

An Analysis of Northwestern Pennsylvania Beekeeping Challenges and Potential Solutions

By

Emily Hindle

Department of Environmental Science

Allegheny College

Meadville, Pennsylvania

May 2025

**Submitted in fulfillment of the senior thesis requirements of the
Department of Environmental Science and Sustainability at Allegheny College
and approved by the senior thesis committee.**

Dr. Kelly Pearce

Date

Dr. Kevin Geyer

Date

Table of Contents

Acknowledgments and Abstract	
<i>Acknowledgments</i>	2
<i>Abstract</i>	2
Introduction	4
Methods	7
<i>Survey Questions</i>	8
<i>Distribution</i>	8
Results	9
<i>Weather Conditions</i>	9
<i>Ranking</i>	10
<i>Open Ended Questions</i>	12
Discussion	13
References	15
Appendix A	21
Appendix B	26
Appendix C	27

Name: Emily Hindle

Date: May, 2025

Major: Environmental Science

Thesis Committee: Dr. Kelly Pearce, Dr. Kevin Geyer

Title: An Analysis of Northwestern Pennsylvania Beekeeping Challenges and Potential Solutions

Acknowledgements

I would like to thank my parents for encouraging me to always explore the outdoors and encouraging my love for the environment. Thanks to you, I have found my passion for environmental science and a field which I am grateful to be a part of.

I would also like to thank the Northwestern Pennsylvania Beekeepers Association for their participation in this project and their willingness to share their knowledge and experience. Your participation will help to educate and inspire the next generation of beekeepers.

Abstract

Honeybees are a vital part of nature and human life and are incredibly important pollinators. In recent years, the beekeeping industry has been rapidly declining due to climate change, changing weather patterns, and parasites. As these issues increase in severity, beekeepers find it more and more difficult to maintain healthy hives. Climate change can accelerate parasites and diseases, which pose a severe threat to honeybees. Many populations of species are declining severely due to issues such as changing climates and habitat loss. Population decline of honeybees in North America has been complex, with slow decline in some species and sharp declines in others. Seasonal shifts have been occurring in Northwestern Pennsylvania, leading to earlier springs and warmer winters. These changes in weather patterns have the potential to directly affect Northwestern Pennsylvania beekeepers and the health of their hives. To gain an understanding of these potentially damaging factors, beekeepers were surveyed through Google Forms, and a physical survey was distributed as well. The survey was distributed to beekeepers of Northwestern Pennsylvania to understand the issues they are facing as well as methods they are taking to adapt to these changes. Through the responses received, it was found that climate

change is only a mild concern amongst beekeepers, and there are very few beekeepers experiencing any negative effects on their hive productivity and survival.

Introduction

The western honeybee (*Apis mellifera*), also referred to as the European honeybee, is the most commonly kept beekeeping species. They have been domesticated by humans for thousands of years for resources such as wax, honey, and crop pollination. With the help of humans, the western honeybee's population began spreading as early as the 1600s (vanEngelsdorp & Meixner, 2010 Crane, 1999). The western honeybee has been managed intensely for thousands of years, and has a native range of Africa, Asia, and Europe. Currently, this species can be found in North and South America, Australia, and Asia, as they have been imported from various areas (Carpenter & Harpur, 2021). Beekeeping has been used all over the world for centuries, and is still done today. However, over the last decade, the beekeeping industry has been rapidly declining (Cilia, 2019).

Insects play an important role in the agricultural field both directly and indirectly, through pollination as well as having specific roles in ecosystems. It is estimated that one third of all crops consumed by humans are pollinated by bees (Khalifa et al., 2021). In the process of collecting pollen and nectar, honey bees provide “an economically valuable pollination service to crops” (Paudel et al., 2015). While insects are usually viewed as pests, there are many species which play an important part in pollination. In the United States, plants rely heavily on pollination to reproduce, as a large number of flowering plants require pollination to produce offspring. Pollination is incredibly important for the agricultural field as approximately two thirds of plant species rely on insects to assist in pollination (Jankielsohn, 2018), and 90% of all commercial pollination is done by managed honeybees (Genersch, 2010).

Bees are beneficial to the economy as pollinators due to their ability to significantly increase quality and or quantity of crops, in turn improving economic outcomes (Khalifa et al., 2021). Honeybees are responsible for contributing over \$20 billion to United States agriculture from pollination services (Calovi et al., 2021), and the United States honey production industry brings in on average another \$300 million for U.S. beekeepers annually (Calovi et al., 2021). While there are many wild colonies which help to manage ecosystem services such as pollination, the number of managed colonies has increased by 45% since 1961 (Smith et al., 2013), which brings in more profits for agricultural businesses who rely on pollination services.

