor fall flow by impacting foraging activity and nectar availability.

Table 1. *Average honey production per colony over time.*

Year	Average honey yield (lb/colony)
2016	63.5
2017	64.5
2018	59.0
2019	78.6
2020	70.2
2021	54.0
Average (2016-2021)	63.8

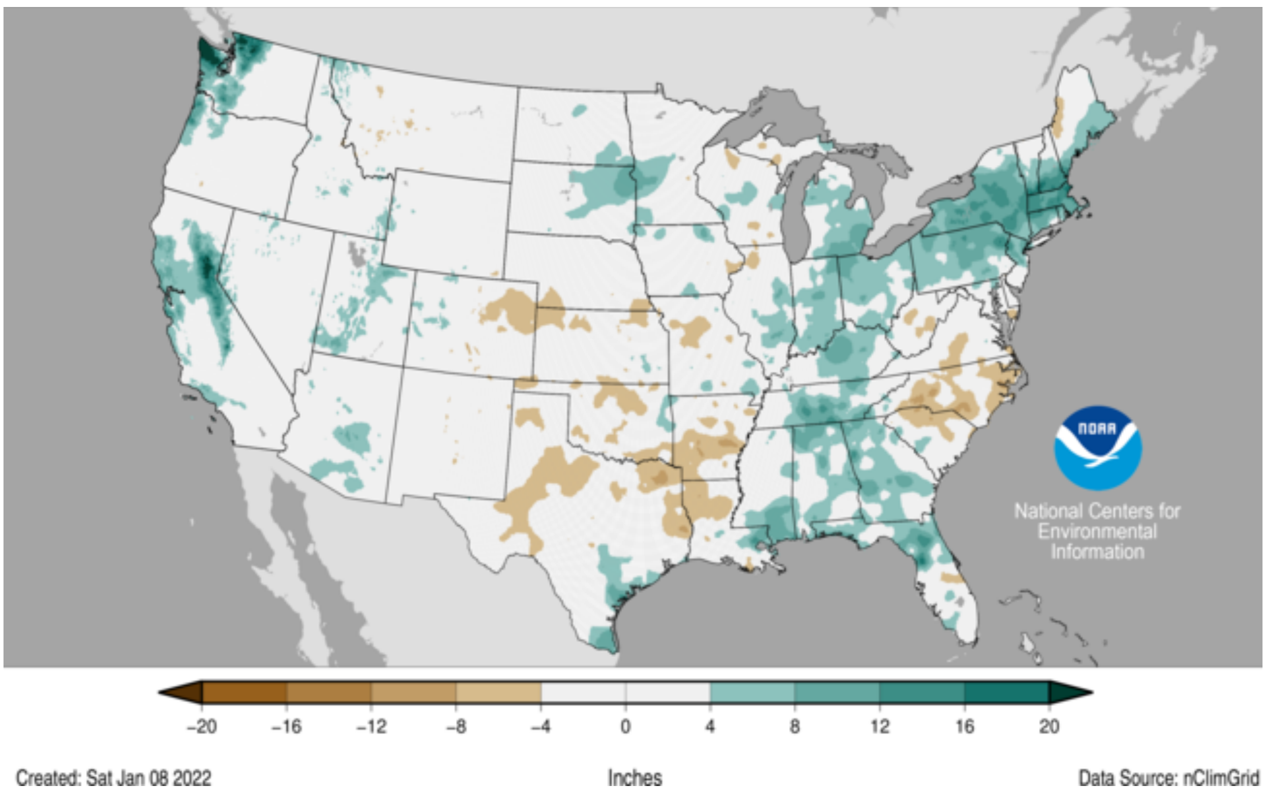

Figure 2. *Precipitation departures from average between July and December 2021*[8]*. These precipitation amounts are departures from the 20th century averages. In 2021, New York State received much more precipitation in late summer and autumn than usual. This excess rainfall coincides with a period of reduced honey production for beekeepers.*

Additional Hive Products

Liquid honey remains the primary revenue source for beekeepers enrolled in the Tech Team program, followed by pollination services, nucleus colonies, queens, beeswax, cut comb and propolis (Figure 3). Table 2 illustrates the amount of other apiary products harvested and the total revenue beekeepers received in 2021 from selling these products.

Table 2. *Hive products harvested from colonies managed by Tech Team beekeepers in 2021.*

Hive product	Total colonies	Total harvested (lb)	Average per colony (lb)	Total value
Liquid honey	6,519	352,599	54.0	$ 615,794.30
Beeswax	5,914	2,640	0.59	$ 19,337.80
Cut comb honey	68	908	23.9	$ 7,298.00
Propolis	48	26	0.54	$ 600.00

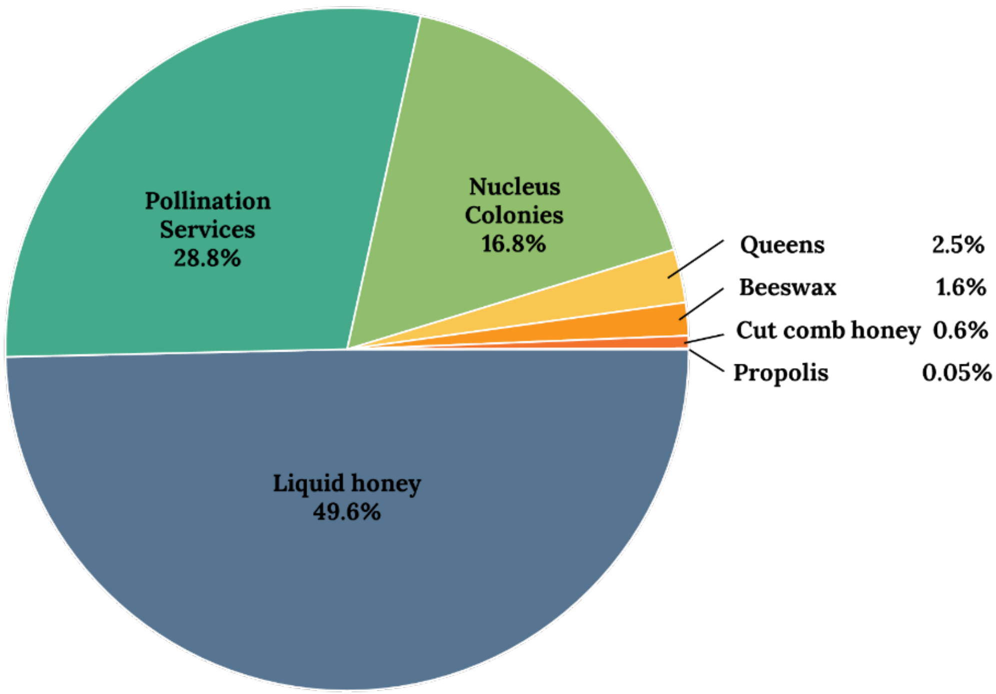

Figure 3. *The revenue of hive products, presented as a percentage, for all beekeepers combined.*

Nucleus Colonies & Queens

Eleven operations (48%) produced nucleus colonies in 2021. A total of 1,321 nucs sold for an average price of $170.00, generating an estimated total production value of $208,625. Five operations (22%) produced queen bees for sale in 2021. These beekeepers sold 804 queens at an average price of $34.00 each, totaling $31,290.00.

Pollination Services

In total, eight operations (35%) participated in commercial pollination in 2021. Seven provided their pollination details in the survey. These beekeepers sent 2,975 colonies to pollinate four different crops across New York and California. Table 3 shows the number of colonies sent to pollinate each crop, the state where pollination occurred, the average reported price per colony, and the estimated revenue. The total value of pollination services provided by Tech Team participants in 2021 was $357,470.00.

Table 3. *Reported pollination services by Tech Team beekeepers in 2021.*

Crop	State	Colonies in pollination	Average price per Colony	Estimated total revenue
Almond	CA	1684	$ 180.00	$ 249,120.00
Apple	NY	1255	$ 85.00	$ 105,250.00
Cherry	NY	350	$ 100.00	$ 1,600.00
Blueberry	NY	20	$ 75.00	$ 1,500.00

Colony Losses

High colony losses continue to be a major concern and management challenge for beekeepers in New York State. The Tech Team calculates winter, summer, and annual colony losses. Winter losses are colonies that die during the period of October 1, 2020 to April 1, 2021, while summer losses occur from April 1, 2021 to October 1, 2021. Annual losses cover the period between October 1, 2020 to October 1, 2021. For a given period, the loss rate is calculated as the total number of colonies that died in the period divided by the total number of colonies kept during that period, using the method established by the Bee Informed Partnership[9]. Figure 4 shows total winter, summer, and annual colony losses for the 23 beekeepers that completed the 2021 NYS Beekeeper Tech Team Management Survey compared to the cumulative colony losses represented by survey respondents since 2017.

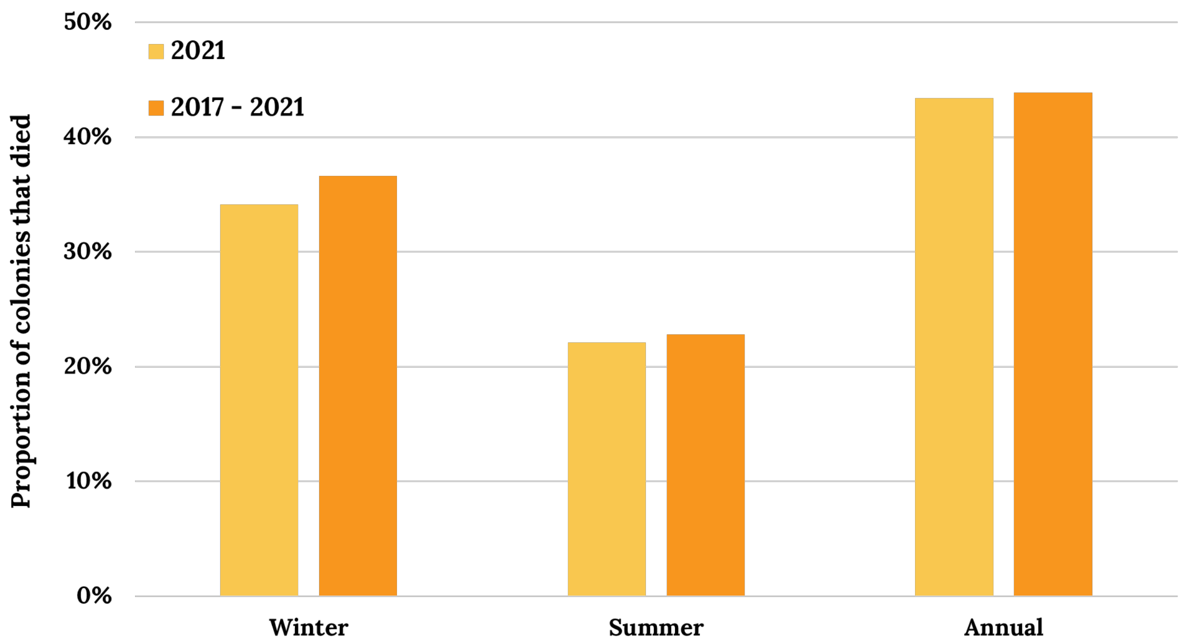

Figure 4. *Colony losses in the 2021 beekeeping season, compared to the historical average from 2017-2021.*

The total annual losses for the 2020/2021 season were 43.4% (5,235 out of 12,067 colonies). This loss is on par with what beekeepers have typically reported over the past five years. Total losses were 41.5% in 2019/2020, 38.5% in 2018/2019, 40.6% in 2017/2018, and 51.2% in 2016/2017 (loss data is incomplete for 2015/2016). Overall, colony losses continue to surpass what beekeepers consider acceptable (20%). Summer losses were 22.1% (1,936 out of 8,768) and winter losses were 34.1% (3,299 out of 9,672 colonies). The Tech Team asked beekeepers what they perceive to be the top causes of colony loss in their operation. Pressure from *Varroa* and its associated viruses was the most common reported cause of colony death in winter of 2021. Queen issues were the most common reported cause of colony death in summer of 2021.

Colony Health

Varroa Mites

Varroa mites (*Varroa destructor*) are the most damaging parasite of honey bees. They negatively impact honey bees in three ways:

1. They directly feed on a special tissue in the bee's body called the fat body, reducing their lifespan. The fat body consists of the honey bee's fat stores and other nutrients and hormones. This tissue also plays a big role in honey bee immunity. The presence of a large fat body in autumn enables winter bees to survive many months over winter. *Varroa* parasitism of these fat bodies contributes to a colony's demise, usually during the early part of winter.
2. *Varroa* mites weaken the honey bee immune system, making them less able to fight off viruses and diseases.
3. They transmit viruses to honey bees. The most common virus transmitted by *Varroa* is Deformed Wing Virus. Mites vector this virus, similar to how mosquitoes vector malaria and ticks vector Lyme disease. When mites reach high populations in colonies, levels of this virus are usually high as well. High levels of viruses are particularly deadly to honey bees, and the combination of mites and viruses is more deadly than either issue is on its own.

To manage *Varroa* effectively, we recommend colonies should be treated every time mite populations reach or exceed 2 mites per 100 bees in spring and early summer and 3 mites per 100 bees in late summer and fall. Beekeepers are encouraged to refer to our *Varroa* resources on our website (pollinator.cals.cornell.edu) and in their Tech Team Resource Binder to learn about monitoring, treatments, using an Integrated Pest Management approach.