Climate change is affecting phenological events such as bloom time in flowers, or honeybee emergence after winter. Honeybees have the potential to be affected by these events, as phenological mismatch can lead to a decline in resources and food. Concern about population decline has been expressed since the late 1950s, as population declines were first noticed. In general, honeybees have been on a gradual decline in the U.S. overall since a peak of 5.9 million colonies in 1947 (Calderone, 2012). Population decline in the U.S. is difficult to track, as some species show a sharp drop in population, while others show a slow decline with no identifiable reason (Williams & Osborne, 2009). Over the last 30 years, there have been a few studies done concerning the topic, but the two main categories of potential bee threats appear to be global changes and aggressors (Decourtye et al., 2019). Currently attributed causes of pollinator declines include changing land-use patterns and habitat loss (Rajagopalan et al., 2022), the loss of genetic variability (Marcelino et al., 2022) and parasites and diseases, (Vercelli et al., 2021) all of which are being exacerbated by climate change. Honeybees are able to maintain their own microclimate within hives, which is incredibly important, as bee broods are incredibly sensitive to any changes in hive temperature (Abou-Shaara et al., 2017). Weather and temperature also has an affect on food stores, which honey bees produce and store in the hive for overwintering. Overwintering in honeybees requires large amounts of honey, as a colony can consume about 20 kg (Seeley & Visscher, 1985).

Changes in weather can also affect foraging behaviors, as temperature determines foraging activities. Honeybees are quite resilient, and often forage in different types of weather, and they have strategies to regulate body heat in low temperature weather (Abou-Shaara et al., 2017). These changing weather temperatures can also affect the plant which the honeybee will forage. During growing seasons, it is important that temperatures are consistent as this can affect the growing period of plants, and make resources available for shorter periods for honeybees, affecting their ability to get food (Calovi et al., 2021).

Honeybees are quite resilient, as they are able to navigate through many different weather events and changes. However, as weather patterns change, specifically in Northwestern Pennsylvania, honeybees may have a difficult time adjusting to these changes. While honeybees are resilient to temperature and weather changes, these changes will begin to affect their pollination strategies, and in turn affects their food intake. As climate change continues to affect areas across the world, this will begin to impact biodiversity (Schweiger et al., 2010). Between

plants and pollinators, there is a mutualistic relationship, where both organisms benefit from pollination. However, as weather patterns begin to shift, flight patterns and foraging may begin earlier, losing sync with flowering plants, which may begin to bloom earlier or later as climates change (Visser & Both, 2005).

Climate change in NWPA can lead to changing weather patterns and changes in rainfall, all of which can have an impact on hive health, as well as water and nectar collection (Landaverde et al., 2023). Honeybees tend to not fly in inclement weather, which in turn makes crops and flowers which bloom in the spring more dependent on other natural pollinators (Reilly et al., 2020). The phenological processes of bees are heavily influenced by temperature, making them vulnerable to climate change or changing weather patterns (Bartomeus et al., 2011). Therefore, by monitoring a colony long term, they can be used to evaluate the overall ecosystem health by serving as “biomonitors” (Cunningham et al., 2022). Monitoring honeybees is important, as they are part of a complicated web within the ecosystem, in which all parts are interconnected and rely on each other. Climate change has been changing the phenology of plants, vertebrates, and insects, which in turn leads to mismatched timing with different organisms within the ecosystem (Parmesan & Yohe, 2003).

Research pertaining to honeybees has been ongoing for decades, however research needs to shift to accommodate changing climates in reference to dangers bees are facing. Habitat loss is among one of these challenges which harms bees as well as beekeepers. Sustainable beekeeping is being made difficult due to climate change, as warming and changing weather brings diseases, difficulties with pollinating, and potential colony loss (Carvell et al., 2017). Across the United States, colony loss has become more and more common, as it is linked to climate change, habitat loss, and urbanization (Insolia et al., 2022). In order to have a successful and sustainable adaptation to climate change, adaptive management approaches will need to be taken (Grimm et al., 2013). Alongside these issues, parasites such as Varroa mites can be vectors for viruses which greatly harm honeybee colonies such as deformed wing virus (DWV). DWV is transmitted between bees through bodily contact and is primarily transmitted by Varroa mites, and is common in hives with low mite control (de Miranda & Genersch, 2010). The deformities of DWV are commonly associated with Colony Collapse Disorder (CCD), which is characterized by the sudden and rapid disappearance of adult bees from a colony, leaving behind the queen,

any remaining food, and colonies of brood. This is classified as CCD when what remains does not have any significant damage from Varroa mites or other parasites (Williams et al., 2010).

Beekeepers across the world have expressed concern about the growing issues that come with climate change, and have noticed the toll it takes on production and survival amongst their hives. A study in Italy found that due to changing climates, some participants found that a more mild winter could be taken positively, as colonies are ready to harvest at an earlier time. However, other participants had concern pertaining to hive imbalances (reduction of drones, failure to fertilize queens) due to changes in climate and weather patterns (Vercelli et al., 2021).