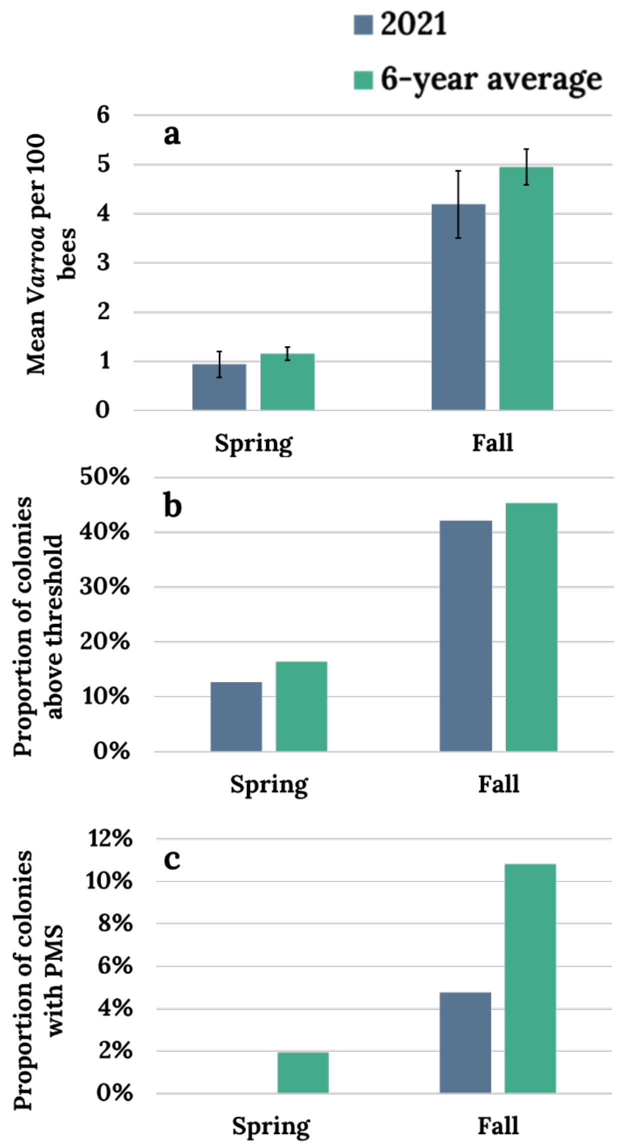

Figure 5. Mean Varroa levels in 2021 ± 95% confidence intervals (a), proportion of colonies that were above the recommended Varroa treatment threshold in 2021 (b), and proportion of colonies with Parasitic Mite Syndrome in 2021 (c), as compared to the 6-year average.

Each year, beekeepers have mite levels well-controlled in June, but struggle to keep them below the treatment threshold in September. The year 2021 continues to follow this pattern; the average *Varroa* level was 0.94 mites per 100 bees in June and 4.19 mites per 100 bees in September. 2021 was a typical year for *Varroa* mites; average mite levels were similar to our 6-year historical average in both spring and fall (Figure 5, top) and there was a similar proportion of colonies above the treatment threshold in both spring and fall (Figure 5, middle).

In addition to collecting average *Varroa* loads in colonies, it is useful to look at the percent of colonies that are at or above the treatment threshold to get an understanding of apiary-level health. For example, if by fall an apiary with ten colonies had nine with low *Varroa* levels and only one with high *Varroa* levels, overall that beekeeper has managed mites effectively in nearly all their colonies during the year. In spring of 2021, only 13% of colonies exceeded the treatment threshold, suggesting that beekeepers have good *Varroa* control in most of their colonies. But by September, *Varroa* was much less controlled, as nearly half (42%) of the colonies we sampled had mites above the recommended treatment threshold.

Varroa is a significant predictor of winter mortality

Over the past six years, Tech Team participants successfully tracked the winter survival of 440 colonies that were sampled in the previous autumn. High *Varroa* loads in fall is significantly associated with winter colony loss (P=0.00207; Figure 6). Our models suggest that the higher the colony's fall *Varroa* levels, the lower its chance of survivorship. The odds ratio is 0.915, which suggests that as the *Varroa* loads increase by 1 mite per 100 bees, the colony's odds of survival go down by 8.5%.

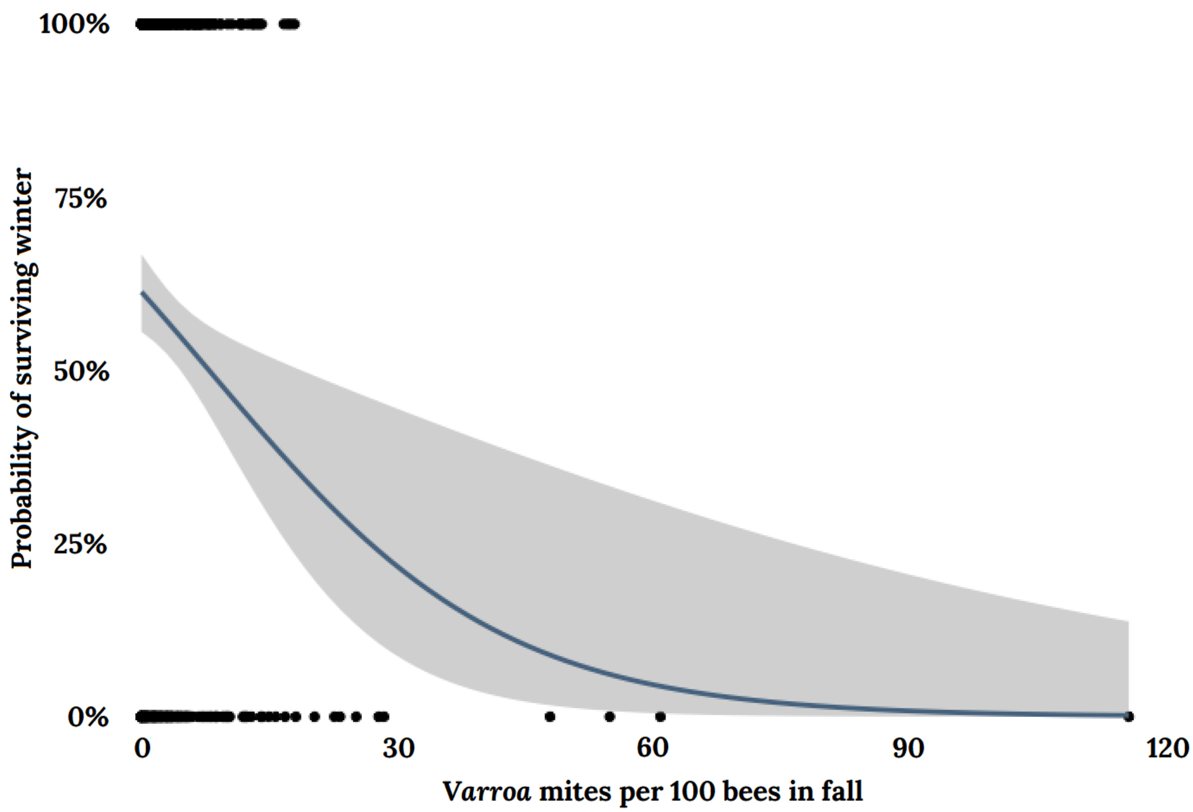

Figure 6. *High* Varroa *mite levels are associated with winter loss in New York State. Points are individual colonies. Points scattered around 0 on the y-axis represent colonies that did not survive winter, and points scattered around 1 on the y-axis represent colonies that did survive winter.*

Parasitic Mite Syndrome

Parasitic mite syndrome (PMS), or *Varroa* mite syndrome, is a condition in honey bee colonies characterized by advanced infestation of *Varroa* mites and infection of the viruses these mites transmit. Colonies with PMS exhibit the following signs:

- Spotty brood pattern
- Pupal cells with perforated or removed cappings. When a capping is removed and the hairless pupa is seen in the cell, it is referred to as "bald brood"
- Partially cannibalized brood, referred to as "chewed down brood"
- Brood lying flat or slightly twisted in their cell with a "melted" appearance. This brood is usually white in color and is not ropy.
- Visible *Varroa* mites on adult bees and/or in brood cells
- Adults with deformed wings

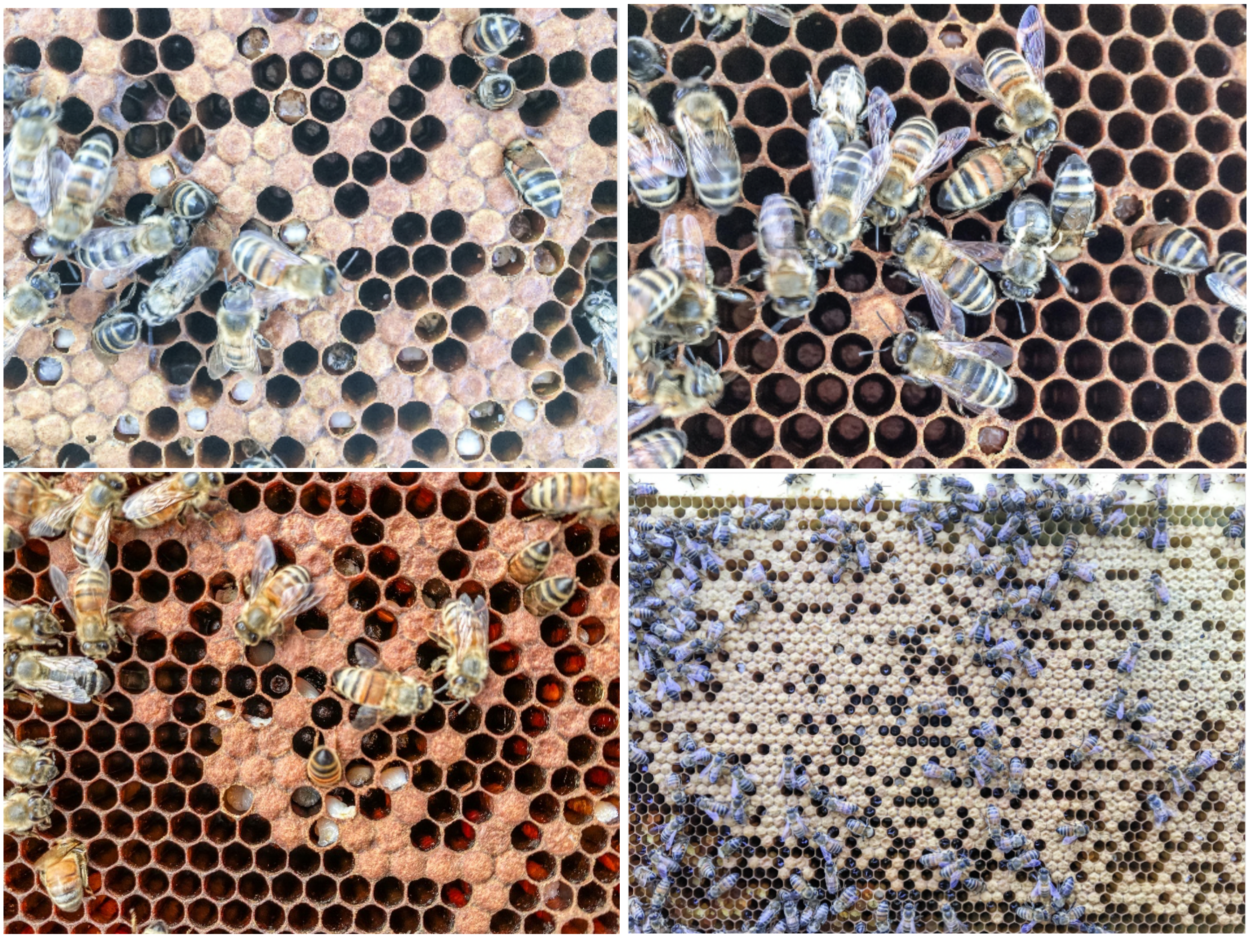

Figure 7. *Photos of colonies with Parasitic Mite Syndrome. Bald brood and chewed down brood (top left), bees with deformed wings (top right), melted brood (bottom left), and widespread* Varroa *damage (bottom right).*

A colony is considered to have PMS when these signs are widespread. See Figure 7 for photo examples. There is a significant relationship between colonies with PMS and *Varroa* levels (Figure 8). Colonies with PMS have significantly more *Varroa* (10.8 mites per 100 bees, on average) than colonies without PMS (2.6 mites per 100 bees, on average). Because *Varroa* mites are small and tend to feed on the underside of the bee, infestations cannot be diagnosed through visual inspection alone. However, the above signs of *Varroa* are useful indicators that there could be a severe mite problem, and so we recommend beekeepers look for these signs every time they inspect their brood nests. If any signs are observed, they should monitor the colony immediately to determine if the mite levels warrant a treatment. Oftentimes once PMS is visible, it is too late for the colony to recover, even if it receives a treatment. However, a treatment is useful to prevent spreading mites to the rest of the colonies.

Colonies generally require months of *Varroa* pressure without effective intervention for PMS to manifest, and so beekeepers typically see a greater percentage of colonies exhibiting signs of PMS later in the season, usually from August to November. From 2016 to 2021, prevalence of PMS has been consistently lower in spring (2% of colonies) than in fall (11% of colonies). Fortunately, PMS was uncommon in 2021, with no colonies showing signs of PMS in spring, and just 5% of colonies showing signs of PMS in fall (Figure 5c). Incidence was highest in colonies managed by commercial beekeepers at 7.4%, followed by sideliners at 5.4% and hobbyists at 2.9%.

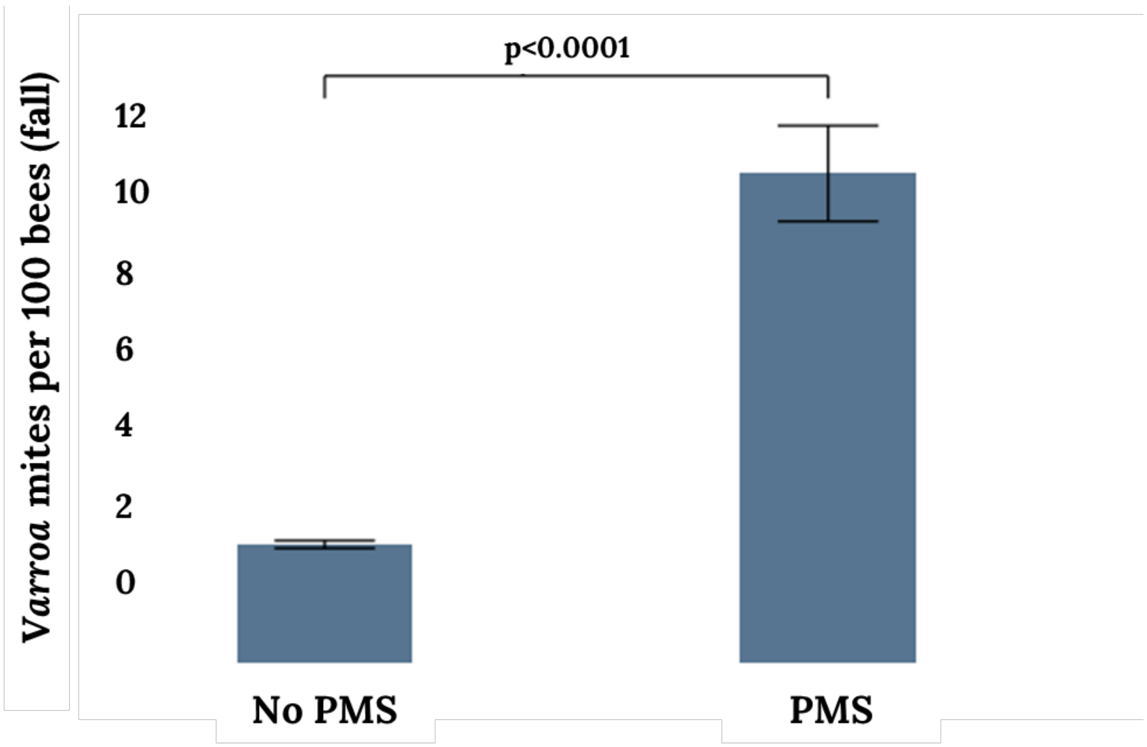

Figure 8. *The average* Varroa *loads in colonies with signs of parasitic mite syndrome compared to healthy colonies.*

Measuring mite populations alone is useful for providing a snapshot of the immediate situation in each colony. By measuring the incidence of PMS, we are instead able to look at the long-term impacts of a beekeeper's *Varroa* management. Because PMS reflects the chronic impacts of *Varroa* and its associated viruses, a lower incidence of PMS in an operation typically indicates colonies maintained low mite levels consistently throughout the year. Sudden high *Varroa* loads in autumn in the absence of PMS may indicate a re-introduction of mites (e.g., robbing, drifting, etc.) rather than their gradual accumulation throughout the year.