Through this project, I expect to gain knowledge into the struggles northwest Pennsylvania beekeepers are facing and the environmental changes which could be linked to these issues. By working directly with beekeepers, I am taking a collaborative approach to this challenge which has the potential to help beekeepers be better prepared for any challenges they might face as well as any they are currently facing. From this project, I will be presenting my findings back to the NWPA Beekeepers Association. While I am working specifically in northwestern Pennsylvania, my project will help to contribute to the expansion of knowledge in the beekeeping community as a whole. Currently, there is not a lot of research regarding these topics that is specific to this region. Due to this, I have the chance to fill in this gap, but this also presents challenges as there is not a lot of research available for this specific area. The goal of this study was to understand the thoughts and opinions of NWPA beekeepers on issues regarding climate change, as well as their biggest struggles and issues in the beekeeping field.

Methods

This study relied heavily on surveys and interactions with the Northwestern Pennsylvania Beekeepers Association. Currently, the NWPA Beekeepers Association has over 300 members, with between 60-90 active members attending meetings. The association spans across five counties (Warren, Venango, Crawford, Mercer and Erie) and provided me with experienced beekeepers who were willing to share their experiences and knowledge. This was achieved through a survey which was distributed to the members via email. The president of the beekeeping association, Cici Sweeney, helped me in contacting members for survey distribution.

Survey Questions/Topics

Survey topics were focused mainly on the concerns and issues the beekeepers are dealing with in northwestern Pennsylvania. The survey included seventeen questions and topics discussed included earlier springs, harsh winters, and dry spells (Appendix C). The survey also included questions on overall hive productivity, mites, treatments, and to share experience with hive loss. The subjects were asked to describe any potential hive loss from mites or other factors such as not enough food. Finally, subjects were asked to share their biggest concern about beekeeping in the NWPA area. The ideal number of responses was 25-30, in order to determine the top two or three common concerns. I focused primarily on beekeepers with more years of experience in the field who can provide more information and share more experiences (Appendix 1). Most questions were open ended and open for discussion, but some were answered using a ranking system. This ranking system consisted of answering questions on a scale of 1-5 with 1 being strongly disagree and 5 being strongly agree. These questions were designed to allow participants to voice their opinions on issues they were facing in the beekeeping industry, how these issues affected their hive health, outlook on future beekeeping, and any changes in their practices they have had to make due to these issues. The survey, both online and physical forms, were administered with informed consent with approval from the Allegheny College International Review Board (IRB).

Distribution

The survey was distributed on January 9th, 2025 on Google Forms to the Northwestern Pennsylvania Beekeepers Association. The surveys were sent out again as a reminder on February 10th 2025. In total, 35 responses were received through Google Forms. Physical copies of the survey were distributed at the first NWPA Beekeepers Association meeting on February 15th, 2025. A physical copy of the survey was distributed to the Northwestern Beekeepers Association's first meeting of the year on February 15th, 2025 at Compton Hall at Edinboro University in Edinboro, Pennsylvania. At the February 15th meeting, 72 members were in attendance, and 5 physical survey copies were distributed and received once completed. A

complete statistical analysis as well as a descriptive analysis could also determine if there is a correlation between any of the previously mentioned factors and the colony's success rates.

Results

In total, 40 northwestern Pennsylvania beekeepers participated in the survey either through Google Forms or physical distribution of the survey. Years of experience in respondents ranged from 1-42 years, with an average of 11 years (Table 1). Respondents also had a range of hives they are currently managing, ranging from 0-200 hives at this time (Table 1). The average number of hives recorded from this survey is 14 hives.

Counties

At the start of the survey, participants were asked to choose the county they reside in. The Northwestern Pennsylvania Beekeepers Association comprises five counties of Pennsylvania: Crawford, Venango, Mercer, Warren, and Erie. Out of the 40 respondents, twenty two percent ($n=9$) reside in Crawford county. The majority of participants (37%, $n=15$) live in Erie county (Figure 1). Venango county had 3 responses at thirteen percent, and Mercer and Warren counties were both equal at nine percent ($n=2$) of responses.

Weather Conditions

Dry Spells

The first question asked participants to share if dry spells had an effect on their hive's survival. Sixty-nine percent ($n=16$) found that dry spells had no effect on their hive's survival, and 26% ($n=6$) found that dry spells decreased survival. One respondent did not answer the question, and one participant found dry spells increased survival (Table 2).

Warmer Winter Temperatures

The second question asked participants to share if warming winter temperatures have had an effect on hive survival. Sixty-five percent ($n=15$) found that warming winter temperatures had no effect on hive survival (Table 2). Seventeen percent ($n=4$) of participants found that warmer temperatures increased survival, and 13% ($n=3$) found that warming temperatures decreased survival.

Earlier Springs

The third question asked participants if earlier springs have had an effect on hive survival. Fifty six percent ($n=13$) found no effect on hive survival. Thirty percent ($n=7$) have found that earlier springs increase hive survival, while 8% found survival decreased with earlier winters (Table 2).

Mites

The final question asked to participants regarded mites and hive damage. They were asked if they had any damage done to their hives from varroa mites. Seventy-eight percent ($n=18$) said they experienced mites, 13% ($n=3$) had no damage from mites and 8% ($n=2$) were unsure, meaning there was damage to their hives which could not be confirmed as mite damage.

Ranking

Participants were asked to rank five different concerns (earlier springs, harsh winters, heavy rainfall, mites, and pesticides) on a scale of 1-5, with one being of most concern and five being of least concern. Results were separated into six different groups based on their years of experience: 1-5 years, 6-10, 11-15, 16-20, 20+ years, and no year given.

1-5 Years Experience

In the range of 1-5 years of experience, participants had three major concerns for their hives. The majority of participants (61% , $n = 8$), listed mites as their top concern (Table 4). The second highest ranked concern was harsh winters at thirty eight percent ($n = 5$). Pesticides were the third most popular issue of concern with twenty-three percent of respondents ($n = 3$). Early springs and heavy rains were of least concern, with two respondents concerned most about early springs, and one concerned about heavy rains (Table 4.)

6-10 Years Experience

In the 6-10 years category, there were three major concerns as well. The majority of respondents (58%, $n = 7$) ranked mites as their number one concern for their hive (Table 5). The second highest concern was much lower, but twenty-five percent ($n = 3$) reported pesticides as their number one concern. Sixteen percent ($n = 2$) of respondents ranked harsh winters as their highest concern. Early springs and heavy rains were both equal, with only eight percent ($n = 1$) each as a top concern among beekeepers.

11-15 Years Experience

In the 11-15 years category, respondents were split pretty evenly on their number one concerns. The issues with the highest ranking were both pesticides and early springs (50%, $n = 2$) (Table 6). The three remaining issues were evenly split with twenty-five percent ($n = 1$) for mites, harsh winters, and heavy rains (Table 6).

16-20 Years Experience

Beekeepers with 16-20 years of experience were very evenly split on which issues they were most concerned about. With only 3 participants in this category, each one was concerned about a different issue. Mites, harsh winters, and pesticides each received one vote (Table 7).

20+ Years Experience

The more experienced beekeepers were divided on which issues were of most concern to their hives. The majority of participants (80%, $n=4$) rated mites as the most concerning issue for their hive. The remaining votes (40%, $n=2$) were for pesticides (Table 8).

No Experience Listed

Three respondents did not list their years of experiences on the survey. Of these three, they were all in unanimous agreement about their top concern. All respondents (100%, $n=3$) listed mites as their top concern in regards to their hive (Table 9).

Open Ended Questions

Mite Treatment

Participants were asked to describe their mite treatments for their hives. Ninety-one percent ($n=21$) of respondents reported using oxalic acid to control mites, while the remaining 8% ($n=2$) use Mite Away Strips.

Hive Loss

Participants were asked to list the two primary factors they believed lead to hive loss in their colonies. The main concerns of beekeepers from these responses are mites and warm winters/early springs. Twenty eight percent of responses ($n=13$) mentioned concern over varroa mites, while 13% of respondents ($n=6$) mentioned concerns of warm winters or early change causing hive loss.

Weather Conditions

Participants were asked to share their experiences with various weather conditions (dry spells, early springs, and harsh winters) and how they have affected their hives. One participant shared

their experience with dry spells, saying that prolonged dry spells result in “ Poor nectar flow for fall build up. Queen slows down or stops laying.” (B4). Another respondent shared that dry spells can weaken a hive, and lead to increased robbing activity (Table 3). Earlier springs were reported to have more of a benefit, but still can cause harm to hives. One respondent stated that earlier springs can allow for earlier foraging opportunities, but could also lead to longer terms between blossoming plants and food supplies (Table 3). This distance of time between blossoming plants can lead to a longer death period, impacting survival negatively. Warmer winters can have a more negative impact on the survival of honeybees over the winter period. Warmer temperatures in the winter can lead to bees consuming more of their winter food store, and lead to dampness in the hive, negatively impacting survival (Table 3).

Discussion

In the United States, beekeepers have different concerns and perceptions regarding changing weather patterns. A survey distributed across the United States found that beekeepers in the U.S. are much more concerned about Varroa mites, pesticides, and disease (Engelbreton et al., 2022). Beekeeping, especially on a large scale, is difficult to manage in the United States. A majority of beekeepers across the U.S. are forced to adopt new hive management strategies due to environmental pressures making it difficult to keep hives alive (Ferenczi et al., 2024). There are many factors which can determine the health of an ecosystem and the organisms which inhabit it. For European honeybees, factors such as weather, seasonal changes, and precipitation can all affect the health of a hive and its food production. There are many activities which occur inside the hive all year round which are necessary for the health of the hive. As one of the only insect species which do not go completely dormant over winter, it is critical that they are able to successfully overwinter properly, in order to meet the needs of early spring pollination (Doeke et al., 2015).

Much like other beekeepers around the United States, climate change is not an issue which they are currently feeling any sort of major impact from. A majority of beekeepers surveyed had mentioned that climate change is a factor which is on their mind, but it is not anything which is doing too much damage to the health of their hives, In a lot of cases, it was the opposite. Many

participants had said that factors such as earlier springs can actually be helpful to hive survival, giving more time for foraging and allowing for more reproduction and activity in the hive.