Beekeeper's practices can impact their colonies' *Varroa* loads

Because high *Varroa* mites are related to winter loss in New York, it is important for beekeepers to track their mite levels by monitoring and managing them, when needed, with treatments. Beekeepers in New York State vary in their approach to monitoring and treating. Among those enrolled in the Tech Team program, monitoring and treating for *Varroa* ranged in frequency from zero times a year to twelve times a year. Frequent monitoring allows beekeepers to 1) understand *Varroa* population dynamics throughout the year, 2) know when to apply a

treatment, and 3) evaluate the efficacy of a treatment. Without regular monitoring, mite populations may grow to very high levels without the beekeeper knowing, or ineffective treatments may go unrealized.

The Tech Team investigated the relationship between fall *Varroa* levels and number of monitoring events beekeepers conducted during the year for 2016 through 2021. More frequent monitoring is significantly associated with lower fall *Varroa* loads. As the number of monitoring events increase, fall *Varroa* levels significantly decrease (P=0.00191; Figure 9). Colonies that are monitored at least 9 times a year are predicted to have *Varroa* levels below the 3% treatment threshold in fall. This result is strong evidence that the more aware beekeepers are of their colonies' mite levels, the more successful they are in managing them. We recommend monitoring monthly from March – November. More frequent monitoring during August, September, and October can help identify sudden late season increases in mites.

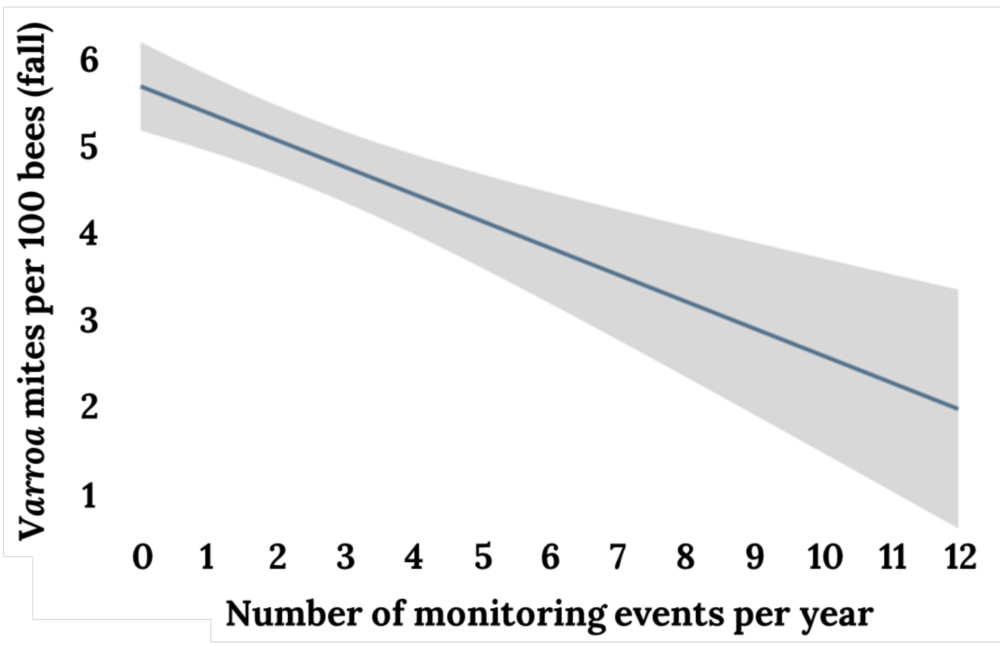

Figure 9. *The relationship between monitoring frequency and fall* Varroa *levels.*

Similarly, and as might be expected, as the number of chemical treatments increases during the year, fall *Varroa* mite levels significantly decrease (P=0.00137, Figure 10). Beekeepers differ in the number of mite treatments they apply during the year, the type of treatments they use, and in the treatment application timing. Hobbyists apply only 1.5 treatments per year, on average. Sideliners apply 2.3, and commercial beekeepers apply the most at 3.0. Among the beekeepers we worked with, the range of treatments varied from no treatments during a year to twelve. The Tech Team recommends treatments should be applied as soon as mites reach or exceed the treatment threshold, preventing a scenario where the population builds up to damaging levels before intervention occurs. In New York, the treatment threshold from March to July is 2 mites per 100 bees, and from August to November it is 3 mites per 100 bees. While there are benefits to frequent treatments, we do not recommend beekeepers over treat their colonies. Excessive treatments may negatively impact colony health and can be expensive. Instead, beekeepers should only provide the number of treatments that are needed by their colonies. The best way to determine how often colonies need treatments is to apply them every time mite populations reach or exceed the treatment threshold.

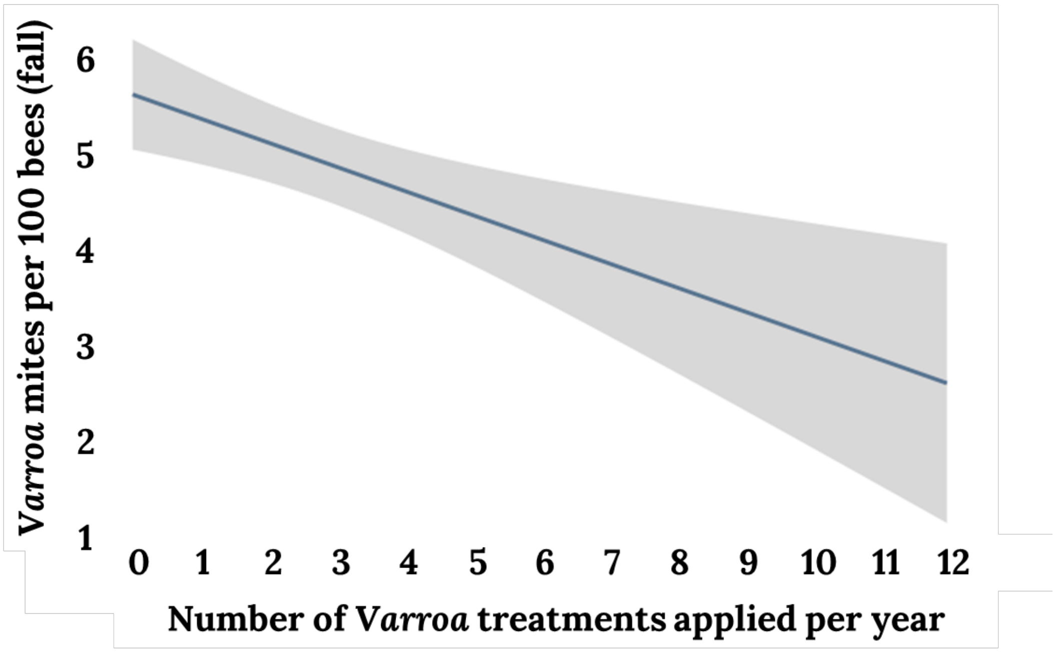

Figure 10. *The relationship between treatment frequency and fall* Varroa *levels.*

Wintering location impacts spring *Varroa* levels

Where colonies spend winter influences their *Varroa* levels the following spring. Some beekeepers leave their colonies in New York State over winter, while others (usually commercial beekeepers) bring their colonies to winter in a southern state. The southern states that beekeepers in the Tech Team program winter their colonies include North Carolina, South Carolina, Georgia, Florida, and Maryland. Colonies managed in the southern states have a disadvantage; they start spring with significantly higher *Varroa* levels compared to colonies that winter in New York State (P=0.02837, Figure 11). Colonies that winter in the south have an average June mite count of 1.5 mites/100 bees, already close to the 2 mites/100 bees treatment threshold, while colonies in New York have an average June mite count of 0.8. This is likely because colonies experience only a short brood break when wintering in a warmer climate, facilitating a longer period for *Varroa* reproduction. Alternately, colonies spending winter in cold New York State experience an extended brood break, which offers an interruption in *Varroa* reproduction. Beekeepers who winter their colonies in southern states should be vigilant about early spring monitoring and may need to prepare to apply earlier or more frequent mite treatments than beekeepers who keep their colonies in New York over winter.

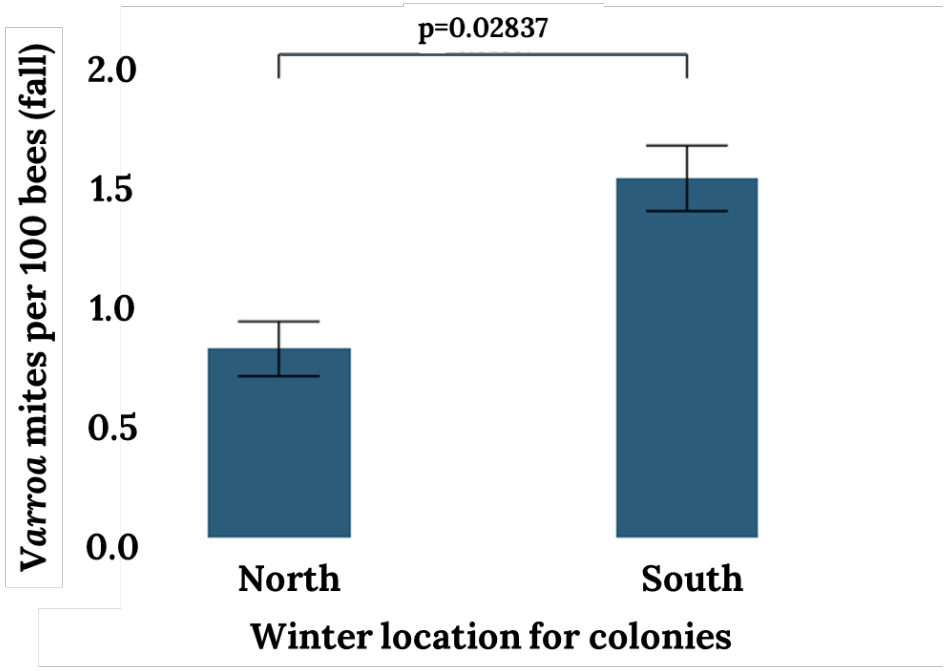

Figure 11. *Average spring* Varroa *levels based on the location the colony spent winter.*

The financial motivation for beekeeping influences winter survivorship

The Tech Team works with beekeepers of all operation scales, from those who manage a few colonies to those who manage thousands. For some participants, beekeeping is their primary source of income. For others, it provides supplemental income or is a hobby. In their surveys, beekeepers provided information as to whether they kept colonies as their primary source of income. We refer to beekeepers who keep bees as their primary source of income as "full-time beekeepers" and those who do not has "part-time beekeepers". We investigated whether operations that were managed either full time or part time differed in colony health metrics related to *Varroa* and survivorship. *Varroa* loads and PMS incidence did not significantly differ between full-time and part-time beekeepers (P>0.05 in both cases). However, winter losses were significantly lower in colonies managed by full time beekeepers compared to part-time beekeepers (P=0.0013; Figure 12). While all beekeepers struggle with *Varroa* in autumn, beekeepers who manage colonies as their primary source of income must be better preparing their colonies for winter in other ways. Perhaps they are addressing or preventing queen issues, providing adequate food, or managing other diseases or issues more successfully than part-time beekeepers. We suspect beekeepers who manage colonies full time have more financial incentive to adequately prepare colonies for winter, as their livelihood depends on their beekeeping success, and so this may translate to more vigilant practices. This association could also be related to their beekeeping experience. Full-time beekeepers have an average of 27 years of experience compared to 17 years for part-time beekeepers.

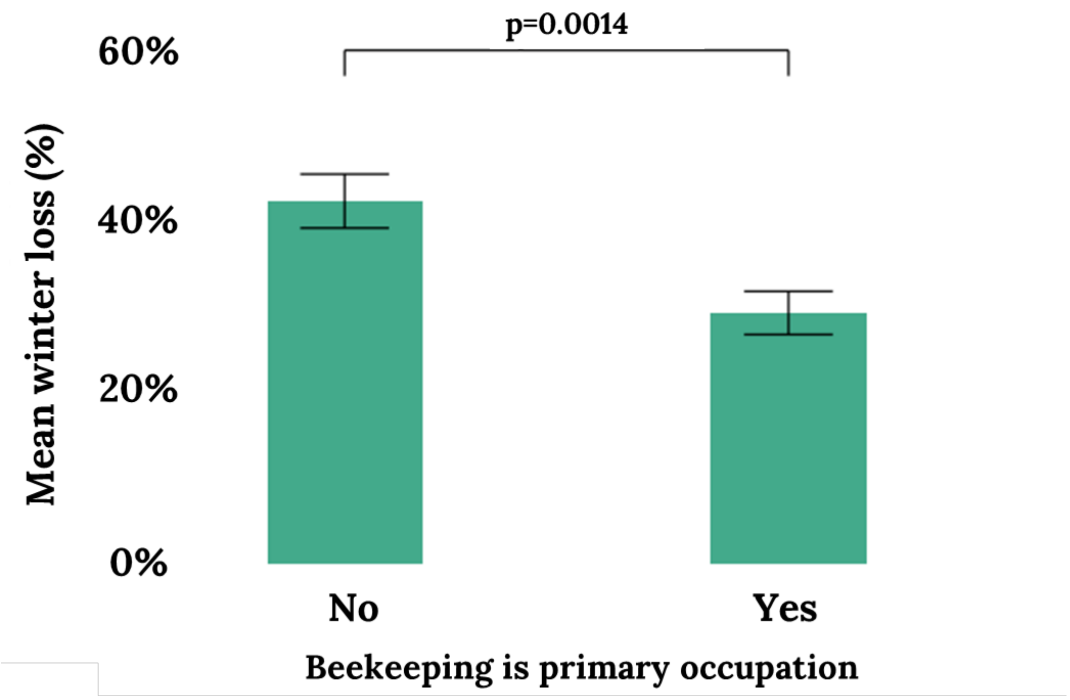

Figure 12. The association between the financial motivation for beekeeping and winter survivorship.

Apiary density is not associated with fall *Varroa* levels

New York beekeepers vary in how many colonies they keep in one apiary. In 2020 and 2021, we collected data on apiary density by counting the number of bee hives present in a subset of the apiaries we sampled (21 apiaries). The lowest density apiary we sampled was 3 hives in a yard, while the most dense apiary contained 68 hives. We predicted apiary density would be associated with fall *Varroa* levels. Other studies have shown apiary density relates to *Varroa*, as drifting and robbing among hives can occur at a higher rate when many colonies are in close proximity[10,11]. However, we did not find a relationship between apiary density and fall *Varroa* levels (P=0.26, Figure 13) in New York apiaries. High *Varroa* colonies, low *Varroa* colonies, and colonies with PMS were found in apiaries of all densities.

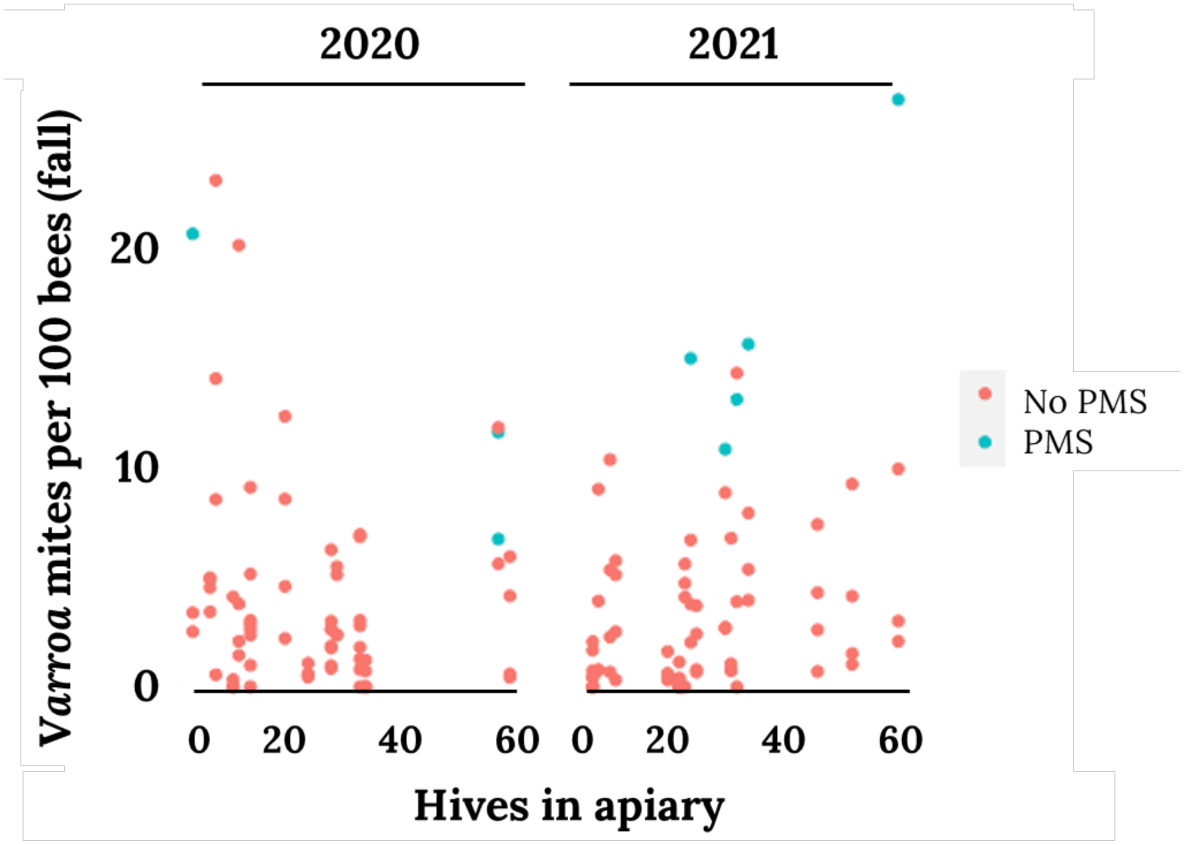

Figure 13. No relationship exists between fall *Varroa* loads and apiary density in the years 2020 and 2021.

Beekeepers' colony health and management changes during their time in the Tech Team Program

Beekeepers enrolled in the Tech Team improve their management practices after receiving our training, recommendations, and services (i.e., "feedback"). More beekeepers monitor, the frequency of monitoring increases, more beekeepers treat, the frequency of treatments increase, more beekeepers incorporate non-chemical controls, and more use thresholds to determine when to apply a treatment instead of basing their treatment applications on a schedule or when they hear others are applying treatments (Table 4). However, beekeepers continue to perceive *Varroa* as a medium to high threat in their operations and they continue to feel like they have only slightly above-average control of *Varroa*. Most of these improvements, however, are simply trends. The only improvement that is significant is that beekeepers treat more frequently during the year after receiving our feedback (P=0.0004, Figure 14).

Table 4. *Comparing* Varroa *management practices of beekeepers who have received feedback from the Tech Team to those who have not yet received feedback. Averages presented as mean ± 95% confidence interval.* Varroa *monitoring includes alcohol washes and sugar shakes. Examples of non-chemical controls include screened bottom boards, drone comb frames, brood breaks, etc.). (n=186)*

Received Feedback (Y/N)	Percent of beekeepers who monitored for *Varroa*	Average times beekeepers monitored for *Varroa* per year	Percent of beekeepers using chemical *Varroa* controls	Average number of *Varroa* treatments applied per year	Percent of beekeepers treating based on *Varroa* thresholds	Percent of beekeepers using non-chemical *Varroa* controls
No	45%	1.3 ± 0.4	68%	1.6 ± 0.4	26%	44%
Yes	72%	3.0 ± 0.6	86%	2.8 ± 0.4	32%	56%

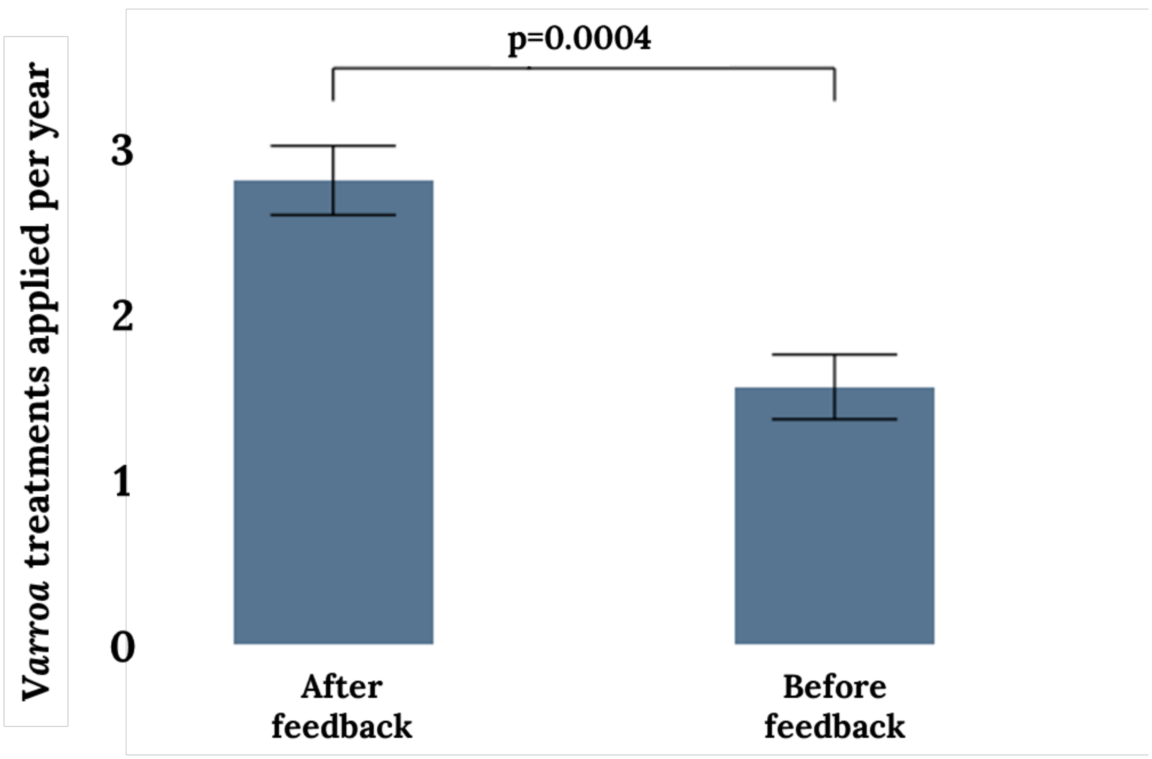

Figure 14. *Beekeepers' average annual treatment frequency before and after receiving feedback from the NYS Beekeeper Team.*

In the Tech Team program, beekeepers learn about the threat of *Varroa* mites in their own operation, are trained to recognize the signs of *Varroa* damage in their colonies, and receive free *Varroa* monitoring kits and training in how to use them. They also receive recommendations for chemical and non-chemical treatment options that are appropriate for their operation size, goals, and their own personal philosophies. Despite beekeepers being informed in Best Management Practices for *Varroa* control, not all beekeepers adopt these practices during their time in the program. If beekeepers know what to do to keep their bees healthy and have the knowledge and skills to implement Best Management Practices, then there must be other barriers that prevent them from adopting these practices. To discover these barriers, we surveyed beekeepers and asked them to identify what they felt were the biggest barriers to effective *Varroa* management. The vast majority (81%) of beekeepers experienced at least one barrier to *Varroa* control. The most common reason for an inability to adequately monitor and treat colonies was "not enough time and/or labor", with 71% including this barrier. Some examples of statements related to these barriers that beekeepers have shared with us include the following:

- In the past they used to be able to independently manage as many colonies as they do now, but now with the number of issues honey bees face it takes much more time to manage the same number of hives. To manage their colonies effectively, they would need to downsize their operation, but along with that may come reductions in revenues.
- It is difficult to find and retain affordable labor for their beekeeping operation.
- Those with small to mid-sized commercial operations feel they would benefit from hiring labor, but their profits make it difficult to do so in an economical way.

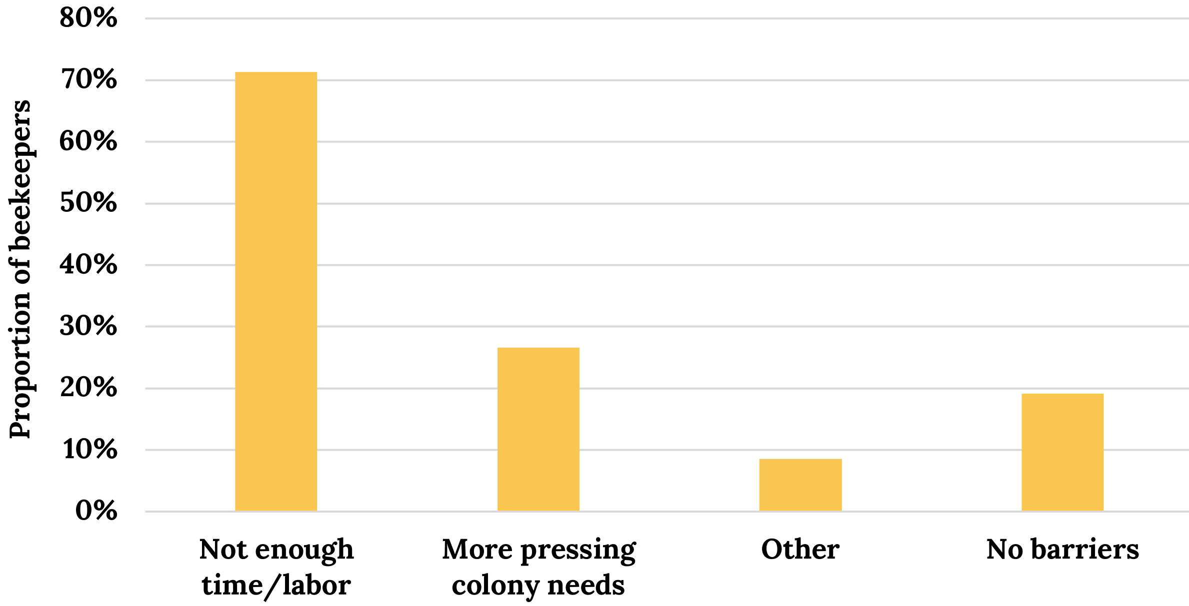

Figure 15. *Proportion of Tech Team beekeepers facing barriers to effective* Varroa *management.*

Figure 16 shows that after beekeepers receive feedback from the Tech Team, their colonies have lower *Varroa* mites (a), fewer colonies are above the treatment threshold (b), and fewer colonies have PMS (c) compared to those before they receive Tech Team feedback. However, none of these relationships is statistically significant (all models had $P>0.05$). There were also no statistical differences between colony losses for beekeepers before and after receiving Tech Team feedback.