While weather patterns have begun to slightly change in Northwestern Pennsylvania, with participants noting an earlier start to spring and less harsh winters, this has not taken much of a toll on honeybee hives in the area. Many beekeepers in the area have noted that these factors have not hindered hive production, and have even helped increase survival rates. Climate change does not seem to be a factor which directly causes hive loss, most beekeepers are concerned much more with varroa mites and pesticides at this time. Specifically, the majority of beekeepers with 1-10 years of experience ($n=25$) were the most concerned with weather changes such as earlier springs and harsh winters. The concern may come from having less experience than more experienced participants. Weather changes can be unpredictable, and participants may be more concerned with overwintering their hives, or monitoring activity during the first few warm days of spring.

Beekeepers with more experience tended to rank other issues as their highest concern, mainly mites and pesticides. More experienced beekeepers have worked many years and been through many seasons with their hives. They have more knowledge on the resilience of honeybees, and how to successfully overwinter colonies, and what signs to look out for if a hive is unhealthy. More experienced beekeepers may understand that the weather does not have as great of an impact on hive health as other issues do (pesticides and mites), which is why they were less concerned about weather related changes.

In conclusion, it is currently difficult to tell if climate change is having an effect on domesticated hives in Northwestern Pennsylvania. Currently, surveyed beekeepers are not noticing many negative effects, noting no change in production/survival or an increase in both. While it is not a current issue, many beekeepers note that climate change is of concern to them in the future. While it is uncertain right now what the effects of climate change will be on Northwestern Pennsylvania, the honeybee has proved to be a strong insect which will be able to adapt and overcome these changes.

References

- Abou-Shaara, H. F., Owayss, A. A., Ibrahim, Y. Y., & Basuny, N. K. (2017). *A review of impacts of temperature and relative humidity on various activities of honey bees. Insectes Sociaux*, 64(4), 455–463. 10.1007/s00040-017-0573-8
- Bartomeus, I., Ascher, J. S., Wagner, D., Danforth, B. N., Colla, S., Kornbluth, S., & Winfree, R. (2011). *Climate-associated phenological advances in bee pollinators and bee-pollinated plants. Proceedings of the National Academy of Sciences - PNAS*, 108(51), 20645–20649. 10.1073/pnas.1115559108
- Calderone, N. W. (2012). *Insect Pollinated Crops, Insect Pollinators and US Agriculture: Trend Analysis of Aggregate Data for the Period 1992–2009. PLoS ONE*, 7(5), e37235–e37235. 10.1371/journal.pone.0037235
- Calovi, M., Grozinger, C. M., Miller, D. A., & Goslee, S. C. (2021a). *Summer weather conditions influence winter survival of honey bees (Apis mellifera) in the northeastern United States. Scientific Reports*, 11(1), 1553. 10.1038/s41598-021-81051-8
- Calovi, M., Grozinger, C. M., Miller, D. A., & Goslee, S. C. (2021b). *Summer weather conditions influence winter survival of honey bees (Apis mellifera) in the northeastern United States. Scientific Reports*, 11(1), 1553. 10.1038/s41598-021-81051-8
- Carpenter, M. H., & Harpur, B. A. (2021). *Genetic past, present, and future of the honey bee (Apis mellifera) in the United States of America. Apidologie*, 52(1), 63–79. 10.1007/s13592-020-00836-4

- Carvell, C., Bourke, A. F. G., Dreier, S., Freeman, S. N., Hulmes, S., Jordan, W. C., Redhead, J. W., Sumner, S., Wang, J., & Heard, M. S. (2017). Bumblebee family lineage survival is enhanced in high-quality landscapes. *Nature (London)*, 543(7646), 547. 10.1038/nature21709
- Cilia, L. (2019). The Plight of the Honeybee: A Socioecological Analysis of large-scale Beekeeping in the United States. *Sociologia Ruralis*, 59(4), 831–849. 10.1111/soru.12253
- Crane, E. (1999). *The world history of beekeeping and honey hunting*. Routledge.
- Cunningham, M. M., Tran, L., McKee, C. G., Ortega Polo, R., Newman, T., Lansing, L., Griffiths, J. S., Bilodeau, G. J., Rott, M., & Marta Guarna, M. (2022). Honey bees as biomonitors of environmental contaminants, pathogens, and climate change. *Ecological Indicators*, 134, 108457. 10.1016/j.ecolind.2021.108457
- de Miranda, J. R., & Genersch, E. (2010). Deformed wing virus. *Journal of Invertebrate Pathology*, 103, S48–S61. 10.1016/j.jip.2009.06.012
- Decourtye, A., Alaux, C., Le Conte, Y., & Henry, M. (2019). Toward the protection of bees and pollination under global change: present and future perspectives in a challenging applied science. *Current Opinion in Insect Science*, 35, 123–131. 10.1016/j.cois.2019.07.008
- Doeke, M. A., Frazier, M., & Grozinger, C. M. (2015). Overwintering honey bees: biology and management. *Current Opinion in Insect Science*, 10, 185–193.