There are many registered *Varroa* treatments in the United States, and the conditions under which each treatment can be used varies. As a result, beekeepers tend to choose different products to control mites at different times throughout the year. Table 5 outlines the most common treatments beekeepers in the Tech Team program were using throughout the 2021 year. The predominant treatment choices throughout the year are in line with what the Tech Team recommends. Amitraz is the most common choice in late winter (if colonies winter down south) or in early spring. It is a good option because it is a long treatment (42 days), can be used when brood is present, and can be used in cool temperatures. When applied in early spring, sufficient time passes before supers are added with the first nectar flow (a 2-week waiting period is required between removing the treatment and adding supers). Once temperatures become warm enough in late spring, formic acid becomes the predominant choice as brood is present and honey supers are added. Some beekeepers are also using amitraz or oxalic acid during this time. At this time of year amitraz can only be used on colonies that are not going to receive honey supers for 56 days (the 42-day treatment plus a 14-day waiting period), so it is only appropriate to use on weak colonies or colonies that are not used for honey production, such as queen breeder colonies. At this time of year, oxalic acid can be used on colonies that are broodless (e.g., packages or recently swarmed colonies). Neither amitraz nor oxalic acid are currently approved for use on colonies that are being used for honey collection.

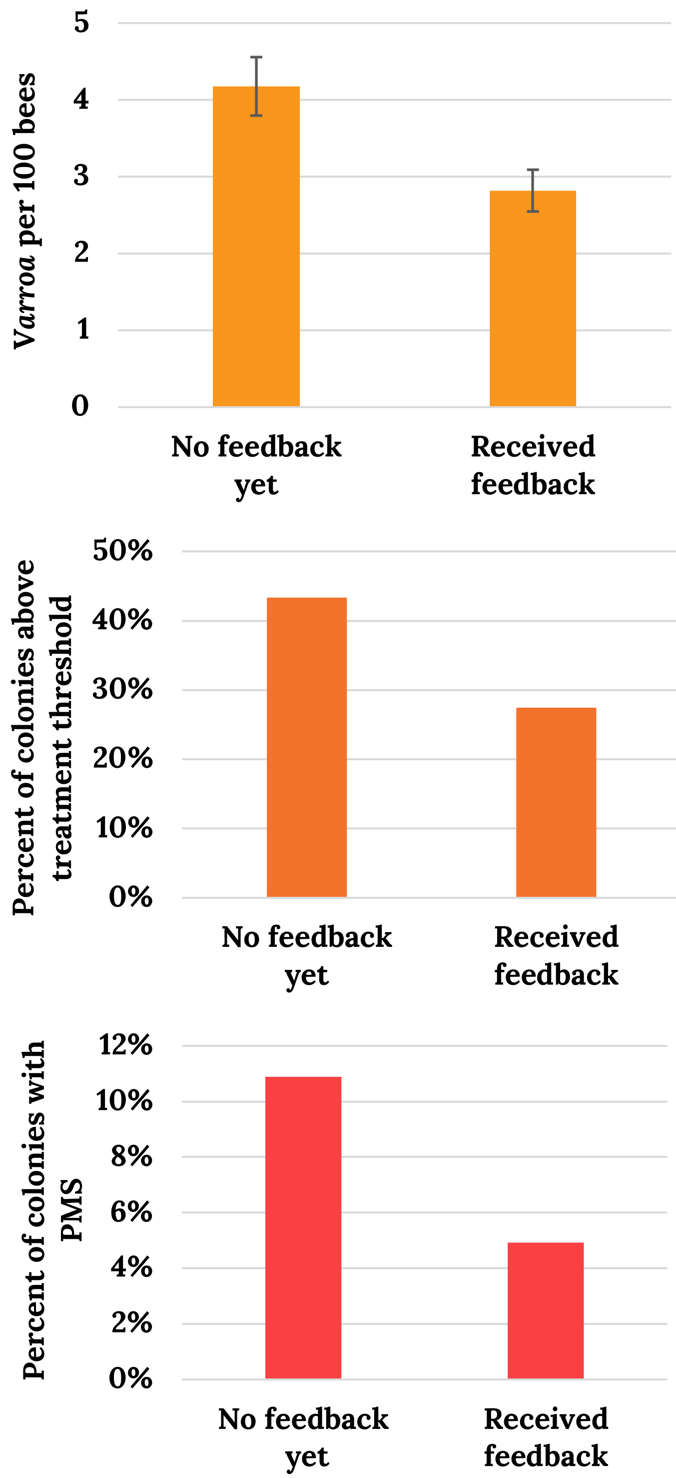

Figure 16. *Comparison of colony health before and after receiving Tech Team feedback. The panels show the mean colony Varroa mites per 100 bees for spring and fall combined (top), the percent of in colonies above the treatment threshold (middle), and the percent of colonies that have PMS (bottom).*

Summer and fall are popular treatment times for beekeepers, which corresponds to times when *Varroa* levels are often exceeding treatment thresholds. 61% of beekeepers are applying treatments in summer and 57% are applying them in fall. In the summer months, formic acid is the top choice for beekeepers. Formic can be used when honey supers are present, and the months of June through August are key times for honey production in New York. Beekeepers applying multiple formic treatments during the year should take note that one month needs to pass between consecutive applications. In fall, amitraz once again becomes the predominant treatment option once honey supers are removed. In November, when colonies finally become broodless, nearly all (93%) treatment applications are oxalic acid. Oxalic acid is most effective when colonies have little to no brood in them, so mid to late November is a great time to apply it.

Table 5. *Treatments applied by beekeepers throughout the 2021 year.*

Season	Percent of beekeepers applying at least one treatment	Primary treatment	Percent of total applications
Late Winter (Jan-Feb)	9%	Amitraz	67%
Early Spring (Mar-Apr)	43%	Amitraz	64%
Late Spring (May-June)	35%	Formic acid	25%
		Amitraz*	25%
		Oxalic acid*	25%
Summer (July-Aug)	61%	Formic Acid	47%
Fall (Sept-Oct)	57%	Amitraz	60%
Winter (Nov-Dec)	26%	Oxalic acid	86%

*Apivar® cannot be used if the beekeeper plans to add honey supers in the following 56 days for the purpose of collecting the honey for human consumption. Oxalic acid can only be applied to packages or broodless (recently swarmed) colonies in spring. With the current approved treatment applications, oxalic acid is not effective when there is brood present in the colony. If there is brood in and/or honey supers on the colony in late spring, we recommend using a more effective treatment, like a formic-based treatment.

Best Management Practices: *Varroa*

Monitor your colonies every month from March to November in New York State or year-round if colonies winter in the south. Monitor at least 8 colonies in every apiary to get an indication of mite levels across your operation. Pay close attention to mite levels in August through October as mites can quickly reach dangerous levels during these months.

Inspect your colonies' brood nests monthly. Keep an eye out for signs of mite damage and Parasitic Mite Syndrome.

Every time mite levels reach or exceed treatment thresholds, apply a registered mite treatment according to the product label. Using treatment thresholds is the best way to time treatments appropriately and to avoid over- or under-treating. If treating based on thresholds is not feasible for your operation size, plan a treatment schedule to ensure colonies receive treatments regularly throughout the year. Continue monitoring throughout the year to receive feedback on how your schedule is working and prepare to alter your strategy if needed. Rotate treatments so that you are not relying on the same product repeatedly. Always monitor after treatments end to evaluate their efficacy.

In addition to monitoring and treating, adopt Integrated Pest Management practices that include cultural methods and *Varroa* resistant genetic stock. Beekeepers are encouraged to refer to the *Varroa* resources on Cornell's website (pollinator.cals.cornell.edu) for more information about managing mites with an IPM approach.

Nosema

Nosema disease is caused by two different fungal gut pathogens: *Nosema apis* and *Nosema ceranae*. Virtually all *Nosema* infections in New York State honey bees are caused by *Nosema ceranae*[12]. *Nosema ceranae* infections are not often obvious to beekeepers, typically manifesting as slow population build-up and reduced honey production. Dysentery is not associated with *Nosema ceranae*.

Nosema does not appear to be a major issue for colonies in New York State. *Nosema* disease follows a clear seasonal pattern; infections are consistently higher in spring and lower in fall every year (Figure 17). In 2021, *Nosema* levels were lower than average in spring (averaging 0.56 million spores per bee) and slightly higher than average in fall (0.42 million spores per bee; Figure 12). But in both seasons, *Nosema* loads were well below the level where the parasites are considered to negatively impact colony health. Although some colonies do continue to be infected in fall, the Tech Team has found the majority of them recover or resolve the infection by spring without any treatments[13]. In 2021, only 34% of colonies that had any *Nosema* spores in spring continued to have spores in fall. Of the infections that were considered high in spring (≥1 million spores per bee), only 21% of those colonies continued to have infection loads at this level in fall. Neither spring (P=0.56) nor fall (P>0.0934) *Nosema* levels are associated with winter loss in New York State. However, colonies that are symptomatic may be less productive, producing less honey, less brood, and weaker adult populations.

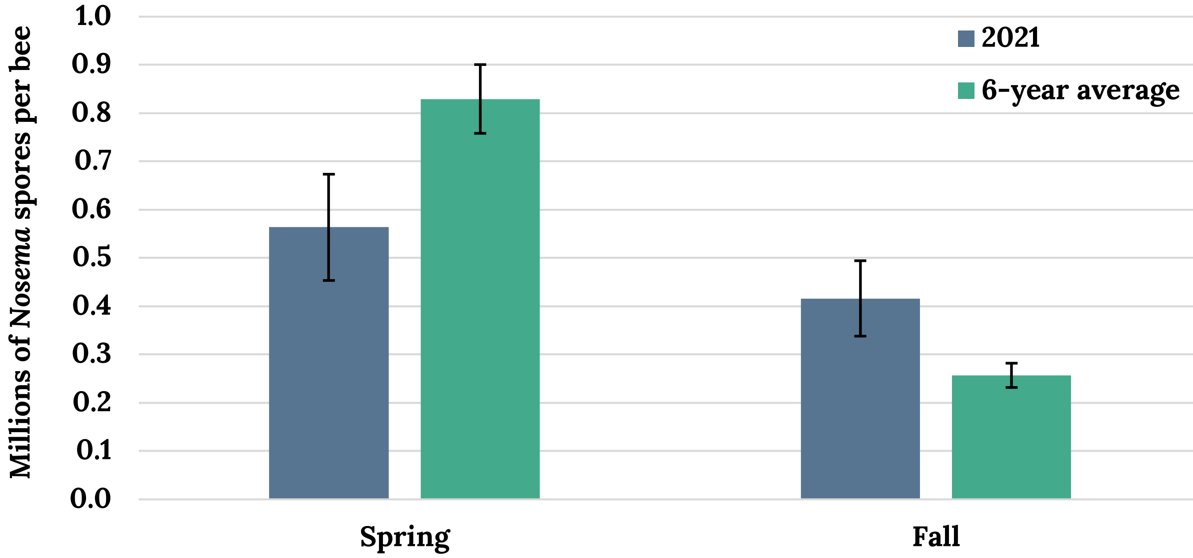

Figure 17. Mean Nosema *levels ± 95% confidence intervals in 2021 as compared to the 6-year historical average.*

Even though most *Nosema* infections resolve on their own without intervention, it is important for beekeepers to be aware of their levels. If beekeepers observe signs of *Nosema* (e.g., weak population, slow population build-up, reduced honey and brood production), they should monitor. Colonies suffering from *Nosema* may benefit from supplemental feeding in spring and should be isolated from healthy colonies. Six months later the colony can be monitored again to see if the infection resolved. If the infected colonies die over winter, it is recommended beekeepers disinfect their equipment before introducing new bees.

Best Management Practices: *Nosema*

Nosema spores are often found in colonies in New York, but it is uncommon for levels to exceed 1 million spores per bee. We recommend avoiding using fumagillin to treat *Nosema* in spring, as most colonies resolve their infections on their own by fall. Fumagillin's efficacy is unreliable for the predominant species of *Nosema* in New York State. If beekeepers choose to use fumagillin, consider applying a treatment only if fall levels are still above 1 million spores per bee. If colonies infected with *Nosema* die over winter, disinfect combs before reusing them. Beekeepers are encouraged to refer to the *Nosema* resources on Cornell's website (pollinator.cals.cornell.edu) for more information about managing this parasite and disinfecting equipment.

Brood Disease & Insect Pests

In addition to *Nosema* and *Varroa*, honey bee colonies in New York are susceptible to insect pests, and brood is susceptible to a variety of viral, fungal, and bacterial infections. Spring 2021 was another healthy season for bees, with 62.3% of colonies showing no signs of disease compared to the 6-year historical average of 54.7%. Colonies in fall 2021 were less healthy than what we typically observed, as 22.2% of colonies showed no signs of disease compared to the 6-year historical average of 32.8%. We still observed a variety of issues in the remainder of colonies, illustrated in Figure 18. The most common issues observed during inspections were signs of *Varroa* infestation, followed by small hive beetles, and European foulbrood.

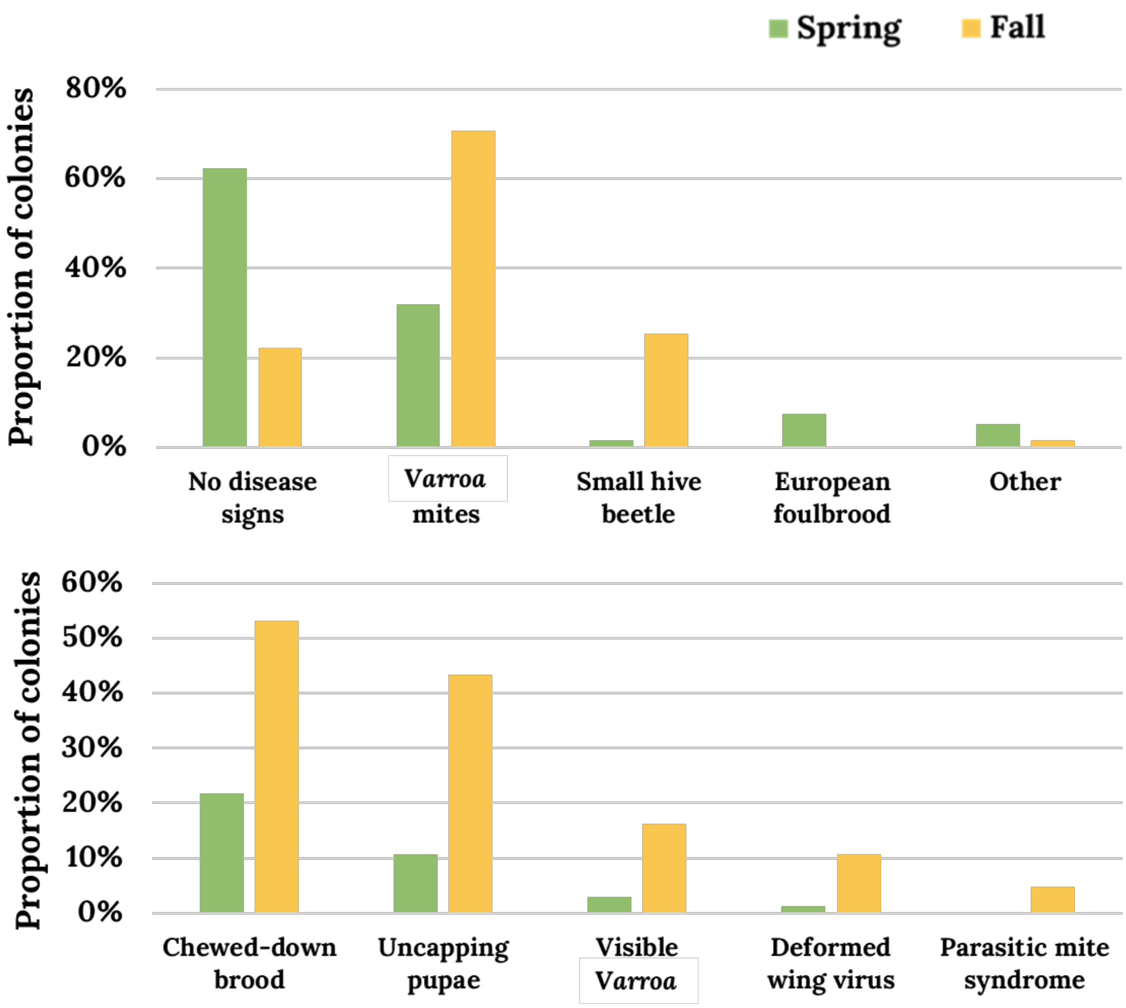

Figure 18. *Prevalence of pests and diseases present in colonies sampled in spring and fall 2021 (a), and a further breakdown of* Varroa *mites and damage by individual signs of disease. *Other issues include chalkbrood, entombed/capped pollen, wax moths, sacbrood virus, idiopathic brood disease syndrome.*

Signs of *Varroa*

Colonies with *Varroa* mites present multiple signs of Varroosis depending on the scale and stage of the infestation. We generally attribute uncapping pupae (perforated cappings and bald brood) and chewed-down brood (partially cannibalized brood) to *Varroa* mites, as some honey bees are able to detect mites reproducing in brood cells and respond by uncapping, cannibalizing, and/or removing infested brood. These behaviors are observed more often in fall, when *Varroa* levels tend to be higher. This was the case in 2021 with just 28% of colonies showing signs of uncapping and/or cannibalizing in spring, while 69% of colonies showed these signs in fall.

As *Varroa* infestations progress, we start to see more visible mites on adult bees, on comb, and in brood; more bees with deformed wings; and colonies on the verge of collapsing from PMS in the final stages of the infestation. These signs of *Varroa* infestation are also more common in fall when *Varroa* populations are generally higher. In spring 2021, merely 3% of colonies had visible *Varroa*, 1% had bees with signs of Deformed Wing Virus, and no colonies had PMS. In fall 2021, 16% of colonies had visible *Varroa*, 11% had bees with signs of Deformed Wing Virus, and 5% of colonies had PMS.

Small Hive Beetle

Small hive beetles are pests in the bee hive. They lay eggs inside the hive and their larvae consume pollen, pollen substitutes, honey, nectar, and brood. In heavy infestations, small hive beetles ferment honey because they defecate in it. It is rare for New York colonies to experience beetle populations strong enough to spoil honey in live colonies, but this can occur in southern states. For this reason, the Tech Team does not recommend using chemical treatments to control small hive beetles in NYS. In cases where beekeepers observe more than a dozen small hive beetles in a colony, the Tech Team recommends using mechanical traps (e.g., Swiffer® pads, Brawny Dine-A-Max® pads, or oil traps) to control them. Small hive beetle populations decrease during cold winters in New York State, so many colonies enter spring with low beetle populations. As the season progresses and beetles reproduce, and as colonies are brought up from southern states where beetle populations tend to be higher, small hive beetle population increase and peak in the fall. In 2021 we observed this typical pattern; only 2% of colonies had small hive beetles in spring; however 25% of colonies did in fall.

European Foulbrood

European foulbrood (EFB) is caused by a bacterium that infects brood. Infections most often occur in spring and can range from mild to severe. Mild cases often clear up on their own as colonies gain access to good nutrition in summer or when beekeepers provide supplemental feed. Severe infections can be resolved with the antibiotic oxytetracycline. In 2021, European Foulbrood was slightly more common than average with 7.4% of colonies infected in spring 2021 (Figure 19). By fall, none of the colonies we inspected had the disease. European foulbrood can be difficult to differentiate from other brood diseases. The Tech Team recommends testing all suspicious brood with a Vita® test kit or by sending a sample to the USDA Beltsville Bee Lab for a free analysis.

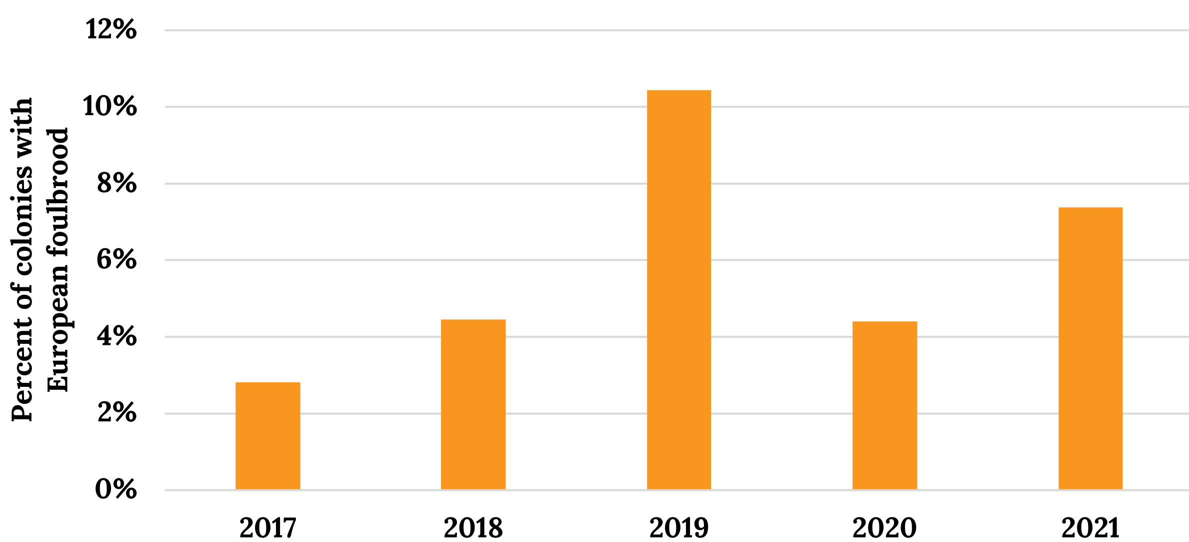

Figure 19. *Percent of colonies with EFB in spring from 2017 – 2021.*

American Foulbrood

American foulbrood (AFB) is the most contagious and destructive bacterial disease that honey bees can contract. Although zero cases of AFB were diagnosed by the Tech Team in 2021, NYS Department of Agriculture and Markets identified 42 colonies with AFB[14]. These colonies were managed by ten different beekeeping operations located in twelve counties. Of these cases, three were confirmed to be resistant to oxytetracycline. Because prophylactic use of antibiotics is now discouraged, and because antibiotics can only be obtained through a veterinary prescription, it is critical that all beekeepers stay vigilant about inspecting and testing their colonies. Although antibiotics kill active AFB bacteria, they do not kill AFB spores and so they do not prevent the spread of the disease. Beekeepers must also stay up to date on NYS regulations for antibiotic use. We recommend beekeepers conduct three careful AFB inspections of every colony each year. They must familiarize themselves with proper inspection techniques and learn how to recognize early signs of infection.

Other Diseases and Issues

Other pests and diseases were uncommon in 2021. Only 5% of colonies in spring showed other signs of diseases. These 5% were comprised of either chalkbrood, entombed or capped pollen, sacbrood virus, or idiopathic brood disease syndrome. In fall, only 2% of colonies had issues. Three colonies in fall had wax moths, and one had sacbrood virus. Chalkbrood is a fungal pathogen of brood often associated with cool temperatures and moisture. Entombed pollen is stored, rust-colored pollen sealed with a thick layer of wax. To date, only rust-colored pollen entombed in this way has been confirmed to contain certain fungicides[15], however this relationship has not been confirmed for all colors of pollen capped in this manner. Sacbrood virus is a brood disease spread by infected nurse bees feeding larvae. Sacbrood virus can cause colonies to dwindle by stifling brood rearing and exhausting colony resources. Idiopathic brood disease syndrome is a condition similar visually to European foulbrood (EFB) but likely caused by one or more unidentified pathogens. Idiopathic brood disease syndrome is distinct from European foulbrood and American foulbrood (AFB), as it tests negative for the species of bacteria which cause EFB, *Melissococcus plutonius* and AFB, *Paenibacillus larvae*. Wax moths are a secondary pest of honey bees but pose the additional threat of destroying equipment in storage.

Best Management Practices: Pests and Diseases

At least three times a year, inspect brood nests **of all colonies** in the operation for disease. Any suspected bacterial diseases should be tested immediately with a Vita® test kit or by sending a sample to the USDA Beltsville Bee Lab for a free analysis.

It is the law to report all AFB infections to New York's State Apiculturist Joan Mahoney at joan.mahoney@agriculture.ny.gov Beekeepers are encouraged to refer to the resources on Cornell's website (pollinator.cals.cornell.edu) for more information about bacterial diseases. Those who are not confident in diagnosing diseases can contact the Tech Team for assistance.

European foulbrood is found most often in spring, usually coinciding with the start of the first honey flow. Mild infections can usually be overcome without the use of antibiotics. We recommend boosting the colony population by adding frames containing healthy capped brood and nurse bees. Requeening your colony with hygienic stock and supplementing with sugar syrup and pollen patties may also help a colony recover from mild EFB. In moderate to severe cases of EFB, discard any frames that contain a lot of infected brood. Boost the colony population by adding frames containing healthy capped brood and nurse bees and treat the colony with terramycin. Reach out to a veterinarian to acquire a prescription for this medication.

Small hive beetles are common in fall, especially in apiaries with sandy soil. The Tech Team does not recommend using chemical treatments to manage small hive beetles in New York. If over a dozen are observed in a colony, install mechanical beetle traps (oil traps between frames or Swiffer pads® or Brawny Dine-A-Max® towels on top bars).

Queen status is an important indicator for winter preparedness

The Tech Team collects a variety of health and performance data from colonies during inspections. Some of these metrics include colony population, brood pattern score, and queen status. We investigated whether any of these metrics in fall were associated with winter loss for New York beekeepers. Queen status in autumn is significantly associated with winter loss ($P<0.0001$, Figure 20). Colonies with a laying queen in September have a higher chance of surviving winter compared to colonies that are queenless, have drone layers, or have virgin queens. This is to be expected, as colonies must have a fertile queen resume egg-laying in January to start building the colony population by spring. Without one, the population dwindles and eventually dies.

We also determined that queen status in autumn is significantly associated with other colony metrics. Colonies that are queenright in autumn have higher brood pattern scores ($P<0.0001$) and higher populations ($P<0.0001$). Queenright colonies had a healthy brood pattern averaging 3.5 out of 5, while colonies that were not queenright had a poor brood pattern averaging 1 out of 5. Similarly, queenright colonies had a stronger population entering winter, averaging 15.2 frames of bees, while non-queenright colonies had a weaker population averaging 11 frames of bees. Neither brood pattern nor population on their own was associated with winter mortality. The presence of a queen is critical for a healthy hive. Beekeepers should verify that colonies are queenright throughout the entire season and again in autumn to ensure they are ready to enter winter. Many areas of New York State receive a fall flow, and this can contribute to late summer and early autumn swarming. If a colony that swarms does not successfully establish a new queen, the beekeeper should provide one.