- Ferenczi, A. F., Szűcs, I., & Gáthy, A. B. (2024). “What’s Good for the Bees Will Be Good for Us!”—A Qualitative Study of the Factors Influencing Beekeeping Activity. *Agriculture (Basel)*, 14(6), 890. 10.3390/agriculture14060890
- Genersch, E. (2010). Honey bee pathology: current threats to honey bees and beekeeping. *Applied Microbiology and Biotechnology*, 87(1), 87–97. 10.1007/s00253-010-2573-8
- Grimm, N. B., Staudinger, M. D., Staudt, A., Carter, S. L., Chapin, F. S., Kareiva, P., Ruckelshaus, M., & Stein, B. A. (2013). Climate-change impacts on ecological systems: introduction to a US assessment. *Frontiers in Ecology and the Environment*, 11(9), 456–464. 10.1890/120310
- Insolia, L., Molinari, R., Rogers, S. R., Williams, G. R., Chiaromonte, F., & Calovi, M. (2022). Honey bee colony loss linked to parasites, pesticides and extreme weather across the United States. *Scientific Reports*, 12(1), 20787. 10.1038/s41598-022-24946-4
- Jankielsohn, A. (2018). The Importance of Insects in Agricultural Ecosystems. *Advances in Entomology*, 6(2), 62–73. 10.4236/ae.2018.62006
- Khalifa, S. A. M., Elshafiey, E. H., Shetaia, A. A., El-Wahed, A. A. A., Algethami, A. F., Musharraf, S. G., AlAjmi, M. F., Zhao, C., Masry, S. H. D., Abdel-Daim, M. M., Halabi, M. F., Kai, G., Al Naggat, Y., Bishr, M., Diab, M. A. M., & El-Seedi, H. R. (2021). Overview of Bee Pollination and Its Economic Value for Crop Production. *Insects*, 12(8), 688. 10.3390/insects12080688

- Landaverde, R., Rodriguez, M. T., & Parrella, J. A. (2023). *Honey Production and Climate Change: Beekeepers' Perceptions, Farm Adaptation Strategies, and Information Needs. Insects (Basel, Switzerland)*, 14(6), 493. 10.3390/insects14060493
- Marcelino, J., Braese, C., Christmon, K., Evans, J. D., Gilligan, T., Giray, T., Nearman, A., Niño, E. L., Rose, R., Sheppard, W. S., vanEngelsdorp, D., & Ellis, J. D. (2022). *The Movement of Western Honey Bees (Apis mellifera L.) Among U.S. States and Territories: History, Benefits, Risks, and Mitigation Strategies. Frontiers in Ecology and Evolution*, 10
<https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2022.850600/full>
- Parmesan, C., & Yohe, G. (2003). *A globally coherent fingerprint of climate change impacts across natural systems. Nature (London)*, 421(6918), 37–42. 10.1038/nature01286
- Paudel, Y. P., Mackereth, R., Hanley, R., & Qin, W. (2015). *Honey Bees (Apis mellifera L.) and Pollination Issues: Current status, impacts and potential drivers of decline. Journal of Agricultural Science (Toronto)*, 7(6), 93. 10.5539/jas.v7n6p93
- Rajagopalan, K., DeGrandi-Hoffman, G., Pruett, M., Jones, V. P., Corby-Harris, V., Pireaud, J., Curry, R., Hopkins, B., & Northfield, T. (2022). *Changing honey bee overwintering dynamics under warmer autumns and winters create new risks for pollination services. Research Square Platform LLC*. 10.21203/rs.3.rs-1394621/v1
- Reilly, J. R., Artz, D. R., Biddinger, D., Bobiwash, K., Boyle, N. K., Brittain, C., Brokaw, J., Campbell, J. W., Daniels, J., Elle, E., Ellis, J. D., Fleischer, S. J., Gibbs, J., Gillespie, R. L., Gundersen, K. B., Gut, L., Hoffman, G., Joshi, N., Lundin, O., . . . Winfree, R.