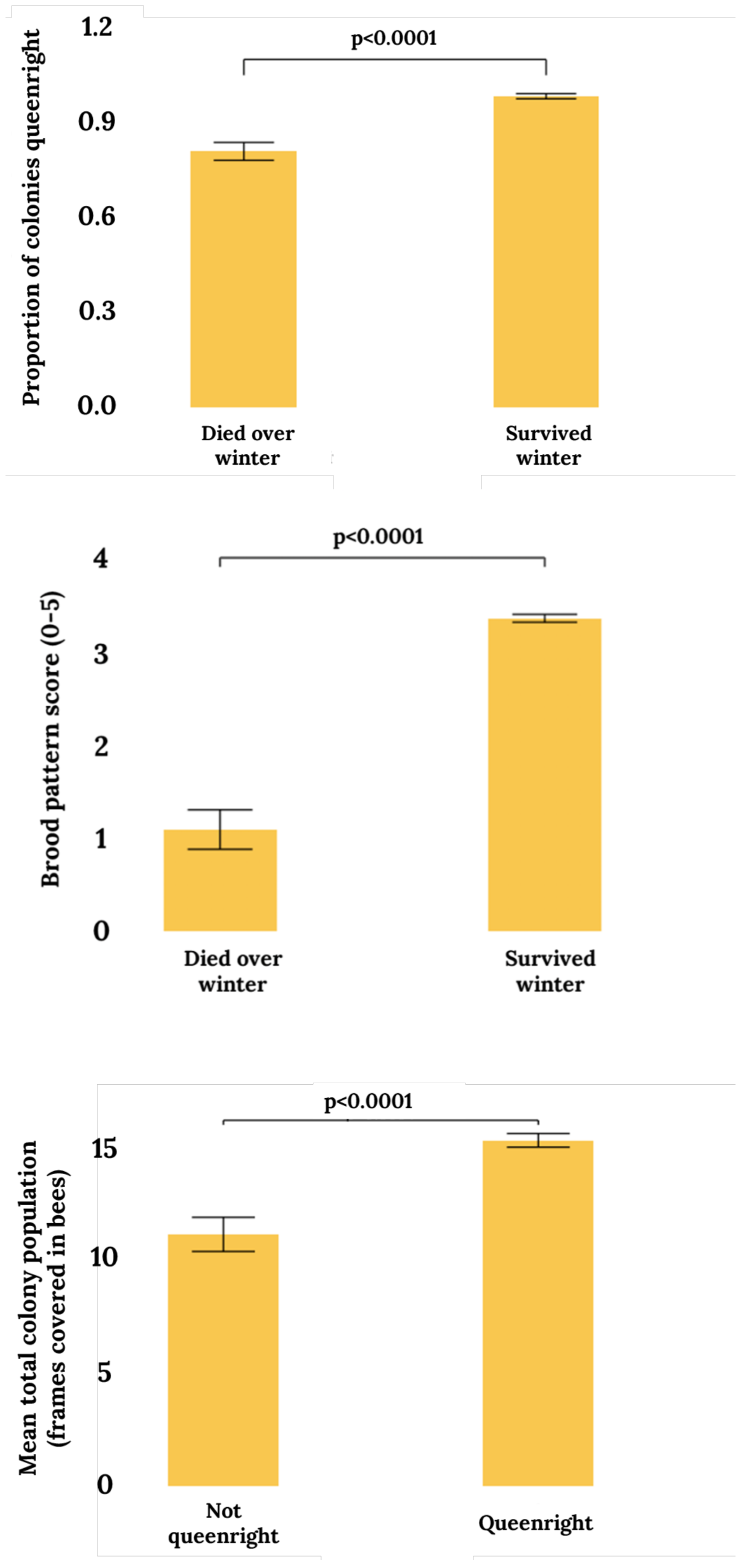

Figure 20. *The relationship between fall queen status and winter survivorship (top), brood pattern score (middle), and colony population in frames of bees (bottom).*

Best Management Practices: Preparing healthy colonies for winter
In August, assess the brood patterns of all colonies by examining at least four frames of brood per hive. Colonies with scores between 0-2 should be managed appropriately for disease or queen issues. See Appendix 4 for brood pattern score examples.

In September after the fall swarm season has ended, verify all colonies have mated queens and strong populations. We recommend colonies have at least 18 frames of bees if they are entering winter in two deeps and at least 9 frames of bees if they are entering winter in one deep. Any colonies that are weaker or queenless (but otherwise healthy) in September should be merged with other healthy, queenright colonies.

In addition to these recommendations for fall, colonies must have adequate food stores, hive ventilation, and a wind-protected and sunny apiary to maximize winter survival.

Pesticides

A pesticide is any substance used to destroy a harmful pest. This includes substances designed to kill weeds (herbicides), fungi (fungicides), mites (miticides, including *Varroa* miticides), or insects (insecticides). Pesticides are a valuable tool used widely in New York State by farmers, orchardists, landscapers, horticulturists, and homeowners. Honey bees are routinely exposed to pesticides when they are foraging in landscapes where pesticides are applied. Contaminated pollen and nectar are brought back into the hive, and beekeepers also apply miticides directly inside hives. For over a decade, the scientific community has documented pesticides in a variety of hive products, including beeswax, pollen, nectar, and even honey bees[16]. The NYS Beekeeper Tech Team surveys colonies every year to track pesticide exposure and risk, and to determine what beekeeping practices influence pesticide levels in hives.

Commonly Detected Pesticides

Since 2016, the Tech Team has recognized that agrochemicals are ubiquitous in NYS colonies, with 98.8% of hives (673 out of 681) containing pesticides. Of the 92 different pesticides screened for in 2021, the Tech Team found 63 were detected in bee hives. The remaining 29 pesticides were not present in any colonies. We detected pesticide residues in wax from every colony sampled in 2021. The number of unique pesticides present in a single colony ranged from 7 to 35 pesticides, with an average of 17.8. Sixty two out of 72 colonies (86%) contained at least one miticide, coumaphos and/or 2,4-DMPF (a breakdown product of amitraz), and all but one colony contained the synergist piperonyl butoxide. Wax from commercial colonies had the most pesticides per colony (21.9) compared to wax from hobbyist (16.3) and sideliner (11.65) colonies.

Pesticide loads ranged from 14.2 to 4,964.7 ppb per colony, averaging 1923.5 ppb per colony. Miticides comprised the majority of pesticide loads with an average of 1827.22 ppb per colony (Figure 21). This is not surprising because they are applied directly to colonies by beekeepers. The second-most common class of pesticides were fungicides, averaging 57.66 ppb per colony, followed by synergists at 13.50 ppb, insecticides at 12.80 ppb, and herbicides at 12.32 ppb. Because miticides were by far the most prevalent pesticides detected in wax, we will explore them further in this report. You can read brief descriptions of the other commonly detected pesticides in Appendix 2.

Most of the pesticide load in beeswax is 2,4-DMPF. Amitraz is widely used by beekeepers in NYS as a miticide and 83% of colonies in 2021 contained it. Of the 23 beekeepers who responded to our survey, 15 applied amitraz to their colonies at least one time during the year. Although amitraz is wax soluble, it is unstable and breaks down quickly. Amitraz only remains in beeswax for one day before degrading into three metabolites that persist for longer periods of time; 2,4-DMPF is the most persistent of its metabolites[17]. The amitraz loads in 2021 varied dramatically from 0 ppb to >4000 ppb, with an estimated average of 1810 ppb. 31 colonies (43%) contained 2,4-DMPF loads that exceeded the level of quantification (4000 ppb). For wax samples taken in September 2021, the more recently colonies were treated with amitraz, the higher their average 2,4-DMPF load (Figure 22). Amitraz is practically nontoxic to honey bees, but it can be toxic to humans at high doses. The Environmental Protection Agency has established tolerance levels for amitraz in beeswax and they consider it to be safe for human use when total residues (including its metabolites) are below 9000 ppb[18]. It is unknown if any of the colonies that exceeded the level of quantification also exceeded the EPA's tolerance level because our upper limit of quantification is 4000 ppb. Beekeepers should always follow the label laws when applying Apivar® (the miticide product that contains amitraz). Treatment time should not exceed 56 days and, to protect consumer health, beekeepers must wait a minimum of two weeks before placing supers. Fortunately, 2,4-DMPF degrades relatively quickly in beeswax. In a recent study that exposed colonies to 10 times the labeled dose of amitraz (20 strips of Apivar® per hive), residues were no longer found in honey or beeswax at detectable levels after 42 days[19].

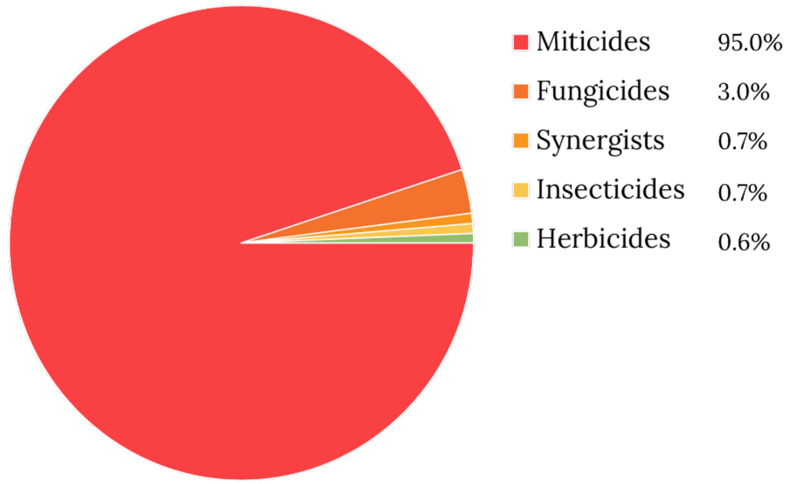

Figure 21. Percent of total pesticide load (ppb) by class in 2021.

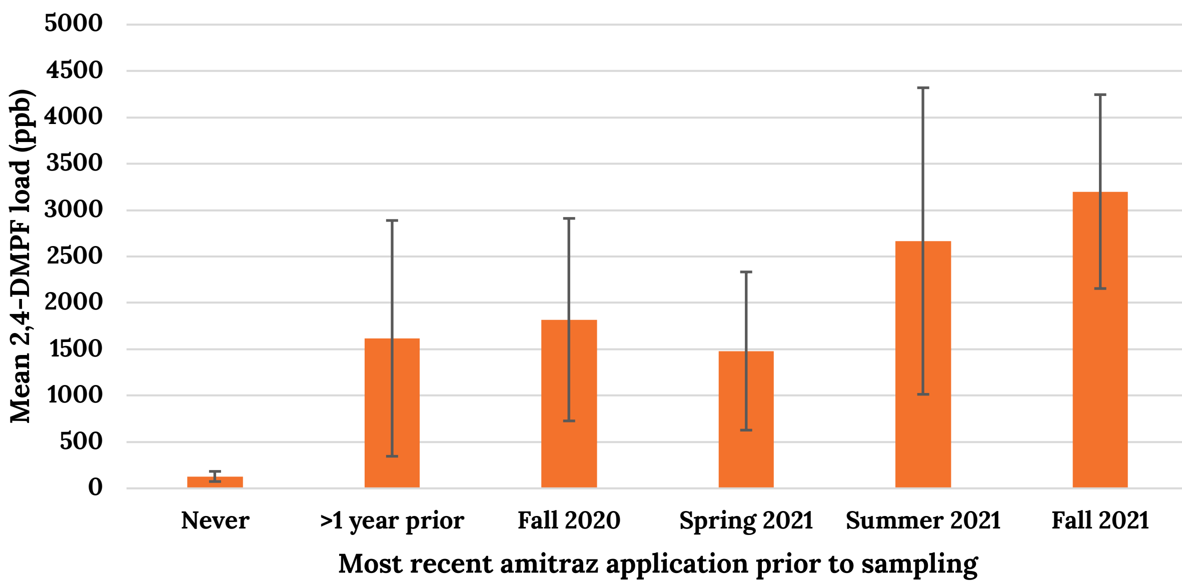

Figure 22. Average 2,4-DMPF loads in colonies based on when they were treated with amitraz.

While amitraz remains an effective *Varroa* control product for many operations, beekeepers should be careful with its use because some operations in the Unites States have mites that have already developed resistance. In 2019, The USDA sampled 12 commercial apiaries in in New York, Louisiana, and South Dakota to test for amitraz resistance[20]. While they found the product was still very effective in most apiaries, they discovered some pockets of amitraz resistance; in two of the twelve apiaries, amitraz was ineffective at controlling *Varroa*. It is not identified in the paper whether either of these apiaries were in New York.

Coumaphos is the other miticide that we screen for in beeswax. Coumaphos (product brand name CheckMite+®) is an old *Varroa* miticide that was registered for use in 1999 in response to mites' development of resistance to tau-fluvalinate (product brand name Apistan®). The product was used widely by beekeepers for several years until mites also developed widespread resistance to this treatment. Virtually no beekeepers participating in the Tech Team program applied coumaphos to their hives in the past 10 years; however, it remains one of the most common pesticides detected in beeswax. In 2021, we detected coumaphos in 43.1% of colonies in 2021, averaging 46.52 ppb per colony. Coumaphos is classified as "moderately toxic" to honey bees. At high levels (usually much higher than what was detected in NYS beeswax), it can also negatively impact queen and drone fertility and survival[21-23].

Coumaphos accumulates readily in beeswax and is very slow to break down. It gets introduced into combs either from beekeepers applying CheckMite+® many years ago and continuing to use those old frames. We expect to continue finding low levels of coumaphos in New York comb for many years to come. Beekeepers who have never used CheckMite+® but whose colonies have coumaphos may have introduced it by installing contaminated foundation[24] or old combs they acquired from nucs.

Pesticide Risk

Despite how common pesticides are in NYS hives, pesticide risk as estimated with wax hazard quotients is low in general. In 2021, most colonies (69 out of 72) had WHQs below the European Food Safety Authority's 3% chronic level of concern. Of the three colonies that exceeded the European Food Safety Authority's 3% level of concern, two were commercial colonies. None of these colonies exceeded the 20% acute level of concern. Because this metric only measures the risk of mortality, it is still possible that colonies can experience sublethal or synergistic impacts from the pesticides in comb. Overall, commercial colonies had the highest average pesticide risk (1.4%) followed by hobbyists (0.9%) and sideliners (0.4%; Figure 23). In 2020 we discovered pollination services are contributing to the higher pesticide risk we see in commercial colonies[25]

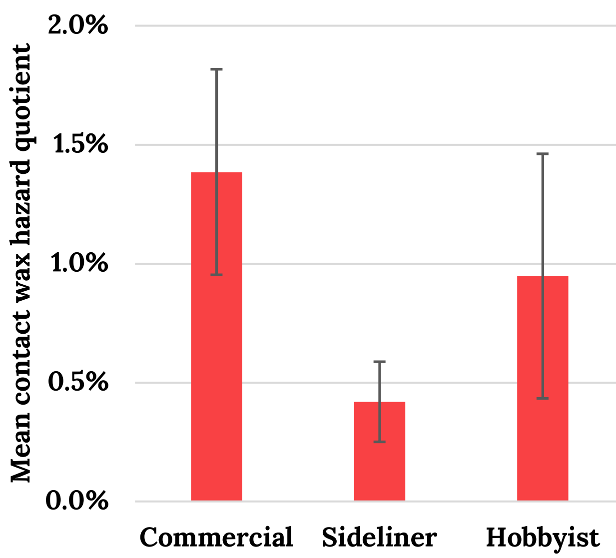

Figure 23. *Mean pesticide risk ± SE across operation scales in fall 2021.*

Not surprisingly, the pesticides that contribute most of the risk to honey bees is coming from insecticides that are applied to control insect pests, as well as miticides applied directly to the hive. The top five pesticides that contributed most to contact risk were, in descending order, 2,4-DMPF (18% of total contact risk, found in 83% of colonies), the insecticide spinetoram (17% of total contact risk, found in 23% of colonies), the neonicotinoid insecticide imidacloprid (14% of contact risk, found in 25% of colonies), the neonicotinoid insecticide thiamethoxam (14% of contact risk, found in 38.9% of colonies), the insecticide and fipronil (12% of contact risk, found in 11% of colonies). While 2,4-DMPF is categorized as practically non-toxic to honey bees with its LD_{50} of 11 ug/bee, the amount that was detected in beeswax amplifies the risk. The top contributors to oral risk were imidacloprid (39% of total oral risk), fipronil (18%), thiamethoxam (17%), the insecticide chlorantraniliprole (13%, found in 29% of colonies), and 2,4-DMPF (5%). These insecticides contributing to oral and contact risk are commonly used in New York agriculture, and honey bees typically come into contact with them when they are foraging in crops or crop margins.