- (2020). *Crop production in the USA is frequently limited by a lack of pollinators. Proceedings - Royal Society. Biological Sciences/Proceedings - Royal Society. Biological Sciences*, 287(1931), 20200922. 10.1098/rspb.2020.0922
- Schweiger, O., Biesmeijer, J. C., Bommarco, R., Hickler, T., Hulme, P. E., Klotz, S., Kühn, I., Moora, M., Nielsen, A., & Ohlemüller, R. (2010). *Multiple stressors on biotic interactions: how climate change and alien species interact to affect pollination. Biological Reviews*, 85(4), 777–795.
- Seeley, T. D., & Visscher, P. K. (1985). *Survival of honeybees in cold climates: the critical timing of colony growth and reproduction. Ecological Entomology*, 10(1), 81–88.
- Smith, K. M., Loh, E. H., Rostal, M. K., Zambrana-Torrel, C. M., Mendiola, L., & Daszak, P. (2013). *Pathogens, Pests, and Economics: Drivers of Honey Bee Colony Declines and Losses. EcoHealth*, 10(4), 434–445. 10.1007/s10393-013-0870-2
- vanEngelsdorp, D., & Meixner, M. D. (2010). *A historical review of managed honey bee populations in Europe and the United States and the factors that may affect them. Journal of Invertebrate Pathology*, 103, S80–S95. 10.1016/j.jip.2009.06.011
- Vercelli, M., Novelli, S., Ferrazzi, P., Lentini, G., & Ferracini, C. (2021). *A Qualitative Analysis of Beekeepers' Perceptions and Farm Management Adaptations to the Impact of Climate Change on Honey Bees. Insects (Basel, Switzerland)*, 12(3), 228. 10.3390/insects12030228
- Visser, M. E., & Both, C. (2005). *Shifts in phenology due to global climate change: the need for a yardstick. Proceedings of the Royal Society B: Biological Sciences*, 272(1581), 2561–2569. 10.1098/rspb.2005.3356

Williams, G. R., Tarpy, D. R., vanEngelsdorp, D., Chauzat, M., Cox-Foster, D. L., Delaplane, K. S., Neumann, P., Pettis, J. S., Rogers, R. E. L., & Shutler, D. (2010). Colony Collapse Disorder in context. BioEssays, 32(10), 845–846. 10.1002/bies.201000075

Williams, P. H., & Osborne, J. L. (2009). Bumblebee vulnerability and conservation world-wide. Apidologie, 40(3), 367–387. 10.1051/apido/2009025

Appendix A: Tables

	Average	Median	Range
Number of Hives	14.05555556	8	200
Experience (years)	11.27142857	8	42

Table 1. A representation of the demographics of beekeepers surveyed. This summarizes the average, median, and range values for the number of hives and years of experience from surveyed participants.

Table 2: Results from the first block of questions which asked participants to indicate if the aforementioned weather patterns have had an increase, decrease, or no effect on survival.

Condition	Level	Percentage	Number
Dry Spells	No	70	28
	Decreased	25	10
	Increased	2.5	1
	No response	2.5	1
Warm winter	No	62.5	25
	Decreased	7.5	3
	Increased	27.5	11
	No Response	2.5	1
Earlier Springs	No	57.5	23
	Decreased	5	2
	Increased	35	14
	No Response	2.5	1

Mites	Yes	70	28
	No	20	8
	Unsure	10	4

Topic	Perception
Warm Winter Temperatures	“Warmer winter temperatures has led to increased dampness in colonies and bees consuming more resources” (B3)
Earlier Springs	“Earlier springs could mean food foraging sooner but a longer term between blossoming plants and food supplies, leading to a longer dearth period and ultimately a negative impact on survival” (B10)
Dry Spells	“During dry spells there is an increase in robbing activity, sometimes dooming a weak hive.” (B14)

Table 3. Perceptions of participants and their personal experiences with warm winter temperatures, earlier springs, and dry spells.

1-5 Years Experience		
Factor	Percentage	Number
Mites	61.53846154	8
Early Springs	15.38461538	2
Harsh Winters	38.46153846	5
Heavy Rains	7.692307692	1
Pesticides	23.07692308	3
Total	146.1538462	19

Respondents ranking of the most pressing issues in beekeeping, 1-5 years experience. Respondents could rank two issues equally, so that will give a reason why the percentages will be over 100.

Table 5.

6-10 Years Experience		
Factor	Percentage	Number
Mites	58.33333333	7
Early Springs	8.33333333	1
Harsh Winters	16.66666667	2
Heavy Rains	8.33333333	1
Pesticides	25	3
Total	116.6666667	14

Respondents ranking of the most pressing issues in beekeeping, 6-10 years experience.
 Respondents could rank two issues equally, so that will give a reason why the percentages will be over 100.

Table 6.

11-15 Years Experience		
Factor	Percentage	Number
Mites	25	1
Early Springs	50	2
Harsh Winters	25	1
Heavy Rains	25	1
Pesticides	50	2
Total	175	7

Respondents ranking of the most pressing issues in beekeeping, 11-15 years experience.
 Respondents could rank two issues equally, so that will give a reason why the percentages will be over 100.

Table 7.

16-20 Years Experience		
Factor	Percentage	Number
Mites	33.33333333	1
Early Springs	0	0
Harsh Winters	33.33333333	1
Heavy Rains	0	0
Pesticides	33.33333333	1
Total	100	3

Respondents ranking of the most pressing issues in beekeeping, 16-20 years experience.
 Respondents could rank two issues equally, so that will give a reason why the percentages will be over 100.

Table 8.

20+ Years Experience		
Factor	Percentage	Number
Mites	80	4
Early Springs	0	0
Harsh Winters	0	0
Heavy Rains	0	0
Pesticides	40	2
Total	120	6

Respondents ranking of the most pressing issues in beekeeping, 20+ years experience.
 Respondents could rank two issues equally, so that will give a reason why the percentages will be over 100.