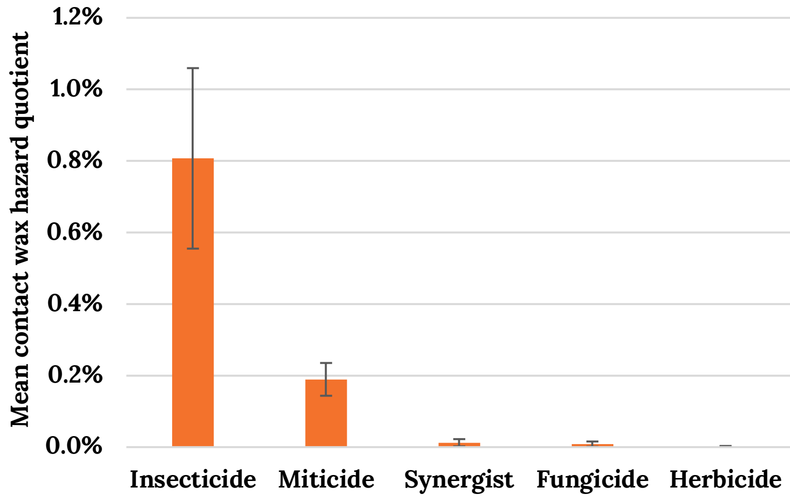

Figure 24. *Mean pesticide risk per colony ±SE by pesticide class.*

Best Management Practices: Pesticides

Many pesticides accumulate in comb over time. Aim to keep all your combs younger than six years old to reduce pesticide load. Accomplish this by replacing two of the oldest frames in each hive body every year. To help you keep track of combs, write on the top bars the year you install the foundation frame.

Rotate chemical treatments throughout the year so that they are not relying on the same product continuously. Repeatedly using the same treatment can promote the development of mite resistance. Only apply miticides when needed to avoid unnecessary exposure and monitor after treatments to verify that they were effective.

We do not recommend using coumaphos (Check Mite +) to control V*arroa* mites or small hive beetles in New York State.

Maintain regular, open communication with growers to learn what pesticides they use and how they protect pollinators on their farm. Visit Cornell's website (pollinator.cals.cornell.edu) to download our pesticide risk guides to learn the different products registered for use in New York agriculture and how they impact honey bee health. Use a written pollination contract with every grower to keep records of your agreements and to help facilitate these conversations. A sample pollination contract can also be found on the website.

Impacts of COVID-19

In 2021, beekeepers continued to experience challenges from COVID-19. The Tech Team's management survey asked beekeepers about how COVID-19 impacted their beekeeping operations. Fewer beekeepers reported obstacles to their usual operation in 2021 (40%) compared to 2020 (53%). Most beekeepers had negative impacts from COVID-19, but one beekeeper reported an increase in online honey sales resulting from the pandemic. The negative issues reported by beekeepers ranged from losses of revenue and marketing, travel restrictions, and obtaining equipment and labor. The issues reported by beekeepers in 2021 were the same as the issues reported in 2020:

- Significant negative impacts on honey sales resulting from cancelled farmers markets, events, and festivals. Reduced tourism at remaining in-person events further contributed to lost sales.
- Neglect to colonies as beekeepers faced difficulties traveling across state lines to inspect and manage apiaries that are spread out across the Northeast. Some beekeepers wintering colonies in southern states faced delays bringing colonies back to New York in spring because they had to complete quarantine orders.
- An increased workload in the apiary as it was difficult to source sufficient seasonal labor.
- Difficulty obtaining supplies and equipment.
- Reduced communication with other beekeepers as club meetings were cancelled.
- Dead queens upon arrival resulting from delayed postal services.

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Appendix 1. Pesticides Detected in Beeswax in 2021

Pesticides are ordered based on prevalence in colonies. Pesticides are highly toxic if the LD_{50} is <2 µg/bee (highlighted orange), moderately toxic if LD_{50} is between 2 and 11 µg/bee (highlighted yellow), and practically nontoxic if the LD_{50} is >11 µg/bee (white).

Rank	Pesticide	Class	% of colonies	contact LD_{50} (ug/bee)	Mean ppb
1	Piperonyl butoxide	Synergist	98.6%	11	13.498
2	Metolachlor	Herbicide	95.8%	110	1.316
3	Fenpyroximate	Insecticide	94.4%	11	1.886
4	Difenoconazole	Fungicide	93.1%	100	5.541
5	2,4-DMPF	Miticide	83.3%	100	1810.139
6	Atrazine	Herbicide	75.0%	97	0.580
7	Diuron	Herbicide	73.6%	145	6.634
8	Pyraclostrobin	Fungicide	68.1%	100	7.168
9	Azoxystrobin	Fungicide	66.7%	200	6.160
9	Trifloxystrobin	Fungicide	66.7%	200	1.520
11	Propiconazole	Fungicide	55.6%	50	9.523
12	Tebuthiuron	Herbicide	54.2%	100	0.696
13	Cyprodinil	Fungicide	52.8%	100	0.556
14	Carbaryl	Insecticide	50.0%	0.232	0.760
14	Fluopyram	Fungicide	50.0%	100	0.134
16	Coumaphos	Miticide	43.1%	20.3	17.084
17	Methoxyfenozide	Insecticide	40.3%	100	3.000
18	Metalaxyl	Fungicide	38.9%	141	0.104
18	Thiamethoxam	Insecticide	38.9%	0.024	0.351
20	4-Hydroxy-chlorothalonil	Fungicide	36.1%	181.29	8.329
20	Penthiopyrad	Fungicide	36.1%	312	1.031
22	Tebuconazole	Fungicide	34.7%	200	5.281
23	Prometon	Herbicide	33.3%	36	3.055
24	Chlorantraniliprole	Insecticide	29.2%	0.706	1.523
25	Spirotetramat	Insecticide	27.8%	242	0.954
26	Imidacloprid	Insecticide	25.0%	0.044	0.648
27	Fenbuconazole	Fungicide	23.6%	292	1.600
27	Spinetoram	Insecticide	23.6%	0.024	0.417
29	Pyrimethanil	Fungicide	19.4%	100	0.104
30	Tetramethrin	Insecticide	18.1%	0.155	0.635
31	Fluoxastrobin	Fungicide	16.7%	200	0.032
32	Acephate	Insecticide	15.3%	1.2	0.306
32	Hexaflumuron	Insecticide	15.3%	58.3	0.306
32	Propazine	Herbicide	15.3%	36	0.029
35	Fumagillin	Antimicrobial	13.9%	Not known	5.352
35	Malaoxon	Insecticide	13.9%	0.2	0.016
37	Acetamiprid	Insecticide	12.5%	7.9	0.219

38	Fipronil	Insecticide	11.1%	0.006	0.073
38	Thiophanate-methyl	Fungicide	11.1%	100	0.101
40	Indoxacarb	Insecticide	9.7%	0.118	0.504
41	Fludioxonil	Fungicide	8.3%	25	2.760
41	Tebufenozide	Insecticide	8.3%	234	0.019
43	Boscalid	Fungicide	6.9%	200	0.648
43	Flupyradifurone	Insecticide	6.9%	122.8	0.139
45	Fluopicolide	Fungicide	5.6%	100	0.037
45	Mandipropamid	Fungicide	5.6%	200	0.019
45	Metconazole	Fungicide	5.6%	100	0.391
45	Myclobutanil	Fungicide	5.6%	39.6	0.019
45	Prometryn	Herbicide	5.6%	96.69	0.003
45	Terbutryn	Herbicide	5.6%	0.16	0.006
51	Ametryn	Herbicide	4.2%	100	0.004
51	Fluazinam	Fungicide	4.2%	143	0.019
51	Fluxapyroxad	Fungicide	4.2%	100	0.083
51	Picoxystrobin	Fungicide	4.2%	200	0.010
55	Clothianidin	Insecticide	2.8%	0.039	0.056
55	Cyantraniliprole	Insecticide	2.8%	0.09	0.056
55	Fenamidone	Fungicide	2.8%	47.1	0.009
55	Phosmet	Insecticide	2.8%	0.066	0.236
55	Triflumizole	Fungicide	2.8%	140	0.006
60	Carbofuran	Insecticide	1.4%	0.16	0.001
60	Diflubenzuron	Insecticide	1.4%	2.58	0.694
60	Spinosad	Insecticide	1.4%	0.003	0.005
60	Thiabendazole	Fungicide	1.4%	4	1.127
61	Avermectin B1a	Insecticide	0.0%	0.03	0.000
61	Bendiocarb	Insecticide	0.0%	0.43	0.000
61	Bromuconazole	Fungicide	0.0%	500	0.000
61	Chlorpyrifos	Insecticide	0.0%	0.01	0.000
61	Clomazone	Herbicide	0.0%	100	0.000
61	Cyanazine	Herbicide	0.0%	193.4	0.000
61	Cyflufenamid	Fungicide	0.0%	100	0.000
61	Cyromazine	Insecticide	0.0%	35	0.000
61	Dimoxystrobin	Fungicide	0.0%	100	0.000
61	Dinotefuran	Insecticide	0.0%	0.047	0.000
61	Fenhexamid	Fungicide	0.0%	207	0.000
61	Fluazifop	Herbicide	0.0%	63	0.000
61	Flufenacet	Herbicide	0.0%	25	0.000
61	Flumioxazin	Herbicide	0.0%	105	0.000
61	Fluometuron	Herbicide	0.0%	193.4	0.000
61	Metazachlor	Herbicide	0.0%	Not known	0.000
61	Methiocarb	Insecticide	0.0%	0.29	0.000

61	Methoprotryne	Herbicide	0.0%	Not known	0.000
61	Metobromuron	Herbicide	0.0%	Not known	0.000
61	Mevinphos	Insecticide	0.0%	0.07	0.000
61	Napropamide	Herbicide	0.0%	Not known	0.000
61	Phenmedipham	Herbicide	0.0%	241.7	0.000
61	Profenophos	Insecticide	0.0%	0.095	0.000
61	Sulfentrazone	Herbicide	0.0%	200	0.000
61	Sulfoxaflor	Insecticide	0.0%	0.379	0.000
61	Tetraconazole	Fungicide	0.0%	63	0.000
61	Thiacloprid	Insecticide	0.0%	37.83	0.000
61	Thiobencarb	Herbicide	0.0%	100	0.000
61	Triadimefon	Fungicide	0.0%	50	0.000

Appendix 2. Top Ten Most Common Pesticides in Colonies in 2021

Rank	Pesticide
1	***Piperonyl butoxide – synergist – found in 98.6% 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 pyrethroids, neonicotinoids, and organophosphates. PBO inhibits 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	***Metolachlor – herbicide – found in 95.8% of colonies***
	This compound is a herbicide of the chloroacetanilide family. It is commonly used across the continental United States for the control of grass and broadleaf weeds in a variety of crops, including soy, corn, and cotton. Metolachlor at higher doses can pose health threats to humans, so metolachlor build-up in groundwater and bioaccumulation in exposed species is an ongoing concern.
3	***Fenpyroximate – insecticide – found in 94.4% of colonies***
	This insecticide is used to control spider mites and other plant-infesting mites, leafhoppers, mealybugs, whiteflies, and psylla. Fenpyroximate is applied to greenhouse vegetables, ornamental plants, nursery crops and non-bearing fruit trees to inhibit feeding and reproduction of target insects. Fenpyroximate is practically non-toxic to honey bees on its own, but has been shown to synergize with piperonyl butoxide, a number of fungicides, and four different mite treatments: tau-fluvalinate (Apistan®), coumaphos (CheckMite+®), amitraz (Apivar®) and oxalic acid.
4	***Difenoconazole – fungicide – found in 93.1% of colonies***
	Difenoconazole is a dioxolane fungicide used for sprays and seed treatments in agriculture. It is moderately toxic to birds, aquatic animals, and mammals (including humans).
5	***2,4-DMPF (N-2,4-Dimethylphenyl formamide) – miticide – found in 83.3% of colonies***
	2,4-DMPF is a metabolite of amitraz (Apivar®), a miticide commonly used to treat *Varroa* mites. While amitraz and its breakdown products degrade quickly are largely non-toxic to honey bees, their accumulation in wax can indicate overuse of amitraz. With growing concerns around amitraz-resistant *Varroa* mites, it is important beekeepers alternate between a variety of miticides in managing *Varroa*.
6	***Atrazine – herbicide – found in 75.0% of colonies***
	Atrazine is a triazine herbicide used for broadleaf weed control primarily in corn, sorghum, and sugarcane. Atrazine is practically non-toxic to honey bees.
7	***Diuron – herbicide – found 73.6% of colonies***
	Diuron is a residual herbicide used in controlling pest plant species in and around bodies of water as well as broadleaf weeds of grass. Diuron is used in a broad range of environments both agricultural and non-agricultural, ranging from weeds in orchards to anti-algal agents in paint for marine vehicles.

8	***Pyraclostrobin - fungicide - found in 68.1% 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 used on golf courses, recreational areas, and residential lawns.
9	***Azoxystrobin - fungicide - found in 66.7% 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.
10	***Trifloxystrobin - fungicide - found in 66.7% 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.

Appendix 3. Brood Pattern Scores

The photos below are examples for brood pattern scores 1-5. If a colony does not have any brood, it receives a score of 0.

This frame is a score of 1. It is very spotty. Look closer for signs of disease or queen issues.

This frame is a score of 2. Look closer for signs of disease or queen issues.

This frame is a score of 3.

This frame is a score of 4. The pattern is quite solid with some open cells.

This frame is a score of 5. The pattern is very solid with only a few open cells.