Table 9.

Experience Not Provided		
Factor	Percentage	Number
Mites	100	3
Early Springs	0	0
Harsh Winters	0	0
Heavy Rains	0	0

Pesticides	0	0
Total	100	3

Respondents ranking of the most pressing issues in beekeeping, no experience listed.

Respondents could rank two issues equally, so that will give a reason why the percentages will be over 100.

Appendix B: Figures

County vs. Percentage of Respondents

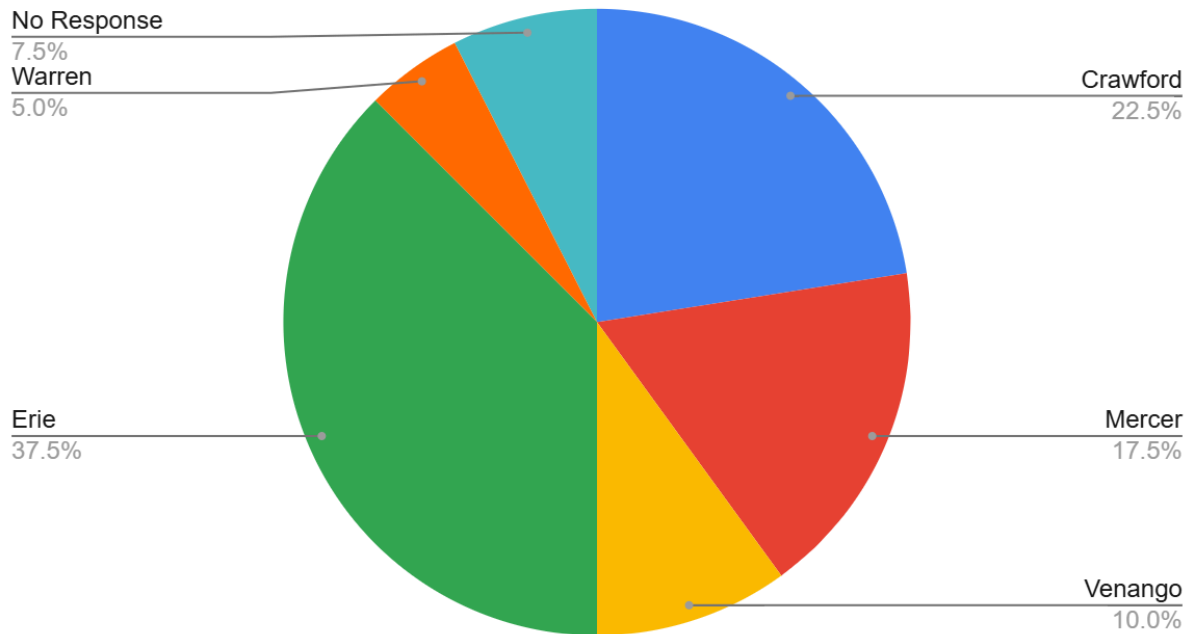


Figure 1. County of Residence of respondents from survey. All respondents are members of the Northwestern Pennsylvania Beekeepers Association, which includes five counties: Erie, Crawford, Mercer, Venango, and Warren counties.

Appendix C: Survey Questions

Years of Beekeeping:

County:

Number of Hives:

Changing Weather Patterns:

In the past 2 years, have the following weather patterns affected your hives? (Please circle)

1. Heavy rainfalls:

increased productivity, decreased productivity, no effect on productivity.

2. Dry spells:

increased productivity, decreased productivity, no effect on productivity.

3. Warm Winter Temperatures:

increased productivity, decreased productivity, no effect on productivity.

4. Earlier Springs:

increased productivity, decreased productivity, no effect on productivity.

If applicable, select one of the factors from above that negatively impacted your productivity, and provide an example:

Mild Winters:

If you selected decreased productivity for any of the above questions, regarding changing weather patterns, could you explain (~2 sentences) what strategies you have implemented to reduce this effect?

Over the past 10 years, temperatures in NW PA have increased by 1.8 degrees Fahrenheit. What, if any, long term impacts do you see on your bee hives due to changes in winter weather patterns?

Mites:

Have you had any damage done to your colonies from mites?

Yes No Unsure

If yes, what methods did you use to treat your hives?

Ranking:

Please rank your concerns for the following issues from 1-5, with 1 being of most concern and 5 being of least concern:

1. Mites or other pests
2. Early Springs
3. Harsh Winters
4. Heavy Rainfalls
5. Pesticides or Pest Control

Hive Loss:

On average, what percentage of your hives have you lost annually, over the past 5 years?

1. 0%
2. >5% of hives
3. 5>10%
4. 10>25
5. 25-50
6. >50%

If you experienced hive loss, please list what you feel are the two primary factors that contributed to your hive loss.

Are there any specific actions you take to mitigate hive loss? If so, how effective have they been?

Future Outlook:

Please list your biggest concern about beekeeping in NWPA in the next five years: