ANALYZING BEEKEEPING IN AOTEAROA NEW ZEALAND: CHANGES IN CLIMATE, CALENDARS, AND CULTURE

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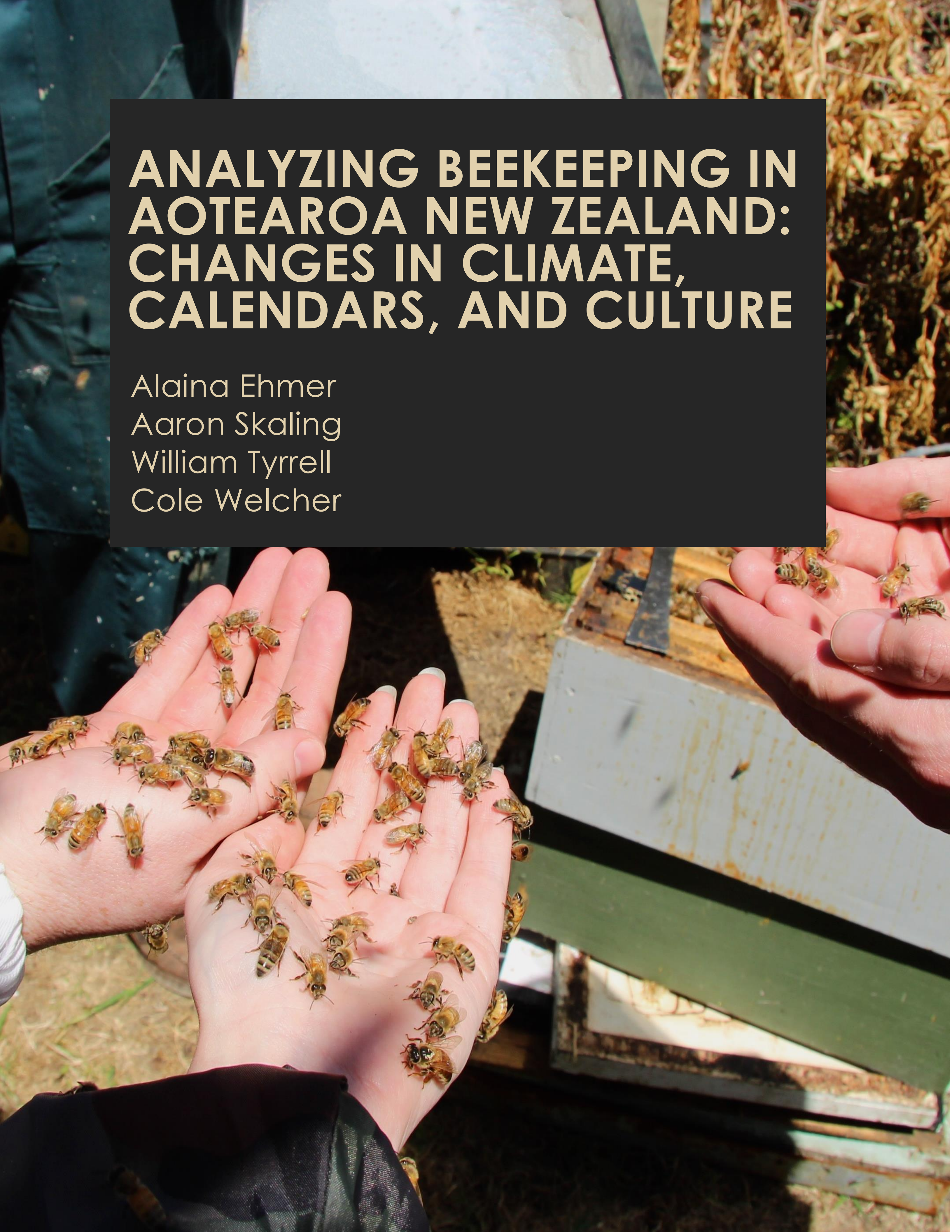

Analyzing Beekeeping in Aotearoa New Zealand: Changes in Climate, Calendars, and Culture

An Interactive Qualifying Project
Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

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ABSTRACT

Our project furthers the work of the global CALENDARS Project to assess climate change indicators, changes in practices, and the outlook regarding beekeeping in New Zealand. We interviewed experienced beekeepers and apiculture experts to collect their perceptions of beekeeping seasons. Discussions revealed that climate science is echoed by the experiences of New Zealand beekeepers. Hand-drawn calendars and the online Calendar Tool were used to collect and synthesize calendar data and could be effective additions to the CALENDARS Project.

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MEET THE TEAM

Alaina Ehmer

My name is Alaina Ehmer, and I am studying chemical engineering with an environmental concentration. I am from Terryville, Connecticut. At home, I work at a nature center where I teach kids about nature and animals. I was excited for the opportunity to work on this project as I have always been passionate about the environment and protecting native species, and the relationship of bees with New Zealand's unique flora and fauna fits perfectly with this.

Aaron Skaling

My name is Aaron Skaling, and I am an industrial engineering major from New Hampshire. I am a member of the WPI football team and am interested in additive manufacturing. This project has made me aware of the complex relationship between climate, humans, flora and fauna and how essential bees are to the environment.

William Tyrrell

My name is William Tyrrell, and I am from Dudley, Massachusetts, studying electrical and computer engineering along with computer science. I am going to be a Captain for WPI Football this upcoming year. This project has revealed to me the importance of bees to the world and also how interconnected their lives are to the environment.

Cole Welcher

My name is Cole Welcher, and I am studying robotics engineering and computer science at WPI and will be pursuing a master's degree in robotics engineering. I am from Rancho Palos Verdes, California. I am interested in surgical robotics 3D printing, and I own bees. This IQP project has opened my eyes to the necessity of bees in everyday life and how large of an effect climate change has on the best pollinators.

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EXECUTIVE SUMMARY

BACKGROUND

THE CALENDARS PROJECT

The CALENDARS Project is a five-year study funded by the European Research Council to conduct empirical research on how individuals and communities perceive, and experience shifts in seasonal patterns. The CALENDARS Project documents the repercussions of changes in traditional seasonal cycles caused by environmental, climatic, and social shifts (*CALENDARS Project*, 2022). In addition to our work in Wellington, New Zealand, the CALENDARS Project is collaborating with other Worcester Polytechnic Institute project sites in Hong Kong; Berlin, Germany; and Mandi, India. Outside of WPI, previous work has been conducted in Norway. The international collaboration provides insight into how climate-dependent activities are being influenced by shifting seasons (*Our Seasonal Cultures*, 2022).

BEEKEEPING IN NEW ZEALAND

Both in and outside of New Zealand, bees play a critical role in food and agriculture production through pollination, “contributing to 35% of the world’s total crop production, pollinating 87 of 115 leading food crops worldwide” (“World Bee Day”, 2023, para. 3). Modern beekeeping methods have been a part of Aotearoa New Zealand since 1839 when the first non-feral bee hives arrived from England (Honey Bees Brought to New Zealand, n.d.). Now there are over 10,000 registered beekeepers with roughly 835,000 hives all throughout New Zealand, most of which are hobbyists, “with 88.3% of them [roughly 800,000 beekeepers] owning an average of only five hives” (*New Zealand Beekeeping*, 2019, para. 3).

CLIMATE CHANGE IN NEW ZEALAND

Climate change is affecting New Zealand, causing more extreme weather (Ministry for the Environment, 2023). New Zealand experienced its warmest year on record in 2022, with an average temperature of 13.76˚C, which was +1.15˚C above the 1981-2010 annual average (NIWA, 2022). This temperature surpassed the previous record in 2021 by +0.20˚C (NIWA, 2022). The top-four warmest years on record have now all occurred since 2016, a trend consistent with climate change, and seven of the past nine years have been among New Zealand’s warmest on record (NIWA, 2022). The winter in 2022 was also New Zealand’s warmest winter on record, surpassing the record set in winter 2021 (IPCC, 2022). New Zealand has more warming being projected, with fewer cold days and more hot days (IPCC, 2022).

GOAL AND OBJECTIVES

The goal of our project was to contribute to the global CALENDARS Project by assessing climate change indicators, changes in practices, and the outlook regarding beekeeping in New Zealand. To accomplish this goal, we examined the influence of climate change on beekeeping in New Zealand; analyzed how beekeeping calendars have changed and how they affect beekeeping practices; and explored the dynamics surrounding beekeeping culture and economics. We field-tested hand-drawn calendars and sought to improve the Calendar Tool, a web-based tool used to gather seasonal perceptions, along with providing answers to three CALENDARS research questions. The CALENDARS research questions prompted insights from our interview participants regarding changes in beekeeping practices and technologies, the presence of climate change indicators and vulnerabilities, and the future of the beekeeping industry.

FIELD RESEARCH METHODS

We conducted 11 in-person and virtual interviews with beekeepers in Wellington and around the North and South Island (Table A). We also gathered data using 10 hand-drawn calendars and three Calendar Tool submissions. We sought out experienced beekeepers and other experts in the New Zealand apiculture. We conducted site assessments at the Wellington Zoo and Wellington Botanical Garden. We also visited the Wellington Farmers Market in search of beekeeping contacts. We were able to visit the Wellington Beekeeping Association beehives and observe the work of beekeepers up close.

Key Informant	Title	Location
Dr. Greg Bodeker	• Owner and Director of Bodeker Scientific (atmospheric research company) • Previous adjunct professor at Victoria University in Wellington researching climate change • Previous climate scientist at NIWA	Wellington, North Island
Rae Butler	• More than 25 years of experience in the beekeeping industry • Varroa sensitive hygiene specialist • Queen honey bee breeder • Bee Smart Breeding business owner	Ashburton, South Island
Barry Foster	• More than 45 years of beekeeping • Former president of the National Beekeepers Association • Partially retired commercial beekeeper • ApiNZ board member	Gisborne, North Island
Karin Kos	Chief Executive of Apiculture NZ	Wellington, North Island
Dr. Phil Lester	• *Varroa destructor* researcher at Victoria University of Wellington • Biology professor at Victoria University	Wellington, North Island
Frank Lindsay	• More than 50 years as a hobbyist beekeeper • Wellington Beekeepers Association member • Former author in The New Zealand Beekeeper • New Zealand New Year Honours Award Recipient 2023	Wellington, North Island
Alistair Little	More than 30 years as a hobbyist beekeeper	Auckland, North Island
Bill McDonald	Owner of Bee Fresh Farms which sells Wellington Mānuka Honey Company honey	Wellington, North Island
Dr. Daithi Stone	Climate Scientist at NIWA (National Institute of Water and Atmospheric Research)	Wellington, North Island
Dr. Michelle Taylor	• Research scientist at NZ Plant & Food Research • Focuses on bumblebee and honey bee research • Researcher in *Varroa destructor* control	Te Puke, North Island
Carlos Zevallos	Head of Apiary Development for Comvita, New Zealand	Hamilton, North Island

Table A: List of our key informants.

FINDING: BEEKEEPER EXPERIENCES ECHO CLIMATE CHANGE SCIENCE

Beekeepers are experiencing changes in weather that reflect climate change science (Figure A). New Zealand is experiencing record heat, increased rainfall, and more severe storms (NIWA, 2023).

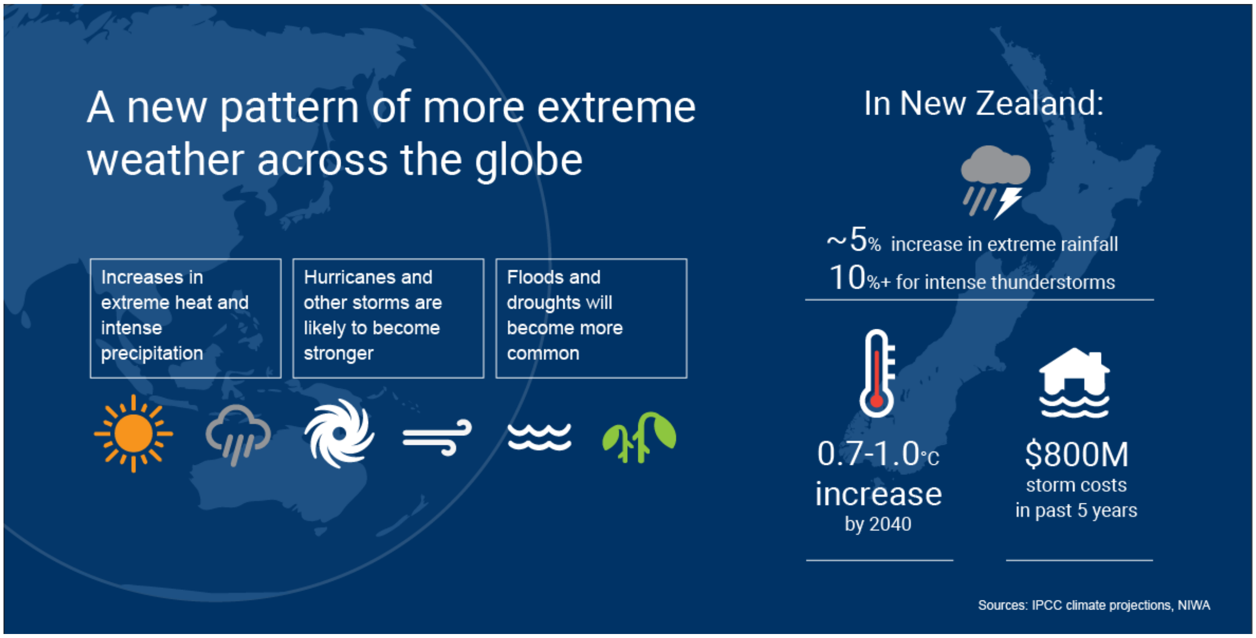


Figure A: Summary of predicted and measured effects on weather in New Zealand due to climate change (NIWA, 2023).

Increased temperatures result in flowering throughout the winter, which alters beekeeping practices as continued flowering causes bees to remain active and require feeding during the winter. Six out of nine Wellington Beekeeping Association Conference hand-drawn calendar participants recorded that they experienced a warmer winter, including Steve Heal, a hobbyist North Island beekeeper who stated, "The winters have been warmer." Key informants also noted increases in rainfall that were out of the ordinary. Carlos Zevallos, Head of Apiary Development for Comvita New Zealand, explained that he observed "double the normal amount of rain" last year in his region. This increase in rainfall is harmful to beekeepers, as it dilutes nectar on flowers leading to losses in honey production.

Severe storms and flooding caused by an increase in extreme weather events are also significant issues. One notable instance was Cyclone Gabrielle in February 2023. While speaking of the storm, Barry Foster, a retired Gisborne commercial beekeeper said, "I thought it was a safe site. It was high enough above a creek. There was no indication that it would flood. Well, 27 hives disappeared overnight." This storm and similar ones have caused beekeepers to rethink what locations are safe for their hives, as they can no longer rely on previous locations and practices.

FINDING: SHIFTING SEASONS AFFECT BEEKEEPERS

Phenological shifts, which are shifts to the timing of events in the natural world, and alterations in weather are causing beekeepers to adjust the timing of their beekeeping calendars (*Phenology*, n.d.). Our discussions with beekeepers and other experts revealed that flowering seasons are shifting across New Zealand, often occurring earlier or with less abundance depending on temperature. These shifts can cause temporal mismatches between bees and the plants in their environments, in which there is decreased interaction between the parties (Figure B). As Rae Butler, a prominent queen breeder from Ashburton (South Island) said, “It's flowering too early, it's kind of out of balance.”

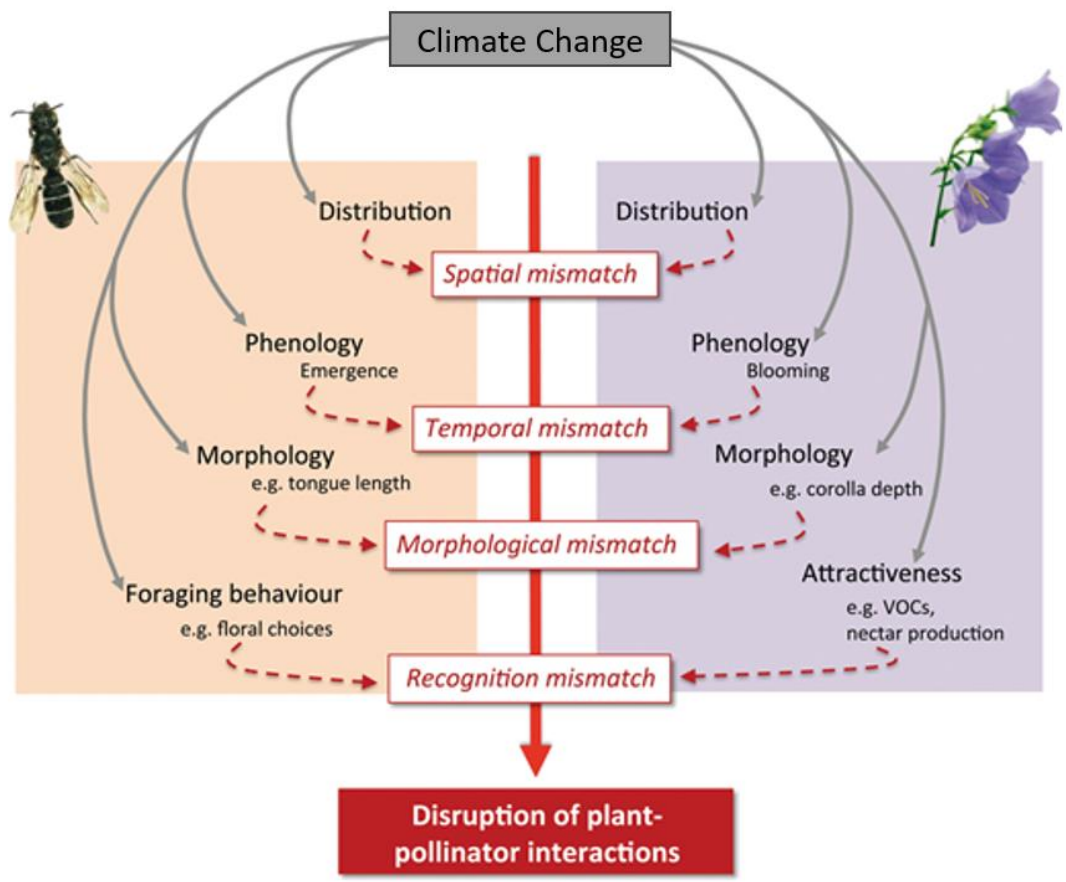


Figure B: Mismatches in different aspects of plant-pollinator interactions as a result of climate change (Gérard et al., 2020).

Shifts in the flowering seasons result in further shifts, such as unpredictable honey harvests. The most significant of these seasonal shifts relates to the threat of Varroa mites, which are parasites that feed on bees and weaken hives. Due to increases in Varroa mite populations, beekeepers now have to add additional Varroa treatments to their calendars, which is expensive. It is also becoming more difficult to treat at the proper times due to shifts in the honey harvest season, which beekeepers cannot treat during, and shifts in the broodless period, a time in which Varroa mite populations decrease. Zevallos said in response to the shifting honey harvest season, "When we used to do it in the past, we cannot do it anymore. We have to change. We need to adjust to what the weather is bringing us. Now it's unpredictable." Phenological shifts are forcing beekeepers to adapt the timing of their calendars.

FINDING: THE CULTURE OF BEEKEEPING IN NEW ZEALAND IS CHANGING

The production of Mānuka Honey is central to the New Zealand beekeeping industry. The initial surge of Mānuka production in 2016 brought many changes to the culture of the industry. Social conflicts between beekeepers, such as encroachment, stealing, and sabotage arose due to the increasing demand for Mānuka honey (Rae Butler, personal communication, January 24, 2024). According to beekeepers, the high profitability of Mānuka honey made them hesitant to share information about where they were locating their hives. New governmental regulations on honey export prevent beekeepers from mixing Mānuka honey with other types (ex. bush honey), causing honey prices to decrease to the point that some beekeepers are unable to continue in the industry (*Mānuka honey testing, n.d.)*. Rae Butler, a queen breeder and business owner with over 25 years of experience in the beekeeping industry, says, "We are not getting enough [money] per honey to cover running costs and other influences." Beekeeping in New Zealand is slowly recovering from the crash in the honey industry, and beekeepers are beginning to share information again to help each other thrive (Figure C).

Figure C: Wellington Beekeeping Association monthly meeting at Johnsonville Community Center. Steve Heal is in the bottom left filling out a hand-drawn calendar for us.

FINDING: CALENDAR DATA REVEALS BEEKEEPING SEASONS IN NEW ZEALAND

HAND-DRAWN CALENDARS

We gathered 10 hand-drawn calendars. These drawn calendars offer a deeper insight into how people view the shape of the year, what they define a season to be, how they picture a calendar, and what indicators mark the changing of an event or season. Often, interviewees would shape their calendars around the 12-month format of the Gregorian calendar (Figure D). Many were also structured around the traditional four seasons: winter, spring, summer, and autumn. These calendars give a deeper perspective into what a beekeeping calendar looks like and allows beekeepers to represent their year with full creative freedom.

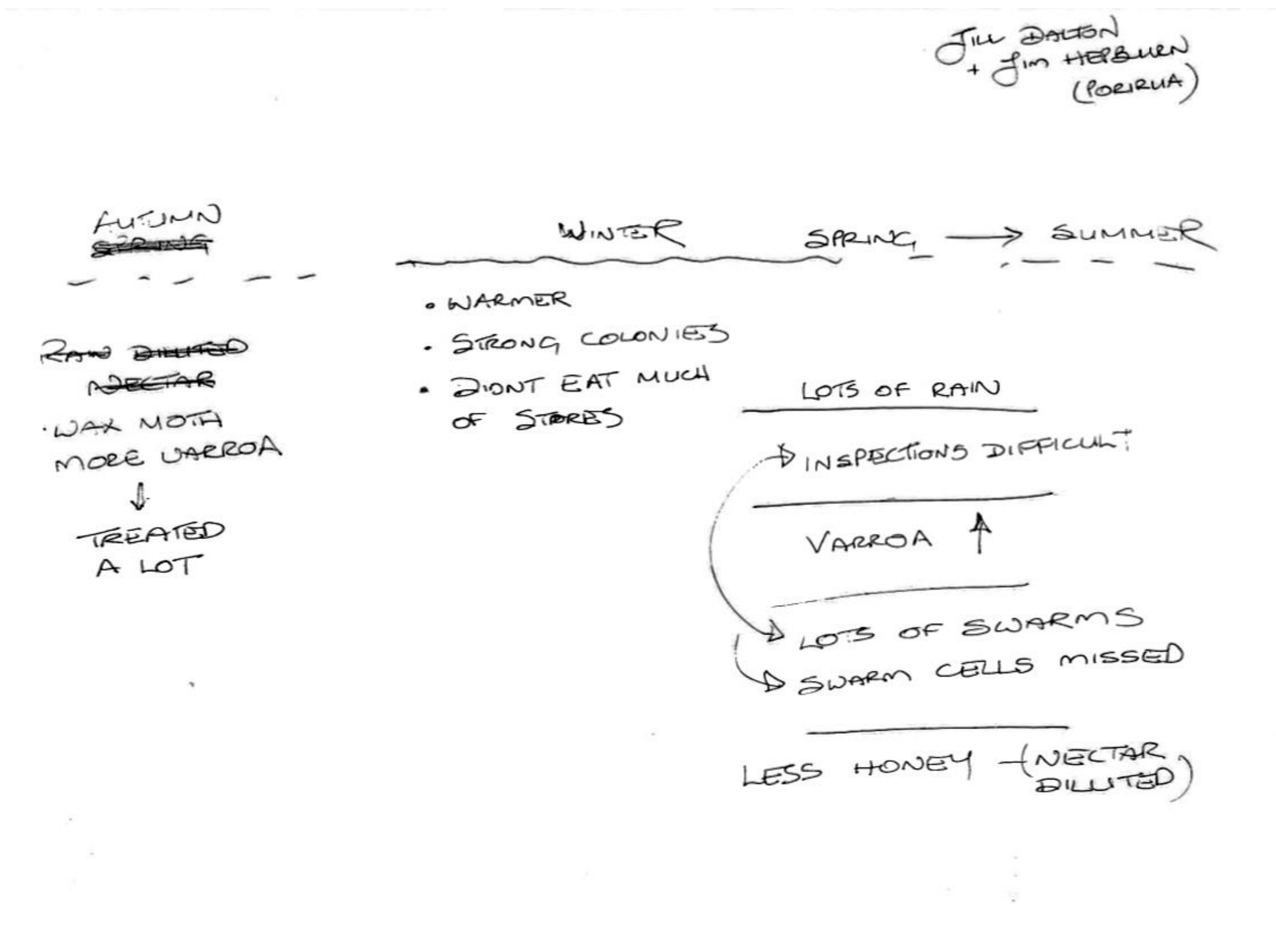


Figure D: Example of hand-drawn calendar created by North Island hobbyist beekeepers Jill Dalton and Jim Hepburn.

THE CALENDAR TOOL

We made improvements to the online Calendar Tool based on user feedback and our own observations (Figure E). Including updating the tutorial page to reflect the user experience more accurately, changing the default color and mode of the tool for ease of use, and increasing the size of the season bar to make it more user-friendly. In addition, we added a section for the user to put notes. We created a YouTube tutorial video on how to use the tool to help guide users through the calendar creation process.

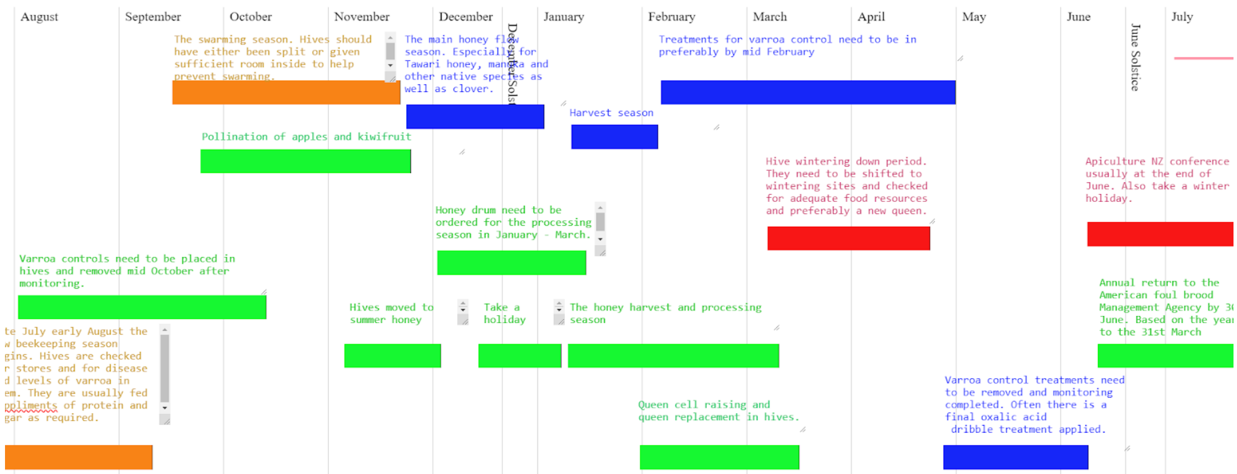


Figure E: A Calendar Tool submission filled out by beekeeper Barry Foster. The events include beekeeping practices like ordering honey drums and pollinating fruit as well as social events like the Apiculture NZ Conference and holidays.

NEW ZEALAND BEEKEEPING CALENDAR

We have discerned roughly four seasons in the calendars of New Zealand beekeepers (Figure F). This was determined by synthesizing calendar data from the Calendar Tool, hand-drawn calendars, and interviews and color coding it by event. The beekeeping year begins in August in New Zealand with population management, followed by honey flow and harvest, wintering down, and ending with a holiday for beekeepers. Varroa treatment occurs throughout the entire year.

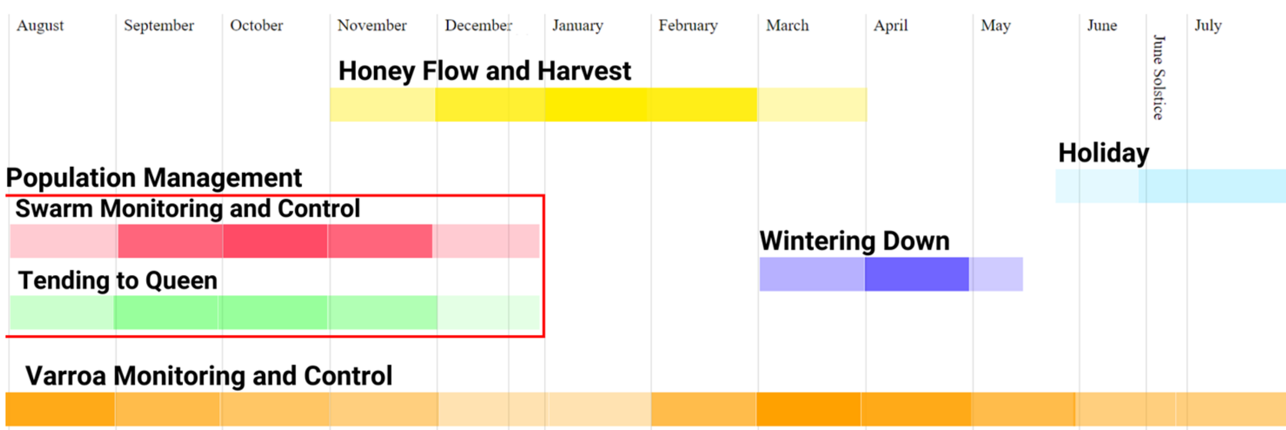


Figure F: The four main seasons of New Zealand Beekeeping: population management (red and green), honey flow and harvest (yellow), wintering down (purple), and holiday (blue).

FINDING: RESPONSES TO CALENDARS PROJECT RESEARCH QUESTIONS

1. WHAT CLIMATE CHANGE INDICATORS AND VULNERABILITIES ARE REPORTED?

The direct effects of climate change, including increased rainfall and warmer temperatures, create uncertainty and vulnerability for beekeepers. More severe storms are making beekeepers increasingly vulnerable to climate change, such as Cyclone Gabrielle. This 2023 cyclone swept hives away by floods, setting beekeepers back by years. Retired commercial beekeeper Barry Foster identified that, “If there is one stark lesson for all beekeepers in New Zealand, past benchmarks on where it is safe to locate apiaries no longer apply” (Foster, 2023, p. 6). Without the past as guidance, beekeepers can only take an educated guess of what environments and locations will be safe, leaving their hives vulnerable to future climate disasters.

2. HOW HAVE BEEKEEPING PRACTICES AND TECHNOLOGICAL TOOLS THAT SUPPORT BEEKEEPING CHANGED?

Numerous beekeepers indicated a technological intervention and then related it to a change in practice. This structure shows the interconnection between technological advancements and changes in beekeeping practices. Varroa mite specialists and beekeepers all agreed that Varroa mite is currently the most prominent issue in the industry. As Rae Butler, a queen breeder put it, “Beekeeping used to be an art, but now it's more of a science.” Due to the research into Mānuka honey in 2016-2017, more commercial beekeepers are turning to migrational beekeeping (Karin Kos, personal communication, January 24, 2024). As research increased on what locations were best for Mānuka honey, beekeepers moved their hives to these locations. According to Rae Butler, farmers shifting to sprinkler irrigation systems has been the biggest technological change to beekeeping. The increased amount of water washes the nectar off of plants and decreases honey production (Rae Butler, personal communication, January 24, 2024). Beekeepers need to be aware of changes in farming technology and the effects they have on their practices, as well as direct threats to bees, including Varroa mites, to best guide their interventions.

3. WHAT IS THE FUTURE OUTLOOK FOR BEEKEEPING AS DESCRIBED NOW BY BEEKEEPERS?

Varroa destructor is the biggest threat to beekeepers worldwide (Phil Lester, personal communication, January 19, 2024). Almost all bee colony losses in New Zealand, apart from starvation, can be credited to Varroa mites (*New Zealand Colony Loss Survey*, 2022). In addition, Tropilaelaps mites are currently found across Asia and in Papua New Guinea and are a looming threat to bees. This parasite is a vector similar to Varroa mites but spreads much faster through brood rather than staying on the bees themselves (*Tropilaelaps mites: What Are Tropilaelaps Mites?*, 2022). Beekeepers in New Zealand are worried about it eventually spreading to New Zealand, and if it did, it would be "absolutely devastating" for bee populations (Barry Foster, personal communication, January 30, 2024).

There are mixed attitudes in the beekeeping community towards what lies ahead, but one thing is consistent: New Zealand needs to have bees. Some people "don't think there's a sense of optimism in the beekeeping community in New Zealand at the moment" because of the severe threat of Varroa mites (Phil Lester, personal communication, January 19, 2024). Others are very confident, including research scientist at NZ Plant and Food Research, Dr. Michelle Taylor, who said that the future "is bright. We may lose some colonies in the interim, but we will find a way. We need to have bees."

RECOMMENDATIONS

Figure G: Close-up of a young honeybee at the Wellington Beekeeping Association beehives.

1. Additional spatial and temporal research on beekeeping in New Zealand could offer further insight beyond the scope of our project.
2. Further research on the connection between Varroa mite and climate change could reveal interesting and important findings not previously considered by New Zealand beekeepers.
3. Hand-drawn calendars offer the interviewee much more creative freedom and opportunity to reflect on their beekeeping practices and could be a beneficial method employed by future CALENDARS projects.
4. The CALENDARS Project could take our updated version of the tool and implement it on its website for further data collection.

Figure H: Close-up of a queen honeybee at the Wellington Beekeeping Association beehives.

CHAPTER 1. INTRODUCTION TO CHANGING CALENDARS

Climate change disrupts environmental-dependent activities, affecting many economic sectors, including beekeeping. Changes in weather patterns caused by climate change in New Zealand send the delicate balance between weather, plants, and pollinators, like honeybees, off-kilter. Season creep, a phenomenon of shifting seasons that disrupt ecosystems and climate-dependent activities, is a direct result of climate change (*Season Creep*, 2016). This shift changes the traditional timelines seasons are expected to follow and affects both local ecologies and economies (*Our Seasonal Cultures*, 2022). As seasonal qualities are modified by climate change, how people interpret and interact with them also changes in response. The traditional Gregorian calendar of 365 days in 12 months no longer provides a reliable outline for modern practices that rely heavily on climate and weather patterns (*Gregorian Calendar*, 2019). Seasonal calendars can be reevaluated to reflect changing environments and temporality more accurately.

Noticing a need to better understand how people adjust to changing seasons, the CALENDARS Project was founded in 2019. This is a five-year project funded by the European Research Council to conduct empirical research on how individuals and communities perceive, and experience shifts in seasonal patterns (*Funding* | CALENDARS Project 2019). The CALENDARS Project documents the repercussions of changes in traditional seasonal cycles caused by environmental, climatic, and social shifts. Gathering information from different sectors of the beekeeping industry can further the CALENDARS initiative and provide insight into the effects of climate change and its relationship to beekeeping routines. Our sponsors are Dr. Scott Bremer, CALENDARS Project Leader and University of Bergen research professor and Dr. Bruce Glavovic, a professor in the School of People, Environment and Planning at Massey University. In addition to this project work in Wellington, New Zealand, the CALENDARS Project is collaborating with other Worcester Polytechnic Institute project sites in Hong Kong; Berlin, Germany; and Mandi, India. Outside of WPI, further work has been conducted in Norway. The international collaboration between climate, social, and environmental scientists may provide an interesting comparison opportunity and could reveal how seasonal-dependent practices have been disrupted in everyday life (*Project Team* | CALENDARS Project 2022).

Shifting seasons result in a vast range of consequences on beekeeping, as honeybee activity is heavily influenced by environmental events, including climate and plant phenology. Phenology, the study of a species' life events, reveals how natural phenomena like the timing of plant flowering align with beekeeping calendars (*Phenology*, n.d.). Beekeepers must discern these phenological indicators and react based on the environment, adjusting their schedules and activities accordingly. Climate change indicators distinguished by beekeepers provide further perspective into beekeeping calendars and how phenology affects season creep. Our research will contribute to the global CALENDARS Project to assess climate change indicators, changes in practices, and the future outlook regarding beekeeping in New Zealand. We examined the influence of climate change on beekeeping in New Zealand, analyzed how beekeeping calendars have changed and how they affect beekeeping practices, and explored the dynamics surrounding beekeeping culture and economic perceptions. In addition, we improved the Calendar Tool and answered the three CALENDARS research questions, which will be used for comparison across the other WPI project sites. The questions are as follows: What climate change indicators and vulnerabilities are reported? How have beekeeping practices and technological tools that support beekeeping changed? What is the future outlook for beekeeping as described now by beekeepers?

CHAPTER 2: RESEARCH CONTEXT

This chapter investigates the delicate interplay between seasonal calendars, climate change, and climate-dependent activities, specifically beekeeping practices in New Zealand. As seasons diverge from their long-standing benchmarks, activities that depend on climate need to adapt and change to meet the current environmental conditions. Additionally, we describe the role of our project's sponsors and present previous CALENDARS Project research, highlighting the influence of shifting seasonality on specific industries.

BEEKEEPING IN NEW ZEALAND

Modern beekeeping methods have been a part of Aotearoa New Zealand since 1839 when the first non-feral bee hives arrived from England (Honey Bees Brought to New Zealand, n.d.). Today, beekeepers and their associations can be found throughout New Zealand, such as the Wellington Beekeeping Association (Figure 1). There are more than 10,000 registered beekeepers with roughly 835,000 hives all throughout New Zealand. Beekeeping is essential to New Zealand's agricultural landscape and its broader economy. From January to March 2021, honey exports were valued at approximately NZ $500 million, roughly 0.2% of New Zealand's GDP in 2021 (*To Bee or Not to Bee Is No Longer a Question*, 2021). Both in and outside of New Zealand, bees play a critical role in food and agriculture production through pollination, "contributing to 35% of the world's total crop production, pollinating 87 of 115 leading food crops worldwide" ("World Bee Day," 2023, para. 3).

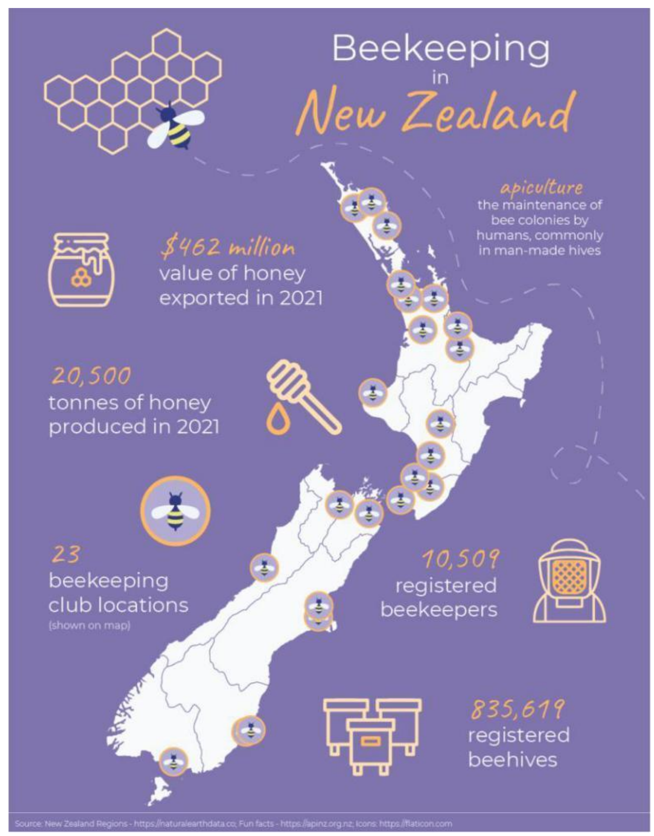


Figure 1: Locations of 23 beekeeping clubs around New Zealand along with general beekeeping facts such as amount of hives and beekeepers and the value of honey exports (Design & Harasym, 2022).

IMPORTANCE OF BEES IN NEW ZEALAND

In addition to honey exports, bees directly affect many vegetables and fruit production. The value of beekeeping extends far beyond the production of honey and produce in New Zealand: "Honey bees further contribute indirectly through the pollination of clover, which is sown as a nitrogen regeneration source for pastoral farms, thus benefiting the meat and dairy export industries through the production and sale of livestock and dairy products" (Newstrom-Lloyd & Dymond, 2013, p. 412). White clover, which is highly attractive to bees, is a primary grazing plant that allows for the efficient rearing of farm animals in New Zealand (Goodwin et al., 2011). Two of New Zealand's primary exports are products from cows and sheep, including dairy, wool, and meat, which are animals that rely heavily on white clover as a source of nutrition. With the help of bees, white clover and other plants are abundant in pastures, allowing for larger, more prosperous farms (Case et al., 2023). This pollination contributes to fruits, produce, and livestock feed and has an "estimated worth of NZ$ five billion a year to the [overall] New Zealand economy," roughly 2% of New Zealand's economy (Wellington et al., 2021, para. 4). The value of bees extends beyond their pollinating ability and into the domains of commercial products like food, pharmaceuticals, cosmetics, wood finishes, and much more.

Figure 2: Mānuka Flower and Mānuka Honey (New Zealand Farmers Encouraged to Plant Manuka, 2015; UMF 15+ Manuka Honey: the Kiwi Importer, n.d.)

MĀNUKA HONEY

New Zealand is well known for its variety and quality of honey, some of which carry unique properties from New Zealand's native flowers. Some of the most common honey types in New Zealand are Mānuka honey, clover honey, Kamahi honey, Acacia honey, and Beechwood honeydew (*New Zealand Honey Varieties - Top 5 Honey Types,* 2020). Mānuka honey, which is one of the most valuable honey varieties in New Zealand, has become sought-after worldwide (Schmidt et al., 2021). Mānuka honey is made from the Mānuka flower in New Zealand and is renowned for having "strong antiseptic, antimicrobial, antioxidant and anti-inflammatory properties" (*Mānuka* *honey benefits: 8 amazing health benefits of Mānuka Honey*, 2022, para. 3). Due to these properties, there was a so-called "Mānuka Boom" in 2016, making Mānuka honey sell for some of the highest premiums. Jo Goodhew, Minister of Food Safety for the Ministry of Primary Industries, remarked that, "New Zealand might not be the biggest supplier of honey by volume, but this value comes from Mānuka" (Luttrell, 2017, p. 14). Mānuka honey is now required to be tested in order to be labeled Mānuka honey (*Mānuka honey testing, n.d.)*. Mānuka honey has almost doubled in market size from 2018-2023, since the research on Mānuka honey showed that it has health benefits (Figure 3).

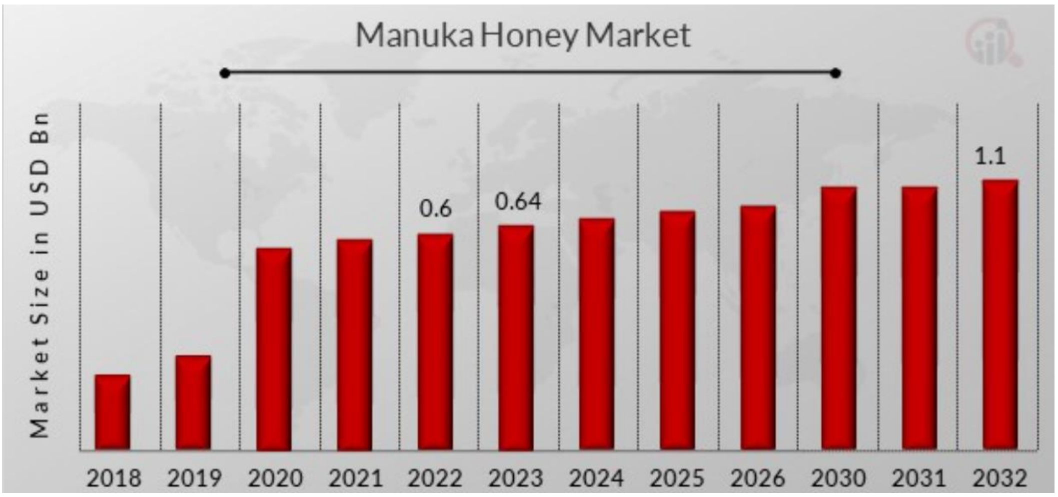


Figure 3: Market share of Mānuka honey in the global market in USD with projected growth rate (Gupta, 2022).

TYPES OF BEEKEEPING IN NEW ZEALAND

HOBBYIST BEEKEEPING

Most beekeepers in New Zealand are hobbyists, "with 88.3% of them [roughly 800,000 beekeepers] owning an average of only five hives" (*New Zealand Beekeeping*, 2019, para. 3). Hobbyists are defined as beekeepers who keep less than 50 hives (Luttrell, 2017). All beekeepers must register their hives due to the Biosecurity Act of 1993 (*Setting up as a beekeeper, 2023*). Registering hives is important for the tracking and management of diseases, especially American foulbrood. American foulbrood (AFB) is a bacterial disease that affects the brood, weaking and killing the colony. Tracking hives helps prevent the spread of disease and illegal importation. Most beekeepers follow the "beekeeping bible" known as *Practical Beekeeping in New Zealand: The Definitive Guide* (Matheson & Reid, 2018). This guide to beekeeping for beginners has five editions showing how much beekeeping has changed in 40 years mainly due to diseases. Many commercial beekeepers started as hobbyists, with one or two hives in their back garden, but then made the jump to being a full-time beekeeper (*Beekeeping in the City*, 2023).

COMMERCIAL BEEKEEPING

Commercial beekeepers own a large percentage of the hives in New Zealand, with commercial beekeepers defined as those who own more than 350 hives and use them as a source of income Luttrell, 2017). Using the minimums of hive ranges from each table, commercial beekeepers own over 350,000 hives, and hobbyists own less than 130,000 hives (Table 1).

AS AT 30 JUNE	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
5 hives or less	2,044	2,463	2,828	3,162	3,639	4,330	4,873	5,262	5,799	6,100
6 to 50[2] hives	678	774	843	964	1,109	1,446	1,781	2,017	2,151	2,214
51 to 500[3] hives	336	351	379	443	530	662	833	911	952	920
501 to 1,000 hives	109	115	122	124	129	135	155	179	192	181
1,001 to 3,000 hives	84	87	90	92	111	126	129	134	139	125
>3,000[4] hives	16	16	17	29	33	36	43	49	49	45
Total	**3,267**	**3,806**	**4,279**	**4,814**	**5,551**	**6,735**	**7,814**	**8,552**	**9,282**	**9,585**

Table 1: Summary of beekeeping enterprises by hive numbers from 2011 to 2020

In addition to needing a substantial amount of space, commercial keepers need to be conscious of over-saturating the land with too many beehives, which could cause bees to starve (*Beekeeping in the City*, 2023). Crowded bees will fight over resources, often causing the loss of hives and the spread of disease (*Beekeeping in the City,* 2023). Additionally, commercial beekeepers lend their hives to farmers during pollination seasons to get a higher crop yield (*Crop Yield Courtesy of Bees*, n.d.). In New Zealand, this is typically done with avocados and kiwifruit (Figure 4). A beekeeper who lends their hives to cattle and lamb ranchers will get land for the hives and the honey they produce, and the rancher gets more grazing food from increased pollination. Both hobbyist and commercial beekeepers must understand current and future threats that affect their livelihood, ranging from pest, pathogens, and diseases to climate change.

Figure 4: New Zealand Beekeepers migrating beehives to pollinate kiwifruit (Campbell and Haggerty, 2012).

CLIMATE CHANGE IN NEW ZEALAND

Climate change is affecting New Zealand, causing more extreme weather (Ministry for the Environment, 2023). New Zealand experienced its warmest year on record in 2022, with an average temperature of 13.76˚C, which was +1.15˚C above the 1981-2010 annual average (NIWA, 2022). This temperature surpassed the previous record in 2021 by +0.20˚C (NIWA, 2022). The top-four warmest years on record have now all occurred since 2016, a trend consistent with climate change, and seven of the past nine years have been among New Zealand's warmest on record (Figure 5). The winter in 2022 was also New Zealand's warmest winter on record, surpassing the record set in winter 2021 (IPCC, 2022). New Zealand has more warming being projected, with fewer cold days and more hot days (IPCC, 2022).

The Intergovernmental Panel on Climate Change has found that, on average, one degree Celsius of warming in the air translates to about 7% more water vapor in the air (IPCC, 2022). While water vapor of higher temperatures can be held in the atmosphere, heavier air masses result in rain bursts that can be 10 to 20% heavier (*The science linking extreme weather and climate change,* 2023).

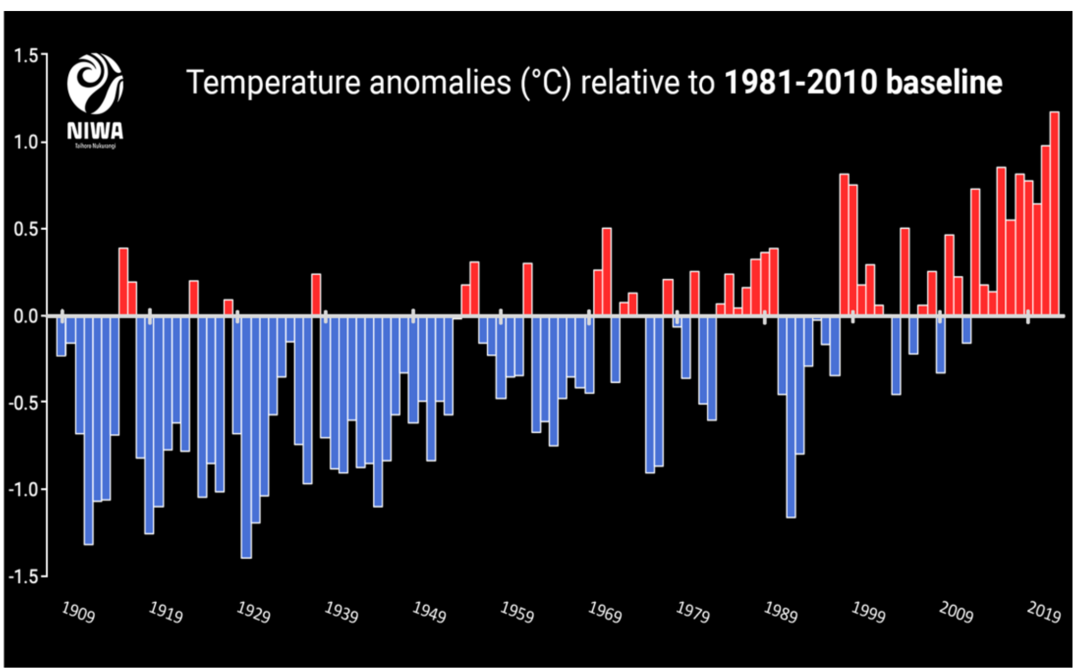


Figure 5: New Zealand temperature anomalies from NIWA's seven station series from 1909 to 2022. Blue indicates temperatures colder than the 1981-2010 baseline, red indicates temperatures warmer than the 1981-2010 baseline (NIWA, 2022).

Enhanced sea surface temperatures can also lead to higher moisture and heavier rainfall during cyclones (Bird et al., 2023).

Another effect of atmospheric warming is the increase in the extent and frequency of the atmospheric rivers that affect Aotearoa New Zealand. Atmospheric rivers transport most of the water vapor outside of the tropics in relatively long, narrow regions of the atmosphere (NOAA, 2010). Climate change is modeled to result in a 60% increase in the frequency of atmospheric rivers and a 20% increase in their strength in the southern mid-latitudes (Shu et al., 2021). NIWA, the National Institute of Water and Atmospheric Research, projects that an increase in the frequency and extent of these atmospheric rivers (ARs) will bring more rain to New Zealand (NIWA, 2020). Atmospheric river storms are found to create greater than two times more daily rainfall than non-atmospheric river storms, including storms that are greater than three times the amount for the west side of mountainous areas of the South Island and northern areas of the North Island. Depending on the region of New Zealand and the season, “40–86% of the rainfall totals and 50–98% of extreme rainfall events are shown to be associated with ARs” (Shu et al., 2021, p. 11). This relationship is even more severe during the winter seasons (Shu et al., 2021, p. 11). The IPCC projects an increase in heavy rainfall intensity, along with greater proportions of severe cyclones (IPCC, 2022). Climate change is directly affecting the intensity of rainfall in certain regions in New Zealand, specifically the west of the South Island and north of the North Island (Figures 6 & 7).

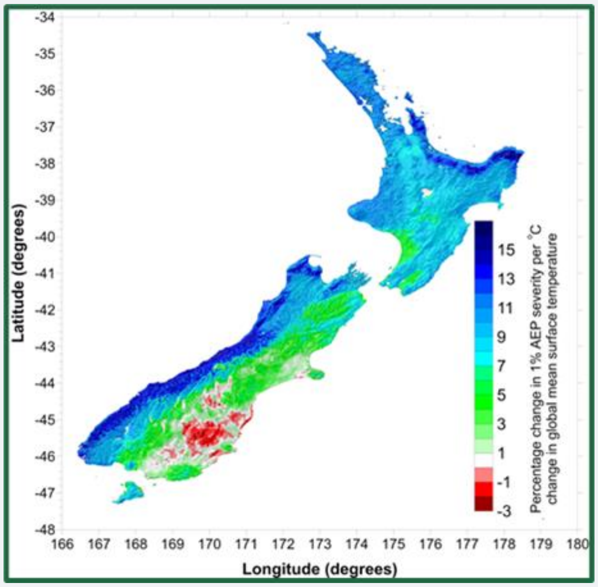


Figure 6: How much precipitation a once in a century severe rainfall event might bring with a change of 1.1°C global temperature for New Zealand (Bird et al., 2023).

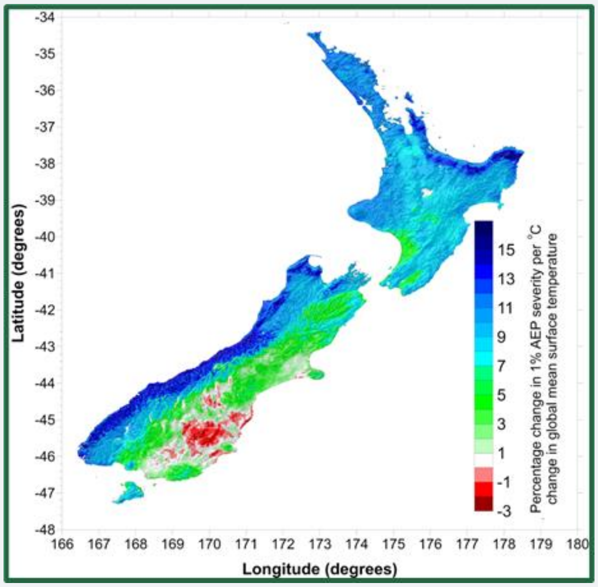


Figure 7: Percentage change in the intensity of a once in a century rainfall event per 1.1°C increase in global temperature (Bird et al., 2023).

In recent years cyclones have shown stronger winds and more intense and frequent rainfall (Nayak & Takemi, 2023). NIWA projects more intense regional cyclonic storms in the southern hemisphere by 2100 (NIWA, 2007). While many areas of New Zealand are projected to experience increased rainfall, including more winter and spring rainfall in the west and more summer rainfall in the east, other regions are expecting much less (IPCC, 2022). The east and north of the South Island can expect less winter and spring rainfall, while the west and central North Island can expect less in the summer (IPCC, 2022). Drought is also projected to be more prominent in the north due to rises in greenhouse gas emissions (Figure 8).

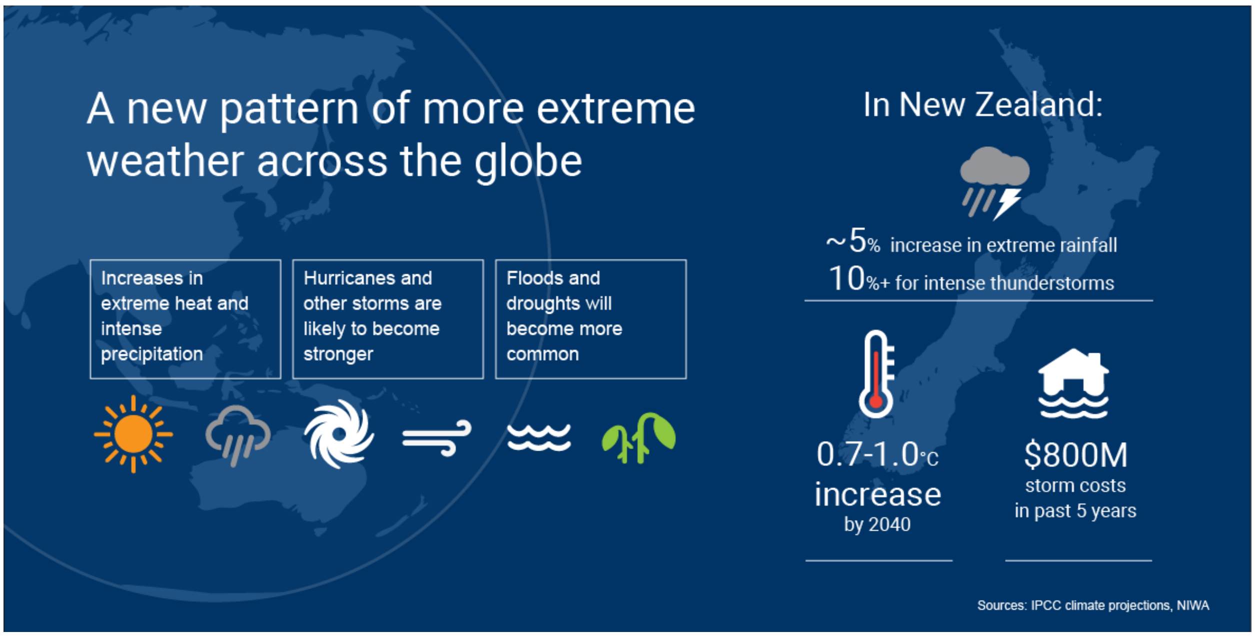


Figure 8: Summary of predicted and measured effects of weather in New Zealand due to climate change (NIWA, 2023).

In addition to increases in rain and drought, the sea level directly affects New Zealand as it is a coastal country. If there is a 0.5 m, as is projected by 2100, of sea level rise (SLR), it will have an estimated cost to New Zealand of NZ$ 12.75 billion if there is a 1-in-100-year coastal inundation (IPCC, 2022). In the last century, the sea level around New Zealand has risen by 0.16 m (Hopkins et al., 2015). A rise in sea level affects New Zealand due to an increase in flooding of low-lying coastal areas. With rising sea levels, larger storms, and bigger waves, "areas of inundation are expected to expand significantly" (Mimura, 2013, para. 50). Consequently, this flooding affects new areas that were not previously thought to be at risk. SLR is projected to cause more frequent flooding in New Zealand before mid-century.

New Zealand is 1°C warmer	→	7% more water vapor in the air
Increased sea surface temperature	→	Higher moisture and heavier rainfall during cyclone
Atmospheric warming	→	20% increase in strength and 60% increase in frequency of Atmospheric Rivers

Figure 9: Climate Change effects on New Zealand

CLIMATE CHANGE EFFECTS ON BEES

New Zealand is being threatened by the progression of climate change. The National Institute of Water and Atmospheric Research (NIWA) is predicting wilder weather in the next 50 years (NIWA, 2020). Temperature fluctuations, more extreme heat and colds, extreme weather events, and extreme rain and wind have led to changes in blooming periods that threaten bee health by reducing their typical food sources (Borghi et al., 2019). This disrupts the synchronization of bee foraging behavior and flowering periods, as if "spring arrives earlier in the year, flowers bloom earlier or in different regions, but bees may not be present to feed on them" (Kerlin, 2022, para. 3). In addition, climate change is affecting both pollinators and plants, creating a spatial, temporal, morphological, and recognitional mismatch due to changing foraging behavior (Figure 10).

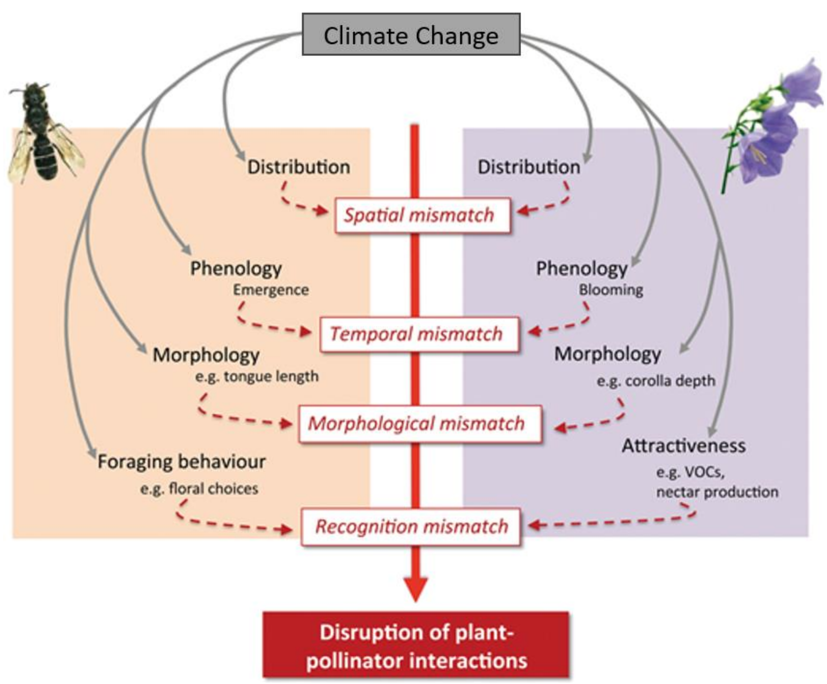


Figure 10: Mismatches in different aspects of plant-pollinator interactions as a result of climate change (Gérard et al., 2020).

In addition, climate change has reportedly reduced colonies' health. Research has shown that when bees experience a simulated heat wave (SHW), they have an increase in colony activity in the afternoon as well as a larger perturbation [mental uneasiness] in colony activity (Bordier et al., 2017). As ambient temperatures around a hive increase, the number of water-foraging bees in the hive needs to also increase, putting more stress on the hive (Bordier et al., 2017). This increase in temperature also brings up aspects of Bergmann's rule, a rule stating that species of larger size are found in colder climate and species of smaller size are found in warmer climates, in relation to the morphology of both flowers and bees. With changing temperatures and out-of-sync clocks, pollinators could follow Bergmann's rule before or after plants have adapted, this would cause starvation in certain pollination species due to tongue size not matching plants' anther size (Gérard et al., 2020). This mismatch is due to the migration of bees for warmer weather, a spatial mismatch causing the evolution of a shorter tongue, a morphological mismatch (Gérard et al., 2020).

More intense rainfall events and windier weather challenge bees' ability to mate and find resources, weakening bees. This makes them more susceptible to disease and less productive (Kerlin, 2022). Bees are very sensitive to their environment; they "can sense changes in humidity, temperature, and barometric pressure" (Allon, 2021, para. 4). Changing weather greatly affects bees due to their survival needs and ability to detect when plants bloom for the plant's nectar. The escalation of season creep due to anthropogenic climate change, such as rising temperatures, is causing plants' and bees' clocks to fall out of sync (Bordier et al., 2017). Both "Plant and insect phenology may respond to different environmental cues or different thresholds of the same cue and thus may not respond equally to climate change" (Schweiger et al., 2010, p. 779). The increase in extreme weather conditions has caused bees to shift their working habits due to hive needs, which changes beekeeping calendars and causes stress to the hive (Allon, 2021).

Extreme weather conditions are prominent in coastal countries, such as New Zealand, where warming and rising sea levels from climate change cause monumental shifts in long and short-term weather patterns due to changing atmospheric river flows. This extreme weather often causes stress and sickness in bee colonies. When bees get severely stressed, typically caused by a lack of food sources, upcoming winter, or heat levels, the "altered colony behavior as a result of environmental conditions can result in increased disease levels" (Calovi et al., 2021, p. 9). Beekeepers are struggling to maintain hives due to diseases, including American foulbrood and *Varroa destructor*, and the total number of hives has slowly decreased worldwide since the 1940s (Stahlmann-Brown et al., 2022).

VARROA DESTRUCTOR

Varroa destructor are the external parasites of honey bees. They are the size of a sesame seed on bees. Comparatively, this is similar to a human with a frisbee-sized parasite. These mites attack honey bees, feeding on their body fat and suppressing the immune system of both the bees and their hives (Lester et al., 2022). Varroa are efficient vectors for spreading bee diseases, as they can also transfer viral particles to larvae. These infections can continue into adulthood, resulting in viruses such as the deformed wing virus. If beekeepers do not conduct periodic treatments, most bee colonies in temperate climates will collapse in a two-three-year period (Rosenkranz et al., 2010).

In 2000, Varroa mites arrived in New Zealand in a still unknown way, and as of autumn 2021, they were present in at least 65-70% of New Zealand hives (Lester et al., 2022). According to the 2022 New Zealand Colony Loss Survey, beekeepers have had no choice but to treat this increasing threat of mites. Out of all respondents from the 2021-22 season, only 1.5% of beekeepers did not treat Varroa (*New Zealand Colony Loss Survey* 2022). In 2022, every beekeeper with more than 50 colonies needed to treat, despite not being required by law (*New Zealand Colony Loss Survey* 2022). The threat of Varroa has since surpassed colony loss due to problems with the queen bees of hives, becoming the largest cause of colony loss at 38.9% in 2021 (Stahlmann-Brown et al., 2022). Due to increases in Varroa populations, beekeepers are now struggling to adequately treat this threat, with the main cause of Varroa attributed to colony loss due to treating at the wrong time (Figure 11).

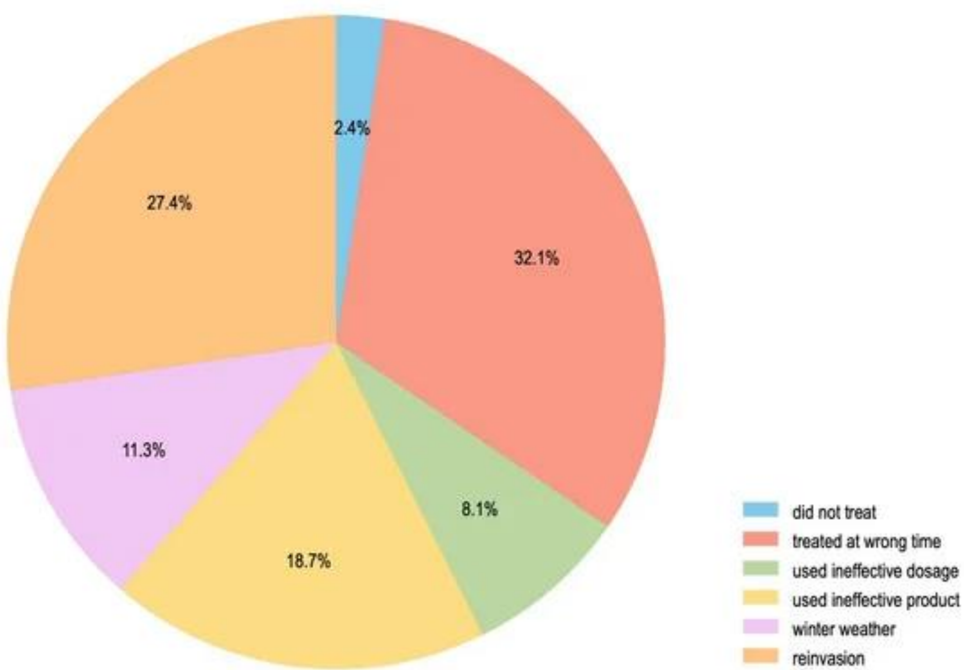


Figure 11: Colony loss survey response for colony losses attributed to Varroa during winter 2021 (Stahlmann-Brown et al., 2022).

CALENDARS PROJECT FOUNDATIONAL WORK

LAUNCHED IN BERGEN NORWAY

The sponsors for this project, the CALENDARS team, is composed of social, environmental, and climate researchers at the University of Bergen, Norway. In 2019, the group formed with the research goal of understanding how seasonal calendars are represented in varied communities and cultural frameworks and determining if these experiences are still an accurate reflection of the year in the face of climate change (*Our Seasonal Cultures*, 2022). In Bergen, the research has been wide-ranging, including investigating seasonal pattern perceptions in primary and secondary school calendars (*CALENDARS Project*, 2022). Researchers found that each student has their own vision of what a year looks like in the same way that each beekeeper has their own rhythm for their yearly actions (Figure 12). In both cases, individuals in these groups had various influences on their calendars, highlighting the broad range of information found in the CALENDARS Project.

Figure 12: A modern representation of a Norwegian calendar of symbols, hand-drawn by a Bergen primary school student in 2019. The symbols on each month show how the student perceives that time of the year (Our Seasonal Cultures, 2022).

SEASONAL REPRESENTATION THROUGH CALENDARS

The CALENDARS team is researching the relationship between seasonal calendars and the extent to which communities are falling out of sync as traditions are disrupted by climate change and new seasonal calendars are adapted (*The Research Approach*, 2022). Their work highlights that seasons are merely a cultural framework with a unique meaning and experience for different locations and communities (*Our Seasonal Cultures*, 2022). At the same time, seasonal rhythms are changing, and cultural and meteorological calendars no longer match ways of life. Recent research has focused on cases including: “farming practices disconnected from a changing climate; fishing rhythms upset by altered ocean habitats; festivals detached from an increasingly diverse society; or obsolete seasonal objects under technological advancement” (*Our Seasonal Cultures*, 2022, para. 2). Climate scientists will describe a year of changes in rainfall and temperature data, but the CALENDARS Project findings show that it is more complex than this. Instead, looking at calendars with a temporal gaze, “to explore how and by whom the times in which we live become told” offers a deeper perspective and a better understanding of seasonal perception (Phillips, 2019, para. 3).

Funding for the CALENDARS Project from the European Research Council is extending into summer 2024, with an increased focus on expanding outside of Norway and New Zealand to investigate further climatic, environmental, and social implications of seasonal representations (*CALENDARS Project*, 2022). Seasonal rhythms in communities are thrown off track as their calendars become disconnected from important cultural events due to environmental changes (*Our Seasonal Cultures*, 2022). For each unique community and location, there is a culture intertwined with specific seasons, dependent on environmental, social, and technological frameworks (*Our Seasonal Cultures*, 2022). The aim is an adapted comprehension of seasons in relation to calendars.

PREVIOUS CALENDARS RESEARCH: CASE STUDIES

1. BEEWARE

The CALENDARS team published the “BeeWare” project, which depicts the correlation between weather and bees and their interplay in Bergen, Norway. Data correlation findings between hive weight and temperature throughout the year sparked interest and conversations among beekeepers at a conference in Norway. The investigation showed that warmer temperatures without extreme weather caused increased honey production in hives, leading researchers to investigate other ways climate may affect bees (Dunn-Sigouin et al., 2022).

2. VITICULTURIST’S PERCEPTIONS OF SEASONAL CALENDARS

In 2020, Worcester Polytechnic Institute students sought to understand and record how seasons and calendars influence the practice of winemaking in New Zealand (Hayden et al., 2020). They investigated how season creep affects winemakers in New Zealand and documented “individuals’ experiences and perceptions of seasons and the calendars they use” (Hayden et al., 2020, p. ii). Their team also created a prototype for an interactive online Calendar Tool for data collection (Figure 13).

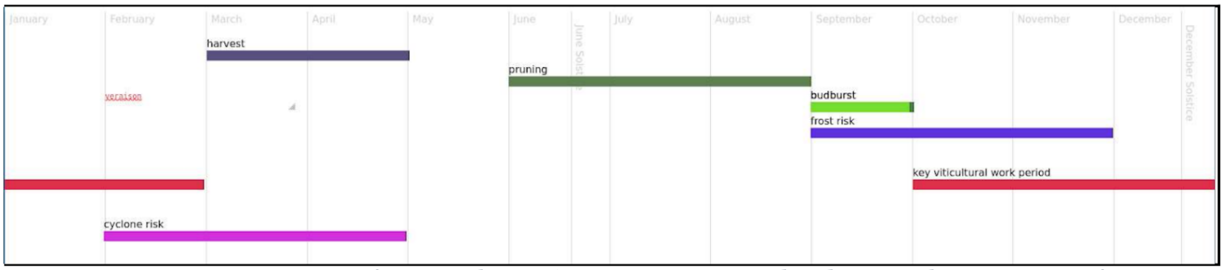


Figure 13: A representation of a viticulturist's year in New Zealand using the prototype for an interactive calendar tool, highlighting winemaking and weather (Hayden et al., 2020).

Their findings indicate that viticulturists react based on their crops rather than specific calendar dates or seasons, for example, knowing it is the spring season when sap appears on the vines. Winemaking further affects how they perceive other seasons and activities throughout the year since their entire calendar framework is built around their duties in viticulture, as evident in their depictions with the Calendar Tool.

SUMMARY

The alteration of seasonal rhythms due to climate change is causing a misalignment between climate-dependent activities and the environments in which they operate. Bees are heavily tied to the environmental and economic landscape in New Zealand and elsewhere, and beekeepers need to make a continued effort to evolve their practices to account for changing climates.

CHAPTER 3: METHODOLOGY

GOAL STATEMENT

Our research will contribute to the global CALENDARS Project to assess climate change indicators, changes in practices, and the outlook regarding beekeeping in New Zealand.

OBJECTIVES

1. Examine the influence of climate change on beekeeping in New Zealand.
2. Analyze how beekeeping calendars have changed and how they affect beekeeping practices.
3. Explore the dynamics surrounding beekeeping culture and economic perceptions.
4. Improve the prototype Calendar Tool and answer the three CALENDARS research questions.

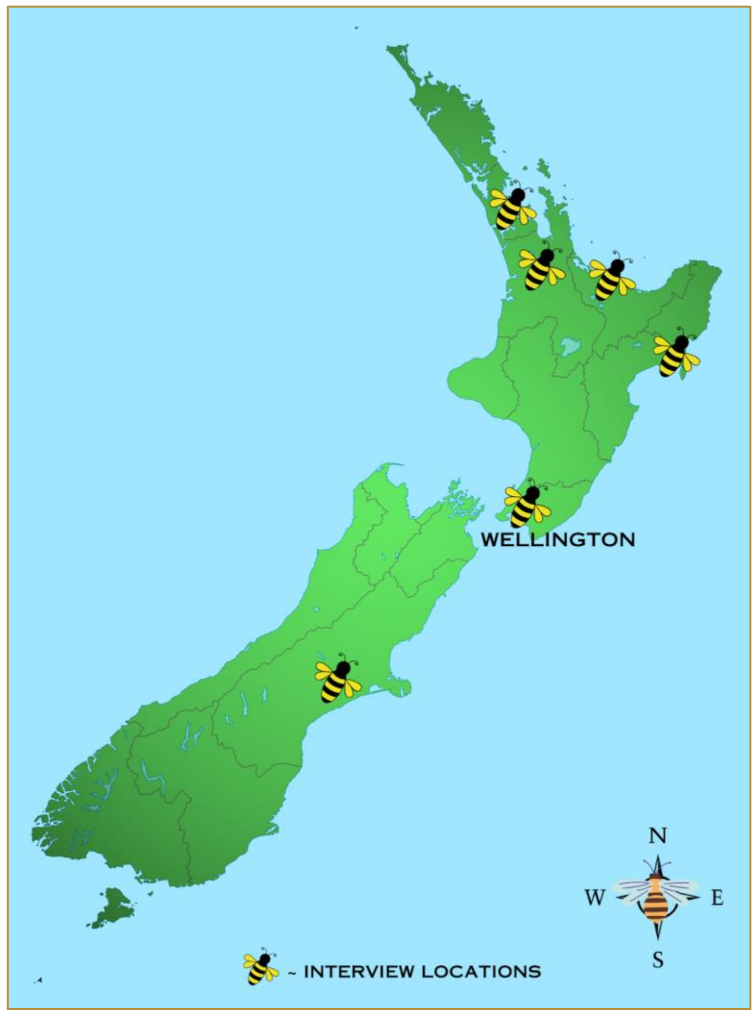


Figure 14: A map of New Zealand labeled with the locations of our interview participants.

This chapter outlines how we addressed our project goal and objectives and describes how we executed our work in Wellington. We used mixed methods including in-person and virtual interviews, site assessments, participant observation, photo documentation, hand-drawn calendars, and the prototype Calendar Tool (Figure 14; Table 2).

Key Informant	Title	Location
Dr. Greg Bodeker	• Owner and Director of Bodeker Scientific (atmospheric research company) • Previous adjunct professor at Victoria University in Wellington researching climate change • Previous climate scientist at NIWA	Wellington, North Island
Rae Butler	• More than 25 years of experience in the beekeeping industry • Varroa sensitive hygiene specialist • Queen honey bee breeder • Bee Smart Breeding business owner	Ashburton, South Island
Barry Foster	• More than 45 years of beekeeping • Former president of the National Beekeepers Association • Partially retired commercial beekeeper • ApiNZ board member	Gisborne, North Island
Karin Kos	Chief Executive of Apiculture NZ	Wellington, North Island
Dr. Phil Lester	4. *Varroa destructor* researcher at Victoria University of Wellington 5. Biology professor at Victoria University	Wellington, North Island
Frank Lindsay	• More than 50 years as a hobbyist beekeeper • Wellington Beekeepers Association member • Former author in The New Zealand Beekeeper • New Zealand New Year Honours Award Recipient 2023	Wellington, North Island
Alistair Little	More than 30 years as a hobbyist beekeeper	Auckland, North Island
Bill McDonald	Owner of Bee Fresh Farms which sells Wellington Mānuka Honey Company honey	Wellington, North Island
Dr. Daithi Stone	Climate Scientist at NIWA (National Institute of Water and Atmospheric Research)	Wellington, North Island
Dr. Michelle Taylor	• Research scientist at NZ Plant & Food Research • Focuses on bumblebee and honey bee research • Researcher in *Varroa destructor* control	Te Puke, North Island
Carlos Zevallos	Head of Apiary Development for Comvita, New Zealand	Hamilton, North Island

Table 1: List of key informants.

SEMI-STRUCTURED INTERVIEWS

The most important method that was common across all objectives were in-person and virtual interviews. Our sampling strategy to obtain interviewees was a mix of snowballing from previous interviews, recommendations from sponsors, and scanning the internet for relevant contacts in New Zealand. We executed snowball sampling by asking each interview participant if they knew of any other contacts, we would benefit from speaking to. We were most interested in talking to key informants in the beekeeping industry, but contacts involved with Varroa mite research and other related fields were accepted. In addition, many interviewees sent us follow-up documents and resources that furthered our research. We focused our initial search in Wellington and later expanded further to more northern parts of the North Island as well as the central region of the South Island. We sought out beekeepers and other experts in the industry around New Zealand to provide a broader view of the beekeeping scene in New Zealand (Table 2). This necessitated that we conduct interviews both in person and virtually, through Zoom or cell phone calls.

The questions for these interviews were loosely structured and open-ended, allowing for the flexibility of probing follow-up questions and developing improved questions for further research. This method encourages two-way communication, allowing both parties to build a rapport (Ward, 2014). Through in-person interviews, we created a better connection which led us to more opportunities. Additionally, we utilized Zoom, phone calls, and email correspondence to gather information from individuals who were outside of our travel range but still important to talk to.

We asked a specific set of questions important to the CALENDARS Project in each interview (Table 3). These questions will also be used in other project sites investigating beekeeping, providing the CALENDARS team with comparison points between these locations. However, we were not limited to only these questions; the other questions that were more pertinent to our project are listed in Appendix A.

1. **How have beekeeping practices and technological tools that support beekeeping changed?**
2. **What is the future outlook for beekeeping as described now by beekeepers?**
3. **What climate change indicators and vulnerabilities are reported?**

Table 2: The three CALENDARS Project research questions.

METHODS BY OBJECTIVE

OBJECTIVE 1: EXAMINE THE INFLUENCE OF CLIMATE CHANGE ON BEEKEEPING IN NEW ZEALAND.

We looked to identify the direct and indirect effects of climate change that were observed and noted by beekeepers, other industry experts, and researchers. We used interviews, hand-drawn calendars, and Calendar Tool submissions to collect data. We aimed to connect climate change with observed indicators to determine their effects on beekeeping practices.

We conducted semi-structured in-person and Zoom interviews with beekeepers and beekeeping organizations to gather data related to climate change in New Zealand. We asked focused questions (Appendix A) to gather data directly related to climate change including indicators, vulnerabilities, and trends. We also talked to climate scientists to help better contextualize our findings of the New Zealand climate.

We conducted interviews in various locations across the North Island and South Island of New Zealand. There are great differences in the ways climate change affects different parts of New Zealand. In surveying key informants across many regions of New Zealand, we hoped to reveal these differences as they related to beekeeping practices.

OBJECTIVE 2: ANALYZE HOW BEEKEEPING CALENDARS HAVE CHANGED AND HOW THEY AFFECT BEEKEEPING PRACTICES.

This objective aimed to identify and analyze changes in beekeeping calendars in the apiculture industry. We collected data from semi-structured interviews, hand-drawn calendars, and Calendar Tool submissions from across New Zealand to discern trends and patterns in seasonal calendars. We also uncovered the reasons for specific changes to beekeeping calendars and practices by exploring all potential factors including climatic, cultural, and technological changes.

In our in-person and virtual interviews, we collected data using the prototype Calendar Tool (Appendix B). We updated the tool based on collected user feedback. The tool is an interactive way for beekeepers and other relevant experts to input events that make up their beekeeping calendar under the structure of the Gregorian calendar. Before each interview, we asked our beekeeper key informants to input their data into the Calendar Tool to guide what questions we would ask during the interview. During our in-person interviews, we asked them to draw a calendar by hand with pen and paper to portray their perception of the beekeeping year with full creative freedom. Hand-drawn calendars offer a creative representation of seasonality unique to each person, varying on how they view their year. This hand-drawn calendar method was utilized at a Wellington Beekeeping Association conference we attended where we obtained calendars from nine beekeepers.

OBJECTIVE 3: EXPLORE THE DYNAMICS SURROUNDING BEEKEEPING CULTURE AND ECONOMIC PERCEPTIONS.

This objective focuses on determining the cultural and economic influences on the beekeeping industry in New Zealand. We interviewed both hobbyists and commercial beekeepers to see how the practices they follow and the technologies they use differ. From this, we were able to distinguish how both cultural and economic factors influence their practices, as for many people, beekeeping is their livelihood as well as their passion. Additionally, we interviewed a broad range of other experts including commercial business owners, the Chief Executive of Apiculture New Zealand, honey bee health and Varroa mite researchers, and climate scientists to view beekeeping through a wide lens and also consider varying opinions on what the future holds for beekeepers. These different angles provided perspectives on how cultural and economic aspects influence approaches in beekeeping and related fields.

Site assessments were an important method to supplement this objective. They offer a visual understanding of the immediate environment surrounding beekeeping operations. We conducted site assessments at the Wellington Zoo and Wellington Botanical Garden to see their bee hives. At Wellington Zoo, we read the information in their beekeeping exhibit and at the Wellington Botanical Garden, we took photos of bee hives. We also visited the Wellington Farmers Market where we browsed the local Bee Fresh Farms honey stand and made contact with the shop owner and CEO Bill McDonald, who we later interviewed. Our site assessment led us to beekeeping contacts.

We took every opportunity to interview beekeepers, and one interview led us to a follow-up participant observation. We were able to visit the Wellington Beekeeping Association beehives with Frank Lindsay and observe the work of beekeepers up close while also participating in the beekeeper practices by putting on beekeeping suits. We interacted with the beehives up close, held bees in our hands, tasted honey straight off the comb, and saw Varroa mites on tracking plates under the hive. This approach helped to supplement our interview data, as being physically immersed in the hives enhanced our understanding of beekeeping technologies and practices. This was a crucial method to help us with the objective revolving beekeeping culture. It was clear how much passion and knowledge Frank Lindsay held for his beehives. allowing us to gain a deeper understanding of the culture. Personal perspectives are valuable for understanding aspects of the beekeeping scene. Throughout our participant observation process, we also took pictures with a digital camera to capture visual documentation of the places we visited. Through these, we depict the technologies and practices found in the New Zealand beekeeping environment, helping us to better understand beekeeping culture.

OBJECTIVE 4: IMPROVE THE CALENDAR TOOL AND ANSWER THE THREE CALENDARS RESEARCH QUESTIONS

THE CALENDAR TOOL

Increasing the user-friendliness of the Calendar Tool is an important objective to allow for the CALENDARS Project to potentially implement this tool on the University of Bergen's website. This would enable people from around the world with internet access, the ability to fill out the tool for various activities at the discretion of the CALENDARS Project's needs.

To determine the Calendar Tool's usability, we asked our interview participants about their user experience with the Calendar Tool to see how we could improve its user-friendliness. We simply added a question to the interview, a sample of what we asked can be found in Appendix A. We asked participants how easy the online Calendar Tool was to understand and fill out, as well as asking if there was any way we could make additions or changes to improve the user experience. The prototype Calendar Tool was updated accordingly with each suggestion made by our interviews. The suggestions that were not feasible in the time frame for this project are posed in the recommendations section. Appendix B shows the state of the prototype Calendar Tool as we received it.

The Calendar Tool is extremely important in attaining raw data from interview participants. It allows them to input events of any length of time, in any location on the map of the months, gives an option to add additional text, and also provides the opportunity to choose different colors. From Calendar Tool submissions we were able to obtain a view of our interviewees' calendar perceptions.

HAND-DRAWN CALENDARS

Hand-drawn calendars were also an important method to gather calendar data. We sent out the Calendar Tool as a precursor to our interview to get a sense of how our interviewee defined their beekeeping calendar. While we conducted the interview, we would ask the interviewee to draw out their calendar. This offered them the creative freedom to format their calendar in any way they saw fit. Interview participants explained the events more in-depth as they were drawing, allowing us to take notes of the things they were saying and later relate them to the drawings. Our group interpreted each hand-drawn calendar into the Calendar Tool for comparison purposes between all our calendar data. This helped us analyze the data by making our own color and location code to clearly see any seasonal blocks or other patterns in all of our calendar data from both hand-drawn calendars and the prototype Calendar Tool submissions. We retained the raw, authentic data from our interview participants, and we did not make any changes. Together with the Calendar Tool, the interpretations gave a picture of the calendar data and allowed us to discern patterns in the data.

CHAPTER 4. FINDINGS

INTRODUCTION TO ANALYSIS OF BEEKEEPING IN NEW ZEALAND

We discovered several critical themes in beekeeping in New Zealand. These themes each shed light on the challenges and opportunities for New Zealand beekeeping. Central to New Zealand is the production of Mānuka honey. The initial surge of the industry in 2016 brought many changes to the culture in the industry. Consequently, this has created many economic struggles and pressures. We were able to identify many indicators of climate change observed by beekeepers. Our key informants reported indicators like erratic weather patterns, seasonal fluctuations and timings, changing flowering patterns, and others. Beekeepers must reconsider the times at which they navigate their beekeeping year. In many cases, beekeepers must pay closer attention to bees as their phenological events undergo alterations. Rather than following a set calendar, many beekeepers need to be more in tune with their bees. Additionally, the threat of *Varroa destructor* is at the forefront of changing beekeeping technology and research. Understanding how to combat this parasite is the most prevalent issue facing the beekeeping community today.

Figure 15: Beekeeper Frank Lindsay at the Wellington Beekeepers Association beehives.

CLIMATE CHADNGE THROUGH THE EYES OF BEEKEEPERS

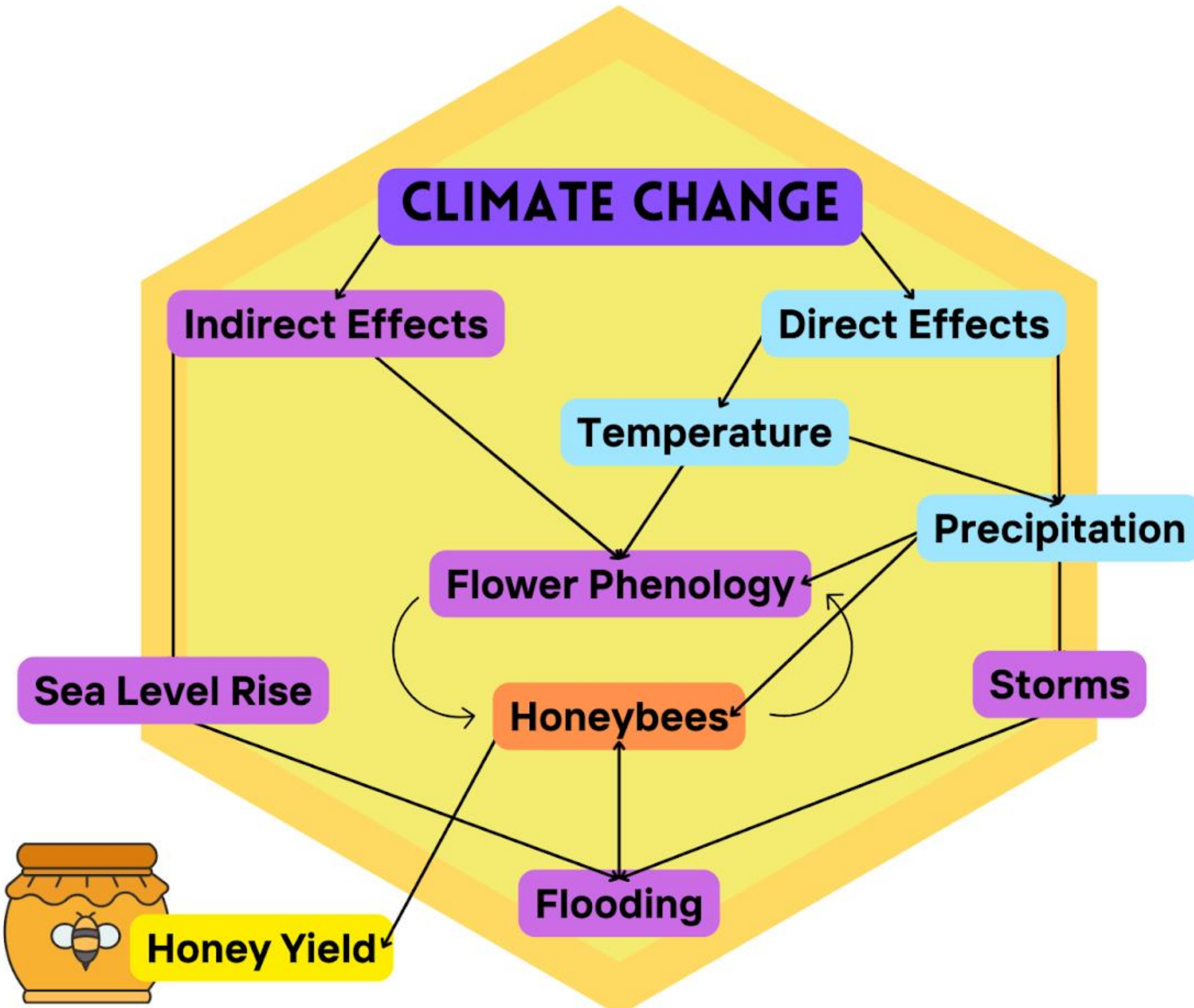


Figure 16: Direct and indirect effects of climate change and their relation to New Zealand bee industry. These climate change aspects are extremely interconnected and affect honeybees and their honey yield.

TEMPERATURE CHANGES

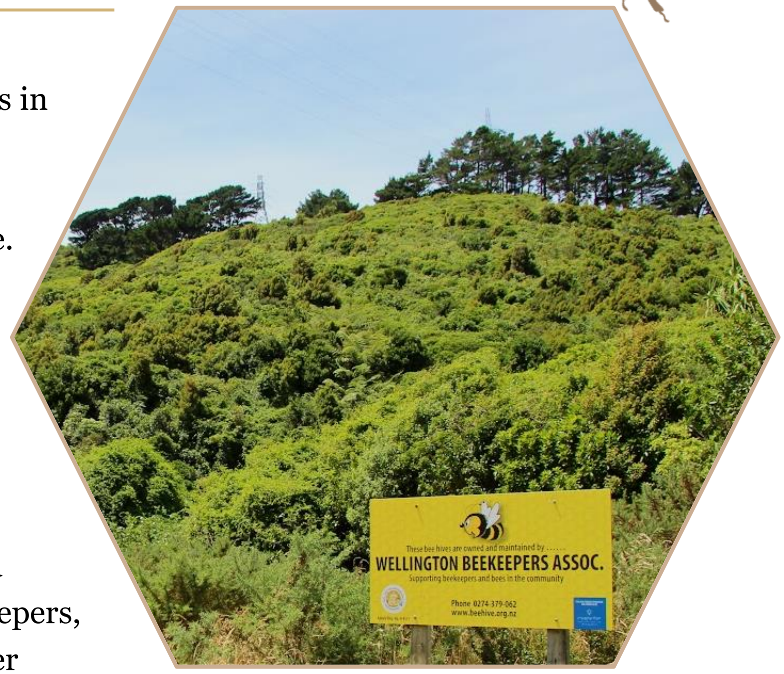


Figure 17: Wellington Beekeepers Association entrance.

Many beekeepers are experiencing changes in weather that echo climate change science. New Zealand has experienced a warming trend and record heat over the past decade. Beekeepers have noticed this temperature increase, including Steve Heal, a hobbyist North Island beekeeper, who noted that “The winters have been warmer.” Six out of nine Wellington Beekeeping Association Conference hand-drawn calendar participants experienced a warmer winter as well. Experienced beekeepers, such as Frank Lindsay, a 50-year beekeeper from Wellington, are increasingly concerned with this trend, as he stated, “Last year was so warm” and that “it was just so warm.” These changes affect beekeeping practices, as increased heat results in flowering throughout winter. Continued flowering causes bees to remain active and require feeding during the winter period. Unfortunately, this shift can result in beekeepers missing feeding windows, including Frank Lindsay who lost six hives due to this shift. Increased heat can even lead to flowering being shifted by years, as some species flowering biannually are now flowering every fourth year instead of every second year (Frank Lindsay, personal communication, January 17, 2024). This shift affects the resources available for bees foraging and can create temporal and recognition mismatches, in which bees do not know when to look for certain species.

PRECIPITATION INTENSITY

Climate change has a direct effect on precipitation intensity and frequency which can have an influence on bees and beekeeping. In interviews, hand-drawn calendars, and Calendar Tool submissions, many key informants noted increases in rainfall that were out of the ordinary. Carlos Zevallos, Head of Apiary Development for Comvita New Zealand, explained that he observed “double the normal amount of rain” last year in his region. From the hand-drawn calendars we received at the Wellington Beekeeping Association conference, Michele Vandaalen, an Upper Hutt hobbyist beekeeper, made note that “last year was very wet.” This makes it more difficult for beekeepers to do inspections because the bees do not leave the hive as much due to the rainfall. This leads to all kinds of problems for beekeepers especially when it comes to checking and treating for Varroa mites. Similarly, another hand-drawn calendar from hobbyist beekeepers Jill Dalton and Jim Hepburn stated that they had gotten “lots of rain” in Porirua, which was unusual for their area. They also added that this made inspections more difficult and increased the threat of Varroa. This increase in rainfall also causes losses in honey, as the rainfall dilutes nectar on flowers and plants. This phenomenon was also explained by Karin Kos, chief executive of Apiculture NZ, as an important threat affecting beekeepers. She described it as a “lack of nectar” due to “rain washing it away.” Rainfall is just one of the many climate indicators that the beekeeping industry has been increasingly aware of.

SEVERE STORMS

Severe storms and flooding are also significant issues, due to the increased severity of extreme weather caused by warming. A notable instance being Cyclone Gabrielle in February 2023. Gisborne beekeeper Barry Foster, former president of the National Beekeepers Association, told us last year, six months before the cyclone, he sold a site with hives to a friend, which was wiped out down the river by Cyclone Gabrielle. Foster says, “this was a site I'd been on for at least 20 odd years. I'd spoken to the farmer, and I thought it was a safe site. It was high enough above a creek. There was no indication that it would flood. Well, 27 hives disappeared overnight.” Dr. Michelle Tayor, research scientist at NZ Plant & Food Research, shared similar concerns with inclement weather increasing the risk of flooding stating that, “having your hives next to a stream is not a great idea anymore.” This theme of uncertainty in hive locations is corroborated by beekeeper, Frank Lindsay, as well. Lindsay stated that “we in the south of the North Island have experienced three massive storms in the last year. The last one causing slips and mud to the extent that some hives could only be seen by the straps on the lids” (Figure 18). An increase in the severity of extreme weather-related events has made areas that were not affected by previous events, such as Cyclone Bola in 1988, no longer safe (Foster, 2023).

Figure 18: Beehives strapped down in order to secure Beehives from wind and flooding

A large number of beekeepers are at risk due to increased rain and flooding (Figure 19). In the above overlay of beekeeping club locations and precipitation depth changes, each purple circle represents a beekeeping club location in New Zealand, showing that most beekeeping clubs are located in areas prone to high precipitation depths. The beekeepers in these clubs may be at risk of increased rain and flooding due to climate change. It is a significant vulnerability, as beekeepers can no longer rely on previous trends of safe hive locations, exposing them to sometimes violent climatic events.

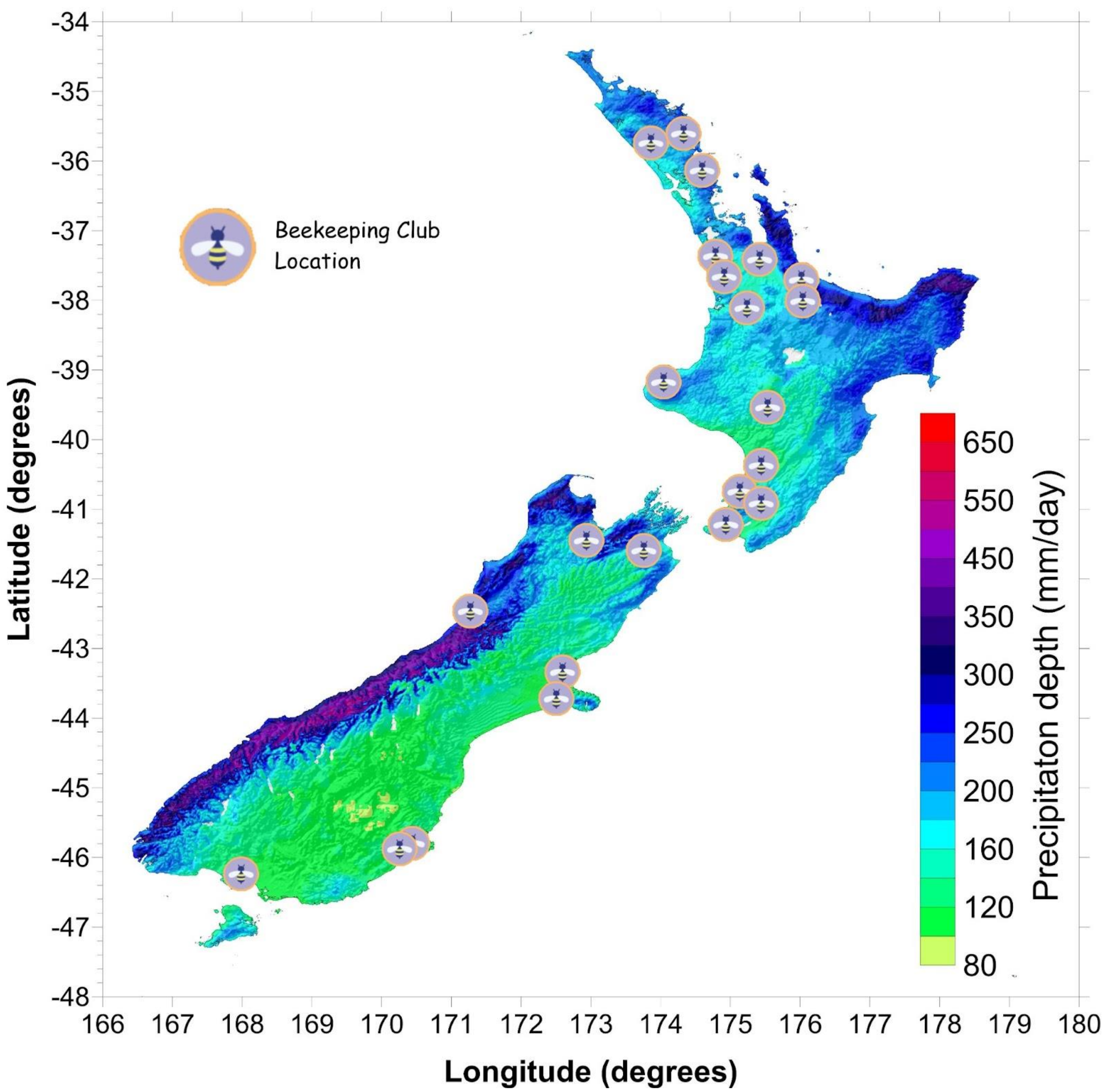


Figure 19: Overlay of beekeeping clubs in New Zealand on precipitation depth (Bird et al., 2023; Design & Harasym, 2022).

SHIFTING SEASONS AFFECT BEEKEEPERS

PHENOLOGY

Shifts in phenological and weather events due to climate change are causing beekeepers to adjust the timing of their beekeeping calendars. One of the most essential phenological events to bees, flowering seasons, has been shifting across New Zealand. Carlos Zevallos, Head of Apiary Development for Comvita, claims that flowering is taking place earlier or with less abundance, all dependent on temperature. If warming temperatures do not equally affect both bees and the plants in their environment, temporal mismatches can occur, which will cause decreased rates of interaction between the two parties (Forrest, 2014). Changes in flowering seasons also can throw beekeepers out of sync with their hives. As Rae Butler, a prominent queen breeder from Ashburton (South Island) said, “it's flowering too early it's kind of out of balance.” Zevallos claims that three to five years ago, beekeepers knew precisely where the honey harvest began in the season. This is a crucial time of the year for beekeepers, as this is the time that bees make the majority of their honey. Beekeepers must know when this season starts to ensure there is enough room for honey storage and when to remove the excess honey. However, due to changes in the start of flowering seasons, achieving this timing is now a challenge. Zevallos said in response to the shifting honey harvest season, “when we used to do it in the past, we cannot do it anymore. We have to change. We need to adjust to what the weather is bringing us. Now it's unpredictable.” Unpredictable weather is causing beekeepers to rethink practices that had previously been done at the same time every year.

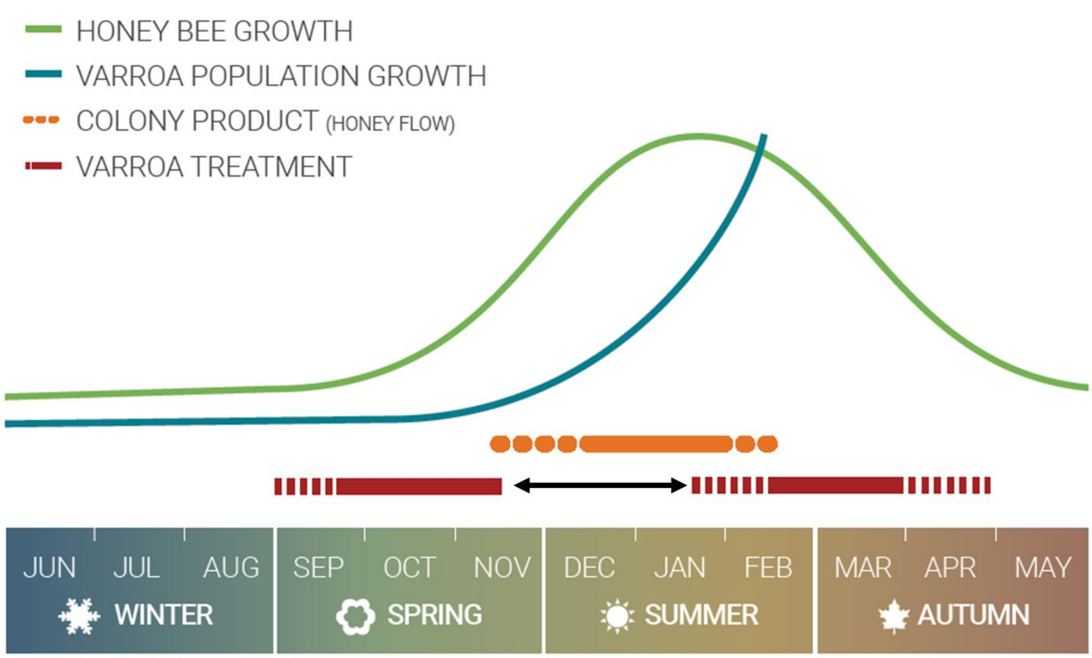
Beekeepers are citing shifts in the honey flow season. One Wellington Beekeeping Association member stated that they noticed an earlier and even longer honey flow; however, this did not result in more honey (Richard Braczek, 2023). New Zealand beekeepers once experienced two types of honey flow: the main and the secondary. However, Zevallos stated that the secondary honey flow no longer occurs due to the timing of the main honey flow being shifted and now unpredictable. Beekeepers are being forced to adapt to phenological shifts causing them to reorder their beekeeping calendars.

SHIFTING VARROA SEASON

The shift in plant phenology and honey harvest season is creating further threats to beekeepers. Rae Butler, a prominent queen breeder from Ashburton, cited the honey harvest season shifting three to four weeks later. This shift results in the loss of colonies and an increased growth in Varroa populations. Varroa is often treated in the spring (end of September) for eight weeks, then again in autumn (end of March) for eight weeks in New Zealand. These treatments are timed around the honey harvest season because honey cannot be harvested until two weeks after the treatment has been taken out of the hive. However, shifts in the honey harvest season make treating Varroa at the proper time an increased challenge by shrinking the window of opportunity. Rae Butler claims that this shift is resulting in the loss of beekeepers' colonies, as beekeepers are now treating too early or too late. Shifting the second treatment back also results in rapid growth in Varroa populations (Rae Butler, personal communication, January 24, 2024). Beekeepers now have to consider sacrificing a honey harvest for the long-term health of their hives.

BROODLESS PERIOD

Beekeepers noted a lengthened broodless period in beehives in New Zealand. A broodless period means the hive has no brood in the developmental stages, including eggs, larvae, and pupae. This period reduces Varroa mite loads, as mites invade a brood cell to lay eggs (Noël et al., 2020). Retired commercial beekeeper, Barry Foster, says that in a now warmer world, bees can keep brood through the winter period. These longer warm seasons allow Varroa populations to continue multiplying. Warmer winter seasons mean that bees remain active, and there are shorter broodless periods, meaning more Varroa reproduction cycles. Many of our research participants from the Wellington Beekeeping Association experienced this trend of milder winters. A hobbyist beekeeper Janine Davis from the Wellington Beekeeping Association stated that, “Over the past few years the winters have been milder (warmer) than in previous years. This has resulted in brood being in the hives all through the year.” Hobbyist beekeeper Michele Vandaalen experienced this trend of warmer winters, describing that it has resulted in, “lots and lots of Varroa in hives” because the queen bee remains active. This shift results in beekeepers needing to treat more often than they have in the past. Another member of the Wellington Beekeeping Association, Dave Henderson, has even stated that warmer winters have forced him to double his Varroa treatments per year because the queen bee continues to lay eggs through the winter (Henderson, 2024). The increased warming and record temperatures are threatening beekeepers.



(Control of Varroa: A guide for New Zealand Beekeepers, 3rd Edition, 2021).

Figure 20: Varroa mite population in relationship to honeybee growth. The Varroa mite population increases exponentially when the honeybee population grows.

HAND-DRAWN CALENDARS

We asked all our interviewees to hand-draw their calendars as a way to offer more creative freedom, which the rigid structure of the Calendar Tool did not allow for. The idea of using hand-drawn calendars arose from the CALENDARS Project website as they had done a similar experiment in their research. Our group also drew out our own calendars for events in our own lives and noticed many interesting similarities and differences.

These drawn calendars offer a deeper insight to how people view the shape of the year, what they define a season to be, how they picture a calendar, and what indicators mark the changing of an event or season. We believe these insights are very helpful in gaining a complete understanding of New Zealand beekeeping calendars. Hand-drawn calendars were most useful in tandem with in-person interviews as well as using the Calendar Tool. We would send out the Calendar Tool as a precursor to our interview to get a sense of how they defined their beekeeping calendar. While we conducted the interview, we would ask the interviewee to draw out their calendar. Interview participants explained the events more in-depth as they were drawing, allowing us to take notes of the things they were saying and later relate them to the drawings. Often, interviewees would shape their calendars through the 12-month format of the Gregorian calendar. Many were also structured around the traditional four seasons: winter, spring, summer, and autumn. Despite these frameworks, four seasons of the beekeeping year could be discerned from this frame which are different from the traditional outlines. These beekeeping seasons were seen in almost all of the hand-drawn calendars with some overlap and shifts due to geographical differences. This extracted calendar (Figure 21) gives a perspective on what the beekeeping calendar looks like and what seasons it is composed of.

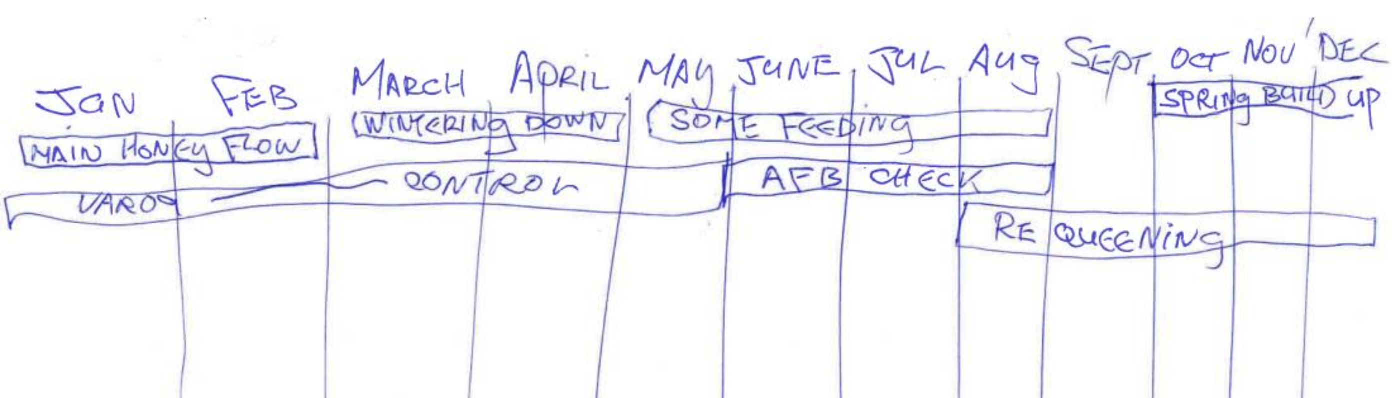


Figure 21: Hand-drawn calendar created by a hobbyist beekeeper in the Wellington Beekeeping Association.

UPDATED CALENDAR TOOL

The prototype Calendar Tool from the previous WPI CALENDARS Project was updated throughout our project. We made improvements to the prototype based on interviewee feedback and our own observations to create an updated version of the Calendar Tool. Some of these changes included updating the tutorial page to reflect the user experience more accurately (Figure 22), changing the default color and mode of the tool for ease of use, and increasing the size of the season bar to make it more user-friendly. Additionally, we included a section for notes where users can choose to write more information without crowding space on the calendar itself. We also created a YouTube tutorial video on how to use the tool to help guide users through the calendar creation process if they are having trouble with the written instructions. The tool takes a bit of practice to grow accustomed to, so these changes and additions will help users of all ages navigate the tool with ease.

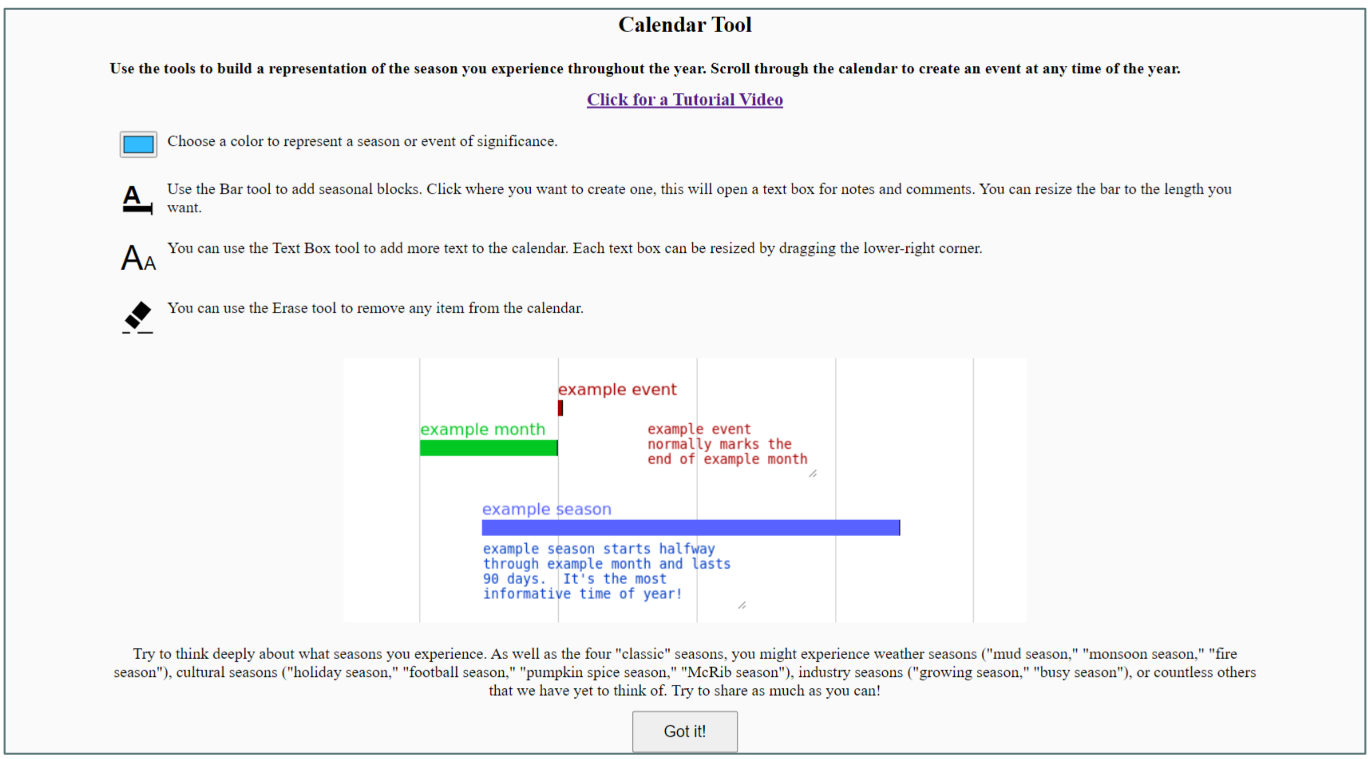


Figure 22: Updated Calendar Tool cover page with instructions.

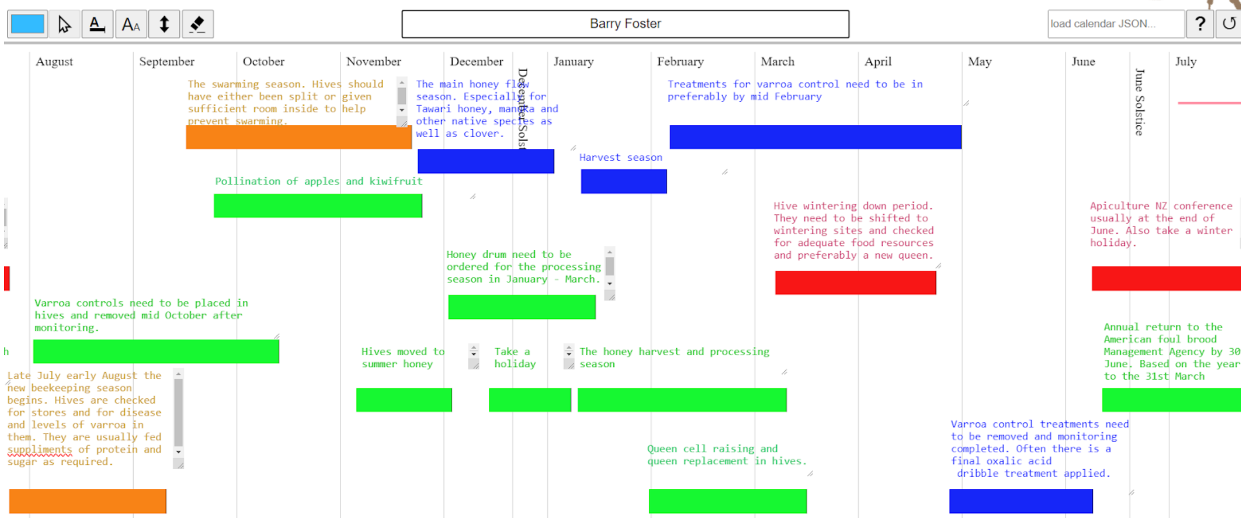


Figure 23: Retired commercial beekeeper Barry Foster's Calendar Tool submission.

NEW ZELAND BEEKEEPING CALENDAR

We translated all of the hand-drawn calendars and verbal descriptions of calendars from interviews with beekeepers into the Calendar Tool, resulting in 14 sources of data for comparison. To do this, we color-coded each event beekeepers mentioned in their calendars and recreated them in the Calendar Tool based on this key. The data was analyzed from 10 hand-drawn calendars, two Calendar Tool submissions directly from interviewees, and two from verbalized descriptions during interviews.

We have discerned roughly four seasons in the calendars of New Zealand beekeepers (Figure 24). Much of the variations in the starting and ending points of the seasons come from different locations and microclimates throughout New Zealand, since we conducted interviews throughout the North Island and South Island. The seasons we were able to discern are population management, honey flow and harvest, wintering down, and holidays.

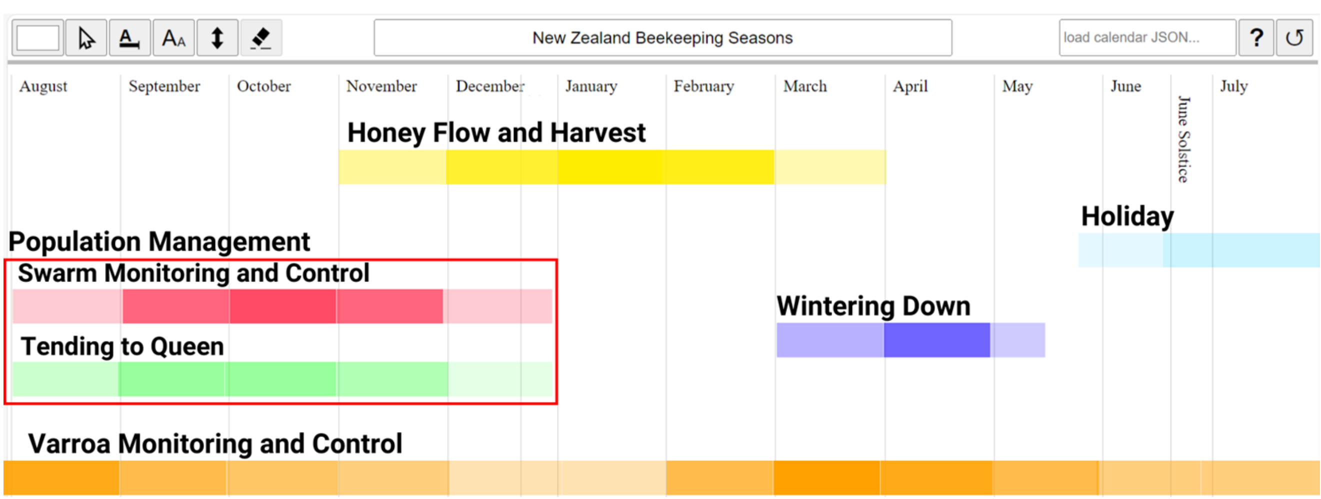


Figure 24: The four main seasons of New Zealand Beekeeping: population management (red and green), honey flow and harvest (yellow), wintering down (dark blue), and holiday (blue).

The population management season marks the beginning of the beekeeping year in New Zealand. During this time, beekeepers deal with swarms and tend to the queen honey bee. Beekeepers monitor swarms and split hives if necessary. They also check on the queen, requeen when needed, and make room for the queen to lay. There are lots of brood in the hive during this time as worker bees are created in preparation for the nectar collection. These tasks are critical in preparing the hive for the upcoming honey season.

The honey flow season starts at the end of November and ends in March with some beekeepers splitting it up into two seasons, the first flow and the second flow. Bees produce honey throughout this time, and beekeepers harvest the honey towards the end of the indicated season when the honey flow slows. Many beekeepers consider the honey harvesting season to be the busiest season of their beekeeping year.

The wintering down season begins after honey flow stops and extractions are completed; it lasts from mid-March until early May. During this season, beekeepers are preparing the hives for the winter. They check the hive to ensure there is enough food for wintering over and feed if necessary. The queen stops laying, resulting in little to no brood in the hives over winter. Varroa mite treatments are often placed during this time after honey is collected.

After an initial check of food stores, beekeepers tend to go on holiday and have a break from their beekeeping duties. They will occasionally check on the beehive if they are around, ensuring there are still enough stores of food in the hives. After the holiday, the beekeeping year restarts with population management as the hive begins to build up in the springtime and prepare for the honey flow. While only two calendars explicitly indicated the “holiday” season on their calendar directly, many left a gap during this time, implicitly suggesting a break period. Additionally, many beekeepers verbalized in interviews that this was a holiday period.

THE CULTURE OF BEEKEEPING IN NEW ZEALAND IS CHANGING

INFORMATION SHARING IN NEW ZEALAND IS CHANGING

Cultural and economic stressors shape communication and information-sharing in the beekeeping community. Mānuka honey created an economic boom and a resulting competitive market in 2016. Social conflicts between beekeepers: such as encroachment, stealing, and sabotage, arose due to the increasing demand for Mānuka honey (Rae Butler, personal communication, January 24, 2024). Many beekeepers had previously shared information and collaborated before Mānuka honey. For instance, when honey bee queen breeder Rae Butler first began beekeeping, she was mentored by older beekeepers. However, when Mānuka became more popular and profitable, "older beekeepers were very hesitant to share information, and there were a lot of cowboys [i.e., individuals who acted independently and often recklessly]. They were not good to each other." Dr. Michelle Taylor echoed the stories of a competitive environment saying, "Beekeepers were pretty tight-lipped about a lot of their stuff, especially when Mānuka came through." Due to the high profitability of Mānuka, beekeepers were hesitant to share information about where they were locating their hives. Now that the price and restrictions on Mānuka honey have leveled out due to regulations set in place in 2017-2018, beekeepers are sharing more information (Karin Kos, personal communication, January 24, 2024).

Figure 25: Wellington Beekeeping Association monthly meeting at Johnsonville Community Center. Steve Heal is in the bottom left filling out a hand-drawn calendar for us.

There is no longer a demand for regular honey (ex. bush honey or clover honey) to be mixed into

Mānuka honey due to regulations on export put out by the New Zealand government (Bill McDonald, personal communication, January 31, 2024). This testing requires a certain amount of Methylglyoxal to be present in the honey to be labeled as Mānuka honey. This stopped the sale of diluted Mānuka honey, which was causing the soaring prices of regular honey. This decrease in demand for just "honey" to be mixed into Mānuka honey has lessened the competitive market in New Zealand, opening up more communication between beekeepers (Bill McDonald, personal communication, January 31, 2024). This community has many resources, including local clubs such as the Wellington Beekeeping Association and new social media groups. Additionally, ApiNZ was established after a restructuring of the National Beekeepers Association of New Zealand to adapt to changing beekeeping culture. ApiNZ also publishes The New Zealand Beekeeper journal, which contains articles throughout the year that draw attention to current issues and events in New Zealand beekeeping including sections on business, research, market, pest and disease control, and a regional reports section from beekeepers in each region of the country. These resources are keeping beekeepers connected and informed throughout New Zealand.

NEW ZEALAND'S BEEKEEPING ECONOMIC DOWNTURN

New Zealand beekeeping is currently in an economic downturn. Honey prices are lower than before and are becoming unsustainable for beekeepers. Rae Butler, a queen breeder and business owner with over 25 years of experience in the beekeeping industry, says, "We are not getting enough [NZ$] per honey to cover running costs and other influences." More and more people are abandoning their hives due to the high cost of beekeeping. When people abandon their hives, the lack of Varroa mite treatment causes the mite infestations to spread rampantly in those hives, then eventually travel to other hives, worsening the issue. Before Varroa mites were brought into New Zealand, beekeepers did not have the expense of treatment. Phil Lester, a Varroa researcher at Victoria University, estimates that "in New Zealand, a commercial operation might spend $50,000 a year on Varroa [treatment]." To cut down on the cost of Varroa treatment, beekeepers are cutting the amount of hives. As Frank Lindsay, New Zealand New Year Honours recipient for apiculture, says, "Most family businesses are still around, but they have cut the hive numbers in half just to go through this period." Beekeeping is slowly recovering from the Mānuka gold rush, and there is optimism in the industry that beekeeping will thrive again.

BEEKEEPERS STILL FACE CHALLENGES

Cyclone Gabrielle, in 2023, was disastrous to beekeepers all over New Zealand. It may take years to recover from the losses of hives and resources for some beekeepers if they are even able to fully recover at all (Foster, 2023). In Gisborne, the Tairāwhiti Hub of Apiculture New Zealand organized a gathering for beekeepers in the area to come together and share stories, both positive and negative, in the wake of Cyclone Gabrielle (Foster, 2023). Beekeeper Barry Foster attended this event and stressed that "although we may compete as businesses, we should not be isolated from one another, particularly in adverse times" (Foster, 2023, p.54). Even though beekeepers compete through their companies, there shouldn't be a "cowboy industry" where everyone's on their own as it used to be during the Mānuka boom (Bill McDonald, personal communication, January 31, 2024). Further generosity in this tough time came from the Taranaki Beekeepers Club, which donated spring nucleus colonies to hobbyist beekeepers to replace lost colonies from Cyclone Gabrielle (Foster, 2023).

Attendees of the Tairāwhiti Hub event reported they would like more social events and agreed that "there are real benefits in exploring future collaborations as we rebuild" (Foster, 2023). Despite the tragedy and the threat of uncertainty ahead, "it's these sorts of things, together with a helping spirit and the generosity of people, that augurs a positive future" (Foster, 2023, p.54).

CALENDARS PROJECT-SPECIFIC QUESTIONS

The three CALENDARS Project-Specific questions guided our field research. These same questions are being asked to interview participants at the other project locations in Hong Kong, Germany, and India; these will allow for comparison between each location. The findings for these questions are interconnected with our main findings, but we have presented them separately because of their importance. The following sections will analyze our data through the lens of the three CALENDARS research questions:

1. What climate change indicators and vulnerabilities are reported?
2. How have beekeeping practices and technological tools that support beekeeping changed?
3. What is the future outlook for beekeeping as described now by beekeepers?

1. WHAT CLIMATE CHANGE INDICATORS AND VULNERABILITIES ARE REPORTED?

BEEKEEPERS REPORT CLIMATE CHANGE VULNERABILITIES AND INDICATORS

The direct effects of climate change, including increased rainfall and warmer temperatures, create uncertainty and vulnerability for beekeepers. The shift in seasons and inconsistency in temperatures described above in the shifting beekeeping calendars section creates unpredictability for beekeepers, as it is nearly impossible to plan around natural events. Cyclone Gabrielle set beekeepers back by years by sweeping hives away in floods. Beekeeper Barry Foster lost many hives in the storm and, as a result, determined that "If there is one stark lesson for all beekeepers in New Zealand, past benchmarks on where it is safe to locate apiaries no longer apply" (Foster, 2023, p. 6). This beehive site where Barry lost hives was safe from the 1988 Cyclone Bola, showing that beekeepers must reevaluate safe apiary locations rather than relying on the past. This is a difficult adjustment, considering many beekeepers rely on previous knowledge from what has been successful in the past. Without the past as guidance, beekeepers can only take an educated guess of what environments will be safe, leaving their hives vulnerable to future climate disasters.

BEEKEEPERS ADAPTING IN THE FACE OF CLIMATE CHANGE

Some beekeepers are attempting to eliminate unpredictability. As Carlos Zevallos, Head of Apiary Development at Comvita, explained, “We still have the challenges due to climate changes. But we have to adjust. We have to adjust management, routine, our program, our plan. It needs to be adjusted according to what we are having.” Carlos Zevallos and Comvita are aware of the challenges presented by climate change and have been proactive in taking steps to avoid the negative effects of it. Comvita has begun to “record data every year on how the temperature is fluctuating during the season.” They then “review [it] every year and see what is going to happen in the following year” (Carlos Zevallos, personal communication, January 25, 2024). Comvita is doing this in an attempt to counteract vulnerabilities caused by climate change.

2. HOW HAVE BEEKEEPING PRACTICES AND TECHNOLOGICAL TOOLS THAT SUPPORT BEEKEEPING CHANGED?

Numerous beekeepers indicated a technological intervention and then related it to a change in practice. This structure shows the interconnection between technological advancements and changes in beekeeping practices.

VARROA MITES ARE FORCING BEEKEEPERS TO ADAPT NEW TECHNOLOGIES

One of the most significant changes in New Zealand and global beekeeping industries is the threat of *Varroa destructor* to bees. Varroa mite specialists and beekeepers agree that it is currently the most prominent issue in the industry. As Dr. Phil Lester, a Varroa mite researcher at Victoria University in Wellington, New Zealand, put it, “Varroa is probably the biggest problem facing the bee industry around the world.” Beekeepers have been looking at varying ways to deal with this growing issue, including synthetic and organic treatments. The use of oxalic acid “10 years ago was very seldom used, but now it's becoming one of the more common approaches to Varroa management” (Dr. Phil Lester, personal communication, January 19, 2024). Oxalic acid is an organic treatment for Varroa mite that can be used year-round at a relatively cheap cost (Rod, 2022). Beekeepers are having to treat more frequently and oftentimes with multiple treatment types to effectively reduce the Varros mite populations in their hives.

Research surrounding *Varroa destructor* has increased, and new technologies are emerging as a result. Dr. Phil Lester is currently researching “double-stranded RNA” and “gene splicing,” which uses dsRNA sequences that target reproductive genes in Varroa mites. It is not harmful to the host or the parasite and prevents Varroa mites from reproducing, but the effects are not permanent. Hence there is a need for additional research to make it an effective treatment for Varroa mites (*Using RNAi to Control Varroa Mites*, 2023). Beekeeper Frank Lindsay also explained a new method of taking “60-second or 30-second recordings using AI to determine the level of mites and AFB [American foulbrood]” in the hive. This technology, which is still in the research phase, would use images and videos taken of the hive along with an [artificial intelligence (AI)] algorithm to measure the amount of Varroa mites and AFB present in the hive (Kaur, 2021). Rae Butler, a queen breeder with more than 25 years of experience, has grown accustomed to these changes and stated, “I always say beekeeping used to be an art, but now it's more of a science.” As Varroa mites and other disease-causing organisms continue to pose a major threat to beekeepers, many are turning to research and science to better understand these issues and adjust their practices.

MĀNUKA HONEY INFLUENCES BEEKEEPING PRACTICES

Research and economic gain associated with Mānuka honey has altered the beekeeping landscape in New Zealand. As Bill McDonald, owner of Bee Fresh Farms, a Wellington Mānuka honey company, told us, “The biggest technological change that's happened in my time has been the invention of Mānuka honey and the research behind it.” This not only changed the industry and economics of honey in New Zealand, but it also changed the practices of commercial beekeepers. Previously, many commercial businesses would not move their hives around. Now, it is commonplace for these companies to relocate to more suitable areas for Mānuka honey. Rae Butler estimated that “75% of the [commercial] beekeepers do migrational” beekeeping, moving their hives to maximize their honey production and sale of Mānuka honey (Rae Butler, personal communication, January 24, 2024). This idea was echoed by Karin Kos, the Chief Executive of Apiculture New Zealand, who mentioned that once Mānuka honey became very profitable, it became commonplace for commercial beekeepers to relocate to areas that were best for Mānuka honey. As research on the beneficial properties of this specialty honey and the demand for it increased, beekeepers moved their hives closer to Mānuka dense locations. This had not previously been the case before the boom in the Mānuka honey industry. This practice also highlights the different practices of hobbyists and commercial keepers, as only commercial keepers practice migrational beekeeping.

CHANGES IN FARMING TECHNOLOGY INFLUENCE HONEY PRODUCTION

Another technological change noted by honeybee queen breeder Rae Butler, was about changes to farming practices and how they have altered beekeeping. Butler explained that farmers' shifting to sprinkler irrigation systems was the most significant technological change she had seen in beekeeping. The increased amount of water washes the nectar off of plants and decreases honey production, similarly to the effects of increased rainfall washing away nectar. While not a change to beekeeping technology specifically, beekeepers need to be aware of farming practices as the change in farming technology directly influences honey production. All of these changes draw attention to the ever-changing landscape of beekeeping; beekeepers must adjust to threats with interventions and new technology for their practices.

Technology and Practices

"The biggest change is with farmers changing to irrigation systems. Everything's wetter, so nothing's yielding as much honey"

Rae Butler
Bee Smart Breeding

"Before Mānuka was valuable, it was considered a rubbish honey"

Beekeeper Alastair Little

"Beekeeping used to be an art but now it's more of a science"

Rae Butler
Bee Smart Breeding

"The biggest technological change that's happened in my time has been the invention of Mānuka honey and the research behind that"

Bill McDonald

CEO Bee Fresh Farms

"We then had to understand more about the lifecycle, the whole dynamics of the hive and how it was interacted with the mites"

Rae Butler
Bee Smart Breeding

"The biggest change is with farming. Farmers don't grow as much clover"

Rae Butler
Bee Smart Breeding

"Varroa is probably the biggest problem facing the bee industry around the world"

Prof. Phil Lester

3. WHAT IS THE FUTURE OUTLOOK FOR BEEKEEPING AS DESCRIBED NOW BY BEEKEEPERS?

DISEASES AND PATHOGENS PRESENT A THREAT TO BEEKEEPERS

The future of beekeeping contains increasing challenges for beekeepers. The biggest threat to beekeepers worldwide is *Varroa destructor*, as almost all bee colony losses in New Zealand, apart from starvation, can be credited to Varroa mites (*New Zealand Colony Loss Survey*, 2022). In addition, Tropilaelaps mites, currently found across Asia and in Papua New Guinea, are a looming threat.

Two species of Tropilaelaps mites (*Tropilaelaps clareae* and *Tropilaelaps mercedesae*) can parasitize honey bees. Tropilaelaps mite infestation causes severe damage to honey bee colonies such as deformed pupae and in adults (stunting and damaged wings, legs, abdomens), parasitic mite syndrome (PMS), and colony decline. The colony may also swarm, further spreading the mite to new locations. Tropilaelaps mites can also spread viruses which further affect the colony's health and disease susceptibility. (*Tropilaelaps Mites «Bee Aware*, 2020). This parasite is a vector similar to Varroa mites but spreads much faster through brood rather than staying on the bees themselves. (*Tropilaelaps mites: What Are Tropilaelaps Mites?*, 2022). Beekeepers in New Zealand are worried that it will eventually spread to New Zealand, and if they did, it would be "absolutely devastating" for bee populations (Barry Foster, personal communication, January 30, 2024). While harder to detect than Varroa mite, many of the treatments known to work on Varroa are also effective at treating Tropilaelaps mites. Tropilaelaps mites can only survive for 48 hours without food or bee brood cells to feed off. Their spread to New Zealand can ideally be prevented if importers wait 48 hours before introducing bees to the colony (*Tropilaelaps | Bee Culture*, 2023).

THERE ARE MIXED OPINIONS ON THE FUTURE OF NEW ZEALAND BEEKEEPING

There are mixed attitudes in the beekeeping community towards what lies ahead, but one thing is consistent: New Zealand needs to have bees. Some people "don't think there's a sense of optimism in the beekeeping community in New Zealand at the moment" because of the threat of Varroa mite (Phil Lester, personal communication, January 19. 2024). Others are very confident that the future "is bright. And we're always going to say that because New Zealanders tend to be a find-a-way people. We may lose some colonies in the interim, but we will find a way. We need to have bees" (Dr. Michelle Taylor, personal communication, January 25, 2024). Human life would be greatly hindered without bees due to the wide range of plants they pollinate.

Others viewed this question more pragmatically, thinking of proactive ways the beekeeping community can advance in modern society and a changing environmental landscape. CEO of Bee Fresh Farms, Bill McDonald is wondering, "What else can you do with honey? What are the other products you can use it for? How can we find more and more rather than it just being a commodity? So I think we have to find ways to be smarter." Considering other avenues will help beekeepers adapt to an ever-changing industry.

Future of Beekeeping

"We vitally need them, so there's no question about that"

Beekeeper Barry Foster

"We may lose some colonies in the interim, but we will find a way. We need to have bees"

Dr. Michelle Taylor
Varroa Mite Researcher

"It's bright. And we're always going to say that because New Zealanders tend to be a find a way people"

Dr. Michelle Taylor
Varroa Mite Researcher

"What else can you do with honey? What are the other products you can use it for? I think we have to find ways to be smarter"

Bill McDonald
CEO Bee Fresh Farms

"It'll keep going. But just with a lot less hives. It'll balance itself out eventually. There's going to be a bit of tragic sort of stories in the meantime"

Beekeeper Alistair Little

"another couple of years and then we'll be back to normal"

Beekeeper Frank Lindsay

"It is going to do a bit of a dive, there is going to be less and less beekeepers"

Queen Breeder Rae Butler

CHAPTER 5: RECOMENDATIONS

THE CALENDARS PROJECT COULD BENEFIT FROM ADDITIONAL SPATIAL RESEARCH

We sampled 11 key informants from across locations in New Zealand. The data we collected from these informants was often different and we noticed different trends across geographical regions in New Zealand. This was to be expected as climate change would have very different effects depending on the part of New Zealand surveyed. These differences could also be seen more locally as coastal areas are affected differently than inland areas that geographically were not that far away. This was echoed in our findings where sometimes observed phenological mismatches were exactly opposite between the North and the South Island.

We believe there is more to reveal about climate change and how it affects beekeeping differently across New Zealand. There are many ways this could be done, including interviewing beekeepers from: the coastal and inland regions, the North and South Islands, and beekeepers in different regions of each island. Much of this research would be dependent on where beekeepers are located. An effective way to do outreach is by contacting beekeeping clubs, located all over New Zealand.

Looking at beekeepers in different geographical regions could be very useful for not only the CALENDARS Project but also for beekeepers. If climate effects are less prominent in certain geographical regions, it would be very valuable knowledge for beekeepers seeking to avoid climate vulnerabilities. It would also be an interesting connection to see how strong the correlation between the projected climate change effects across the country are compared to those experienced by beekeepers. We found some of these differing effects to be prevalent in our research but needed more interviewees to determine if the predicted trends truly matched the experiences of beekeepers across New Zealand.

FURTHER RESEARCH INTO *VARROA DESTRUCTOR* AND CLIMATE CHANGE COULD PROVIDE INSIGHTS FOR NEW ZEALAND BEEKEEPERS

As we conducted our interviews and gathered data using the Calendar Tool and hand-drawn calendars, we could not avoid the presence of Varroa mite as a major concern for the beekeeping industry. We learned much about the research efforts that have been developed to combat the threat of Varroa and how much influence it is having on beekeepers' calendars. To tie it more directly to our research, we sought to find a connection between the increasing Varroa threat and climate change. We did find correlations to shifting and changing calendars and practices due to Varroa that possibly connected to climate change. There is some research on this subject suggesting warming temperatures would exacerbate the growing Varroa problem. We found some details suggesting that due to a shortening broodless period in New Zealand bees, the opportunity for Varroa populations to continue to grow would increase. We did not have any key informants who were confident in this claim, but it was considered a possibility.

Further research on the connection between Varroa mite and climate change could reveal interesting and important findings not previously considered by New Zealand beekeepers. Finding this connection could help to improve Varroa treatment and provide a more robust understanding of an already difficult and complex threat. As we discovered, Beekeepers are relying more and more on research to aid their hives.

THE CALENDARS PROJECT COULD BENEFIT FROM EXPANDED TEMPORAL RESEARCH

To gather a more robust understanding of beekeeping in New Zealand, research could be conducted at different points of the year to gather a wider range of data. This perspective is missing in our project and could offer valuable insights to the CALENDARS Project.

Determining climate trends is a process that cannot be done in a vacuum. It is a combination of many years worth of data collection and research. While we were only able to sample in a small two-month time frame, getting a perspective from all parts of the year could give a more robust understanding of a beekeeping year. Doing this research over a longer span of years can better help beekeepers as they can adapt and change as more and more research is done on climate change and its consequences on bees.

Doing this research over time could also reveal the amount that calendars are changing each year. We were only able to collect data and compare it with what beekeepers told us the seasons used to look like. Doing this research over multiple years could allow for quantitative analysis of yearly beekeeping calendars to uncover how much seasons were shifting. This could answer all kinds of interesting questions like are calendars uniformly shifting or are only certain seasons shifting? This perspective is not only useful to the CALENDARS Project's research but also to beekeepers looking to adapt their practices as new threats to the industry emerge.

THE CALENDARS PROJECT COULD USE HAND-DRAWN CALENDARS IN FUTURE RESEARCH

Implementing the process of using hand-drawn calendars in tandem with in-person interviews and the Calendar Tool could be a beneficial method employed by future CALENDARS Projects. This is something that CALENDARS has done in the past and we believe should be a staple of their research. Hand-drawn calendars offer the interviewee much more creative freedom than can be lost in an interview or with the Calendar Tool.

This implementation is best paired with an in-person interview. As the interview is conducted, the interviewee can draw out their calendar. This is best done with multiple colors, as it allows them to color-code their calendar. Coming prepared with multi-colored writing utensils as well as paper for the interviewee to use streamlines this process. It is important to take notes during the interview because the interviewee might talk to the interviewer through their calendar. Using notes, their words can later be pieced together with the drawn calendar. These hand-drawn calendars provide details missing from other data collection methods. It is hard to gather a full view of a beekeeping calendar from an interview alone without rigorously going through transcripts and recordings. The Calendar Tool helps to make this process more straightforward; however, the Calendar Tool forces the user into a rigid structure. The calendar can take whatever shape the interviewee desires with a hand-drawn calendar. This is a unique perspective that CALENDARS can use not only to understand beekeeping calendars but also to perceive what defines a calendar or season.

THE CALENDARS PROJECT COULD USE THE CALENDAR TOOL FOR ADDITIONAL DATA COLLECTION

The prototype Calendar tool that we adopted for this project has been a useful method of data collection and has aided in the analysis of our data. We recommend adding a circular depiction of the tool to give a more concise view of the data without the scrolling calendar in the current tool. Giving the user a choice between a circular and linear tool also allows for more creative freedom in the portrayal of seasonal perceptions. Further improvements that could be beneficial would be a place for the user to input more data like the location they are from, the industry they work in, and a feature that looks for trends in the data of similar types and generalizes the seasons. Being able to look at the trends and average the data would require reworking the tool so that when season bars are saved, it looks at user aspect ratio and screen size. This would allow someone on the backend to take the ratio and average out the formatting between different users so that the data was placed accurately on an average calendar. Accessibility features such as increased font size, left-right movement, and a date selector for precise calendar mapping would be beneficial to make the tool more useful for people of all ages and technical skills.

The CALENDARS Project could then take this updated version of the tool and implement it on their website for further data collection. The CALENDARS team could advertise the tool to future research groups to streamline data collection and comparison. Having a single place for all quantitative data will make their research more efficient. Using this data collection strategy would allow the CALENDARS Project to get a wide range of calendar data across many locations and also across many different disciplines.

The CALENDARS Project will need a server that can host HTML files as well as a database that can accept HTTPS Post requests and save them locally for further use and comparison. This expanded research will not only further the CALENDARS Project research on calendars but will allow the project to expand to locations that they might not have otherwise done.

CHAPTER 6: CONCLUSION

We analyzed beekeeping in New Zealand through the lenses of climate change, calendars, and culture. We found that much of New Zealand climate science is echoed by the experiences of beekeepers as they notice climate change indicators like warmer temperatures, milder winters, increased rainfall, and more severe storms. These create phenological shifts in the beekeeping environment. The timing of events such as flowering and the broodless period in hives have become unpredictable due to season creep. Rather than following a set calendar, many beekeepers react based on their bees and have been adjusting their beekeeping calendars to match their current environment. These changes present a challenge for beekeepers, along with increased *Varroa destructor* populations and a downturn in the New Zealand honey market. Beekeepers now incorporate science and research into their practices, rather than relying solely on previous knowledge. Cultural, climatic, and calendar frameworks highlight the changes in beekeeping practices and provide insight into understanding of the past, present, and future challenges facing beekeeping in New Zealand.

We were only able to collect information during a small portion of the beekeeping year in their busiest season, the honey harvest season. Future CALENDARS Project research could further explore the ideas outlined in this report over a longer time period to reveal trends and data that we were unable to discern in our brief research period. The suggestions for the CALENDARS Project in using the Calendar Tool as a data collection method will be useful in a global comparison. Our utilization of hand-drawn calendars, along with the online Calendar Tool, allowed for a full understanding of how beekeepers perceive their seasonal calendars. Applying these methods to other climate-dependent activities may allow the CALENDARS Project to form a more robust understanding of seasonal calendar perceptions.

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APPENDICES

APPENDIX A: INTERVIEW GUIDE FOR EXPERTS AND BEEKEEPERS

THREE CALENDARS QUESTIONS

1. How have beekeeping practices and technological tools that support beekeeping changed?
2. What is the future outlook for beekeeping as described now by beekeepers?
3. What climate change indicators and vulnerabilities are reported?

ADDITIONAL INTERVIEW QUESTIONS

4. Have you noticed shifting seasonality affecting your beekeeping calendar?
5. What do you do on a typical beekeeping day? How does this routine change at different points in the year?
6. Could you describe the beekeeping season and the shape of the year? What is the timeline for the process?
7. Who is in charge, the bees or the beekeeper?
8. In what ways does weather affect your hives? Is a specific temperature/weather condition best for the hive?
9. Have production levels of honey or the quality of the honey changed? What factors seem to have an influence?
10. What other concerns have you noted as a beekeeper in the industry?

CALENDAR TOOL USER EXPERIENCE QUESTIONS

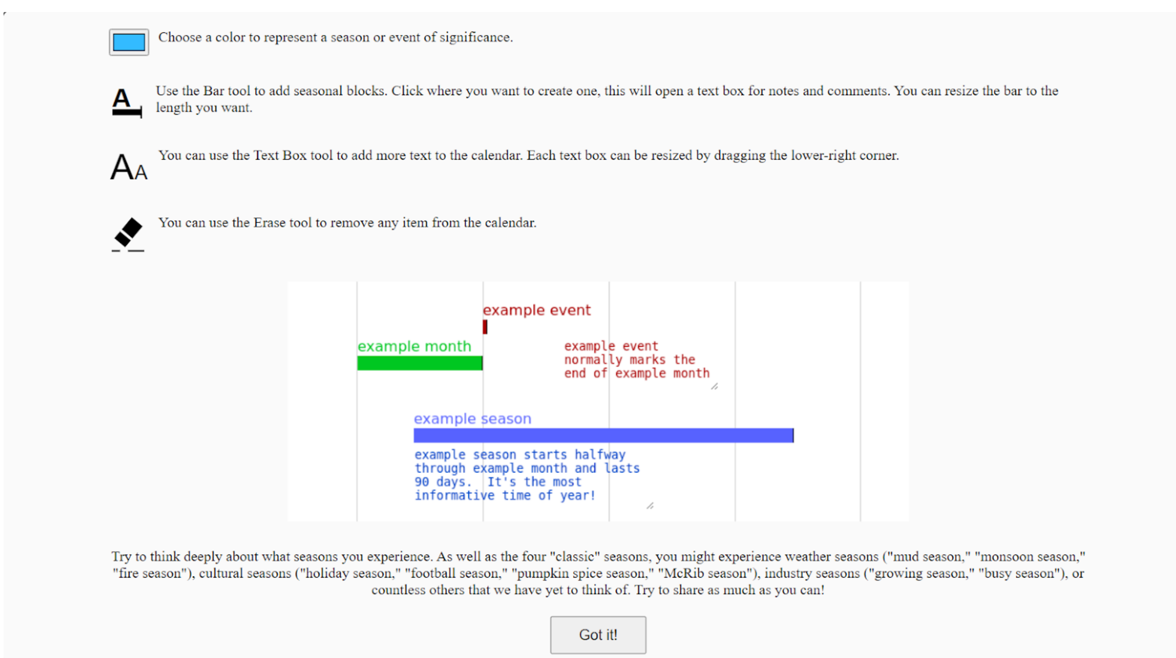
1. How was your experience using the Calendar Tool we sent you?
2. Are there any changes or additions you recommend we make to the Calendar Tool?

APPENDIX B: PROTOTYPE CALENDAR TOOL

Using the Calendar Tool, we got a geographical representation of beekeeping seasons throughout New Zealand. We saw that there is a shift in beekeeping calendars based on a regional location in New Zealand. Here is the tool.

Here is what a blank map looks like on the prototype Calendar Tool where people can put their calendars:

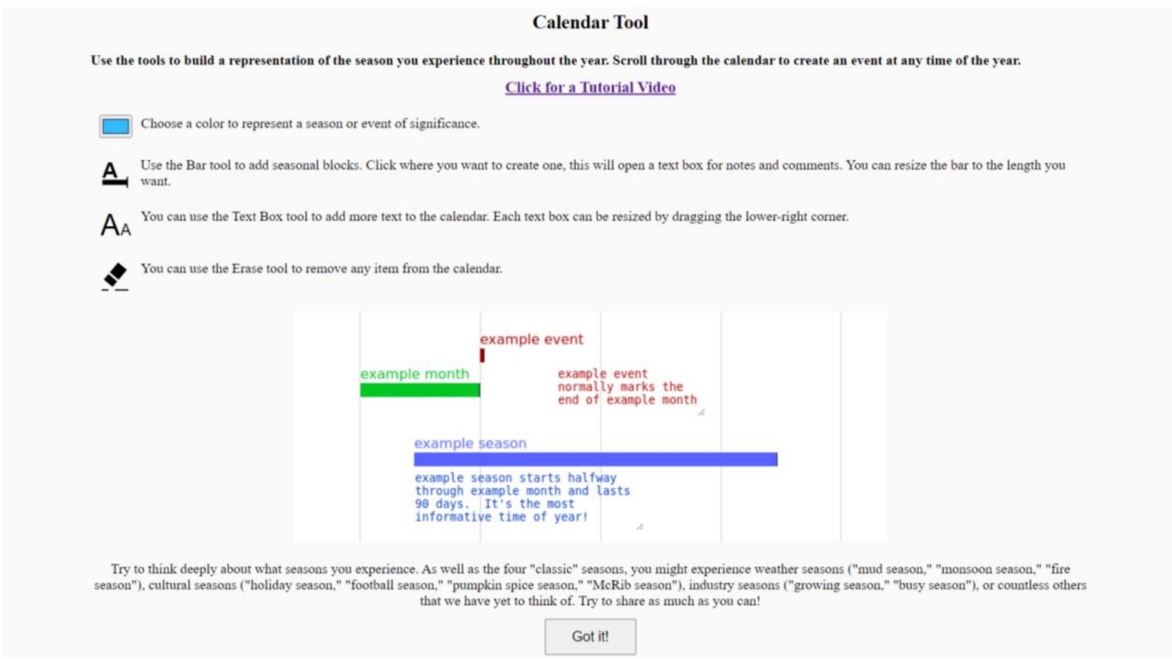
Here is the instructions page on the prototype Calendar Tool:



APPENDIX C: UPDATED CALENDAR TOOL

The Calendar Tool has been updated. We added a title as well as more useful instructions including a YouTube tutorial video. There is also now a section to add notes, the user is defaulted to the season bar option, and the WPI and CALENDARS Project logo is now visible.

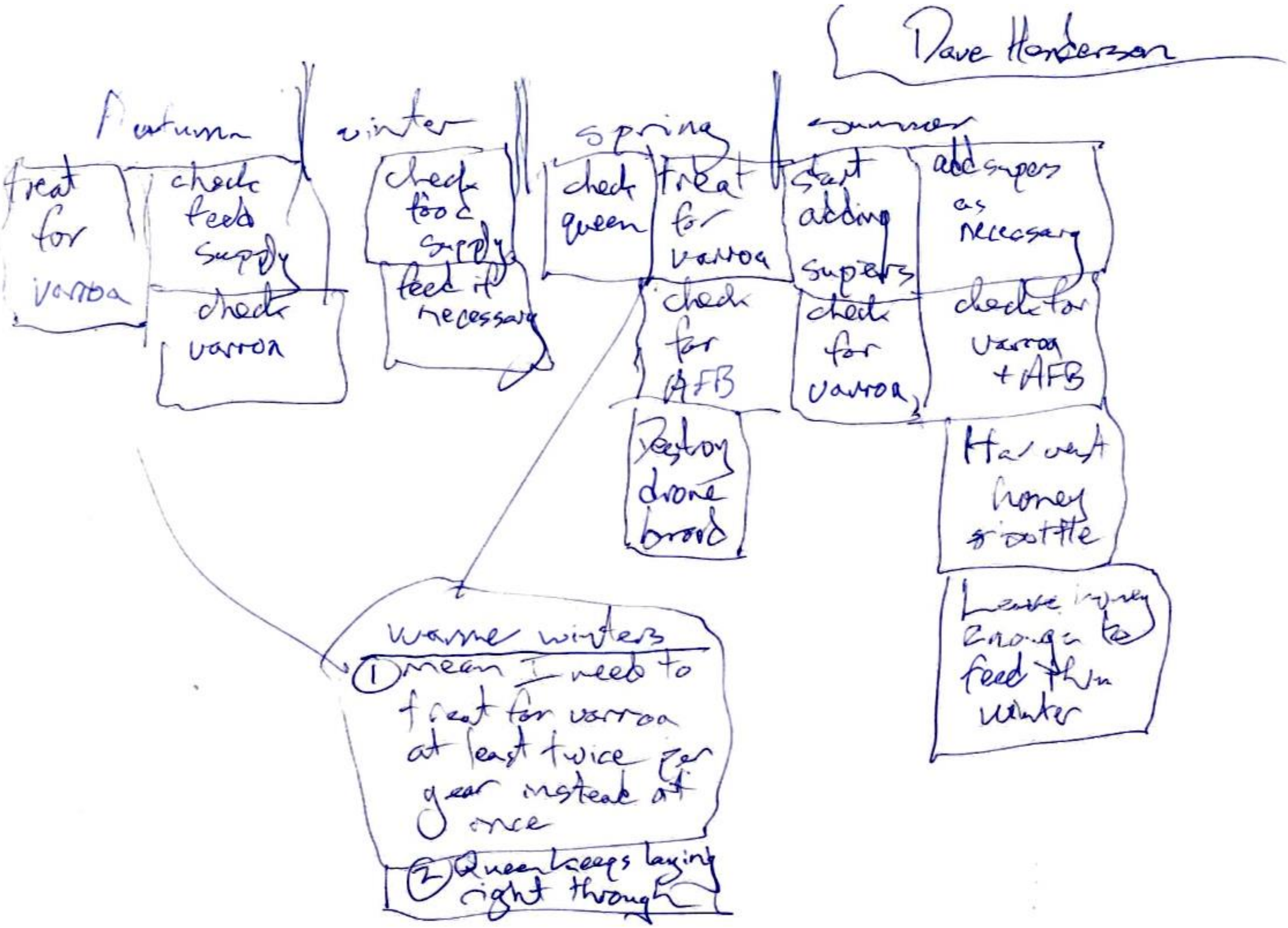
Instructions page on updated Calendar Tool:



Blank Map on Updated Calendar Tool:

APPENDIX D: HAND-DRAWN CALENDARS

10 Hand-drawn calendars from beekeepers in the Wellington Beekeeping Association are shown on the following pages:



Dave Henderson
Autumn
treat for varroa
check feeds supply
check varroa
winter
check food supply
feed if necessary
spring
check queen
treat for varroa
check for AFB
Destroy drone brood
summer
start adding supers
check for varroa
add supers as necessary
check for varroa + AFB
Harvest honey + bottle
Leave honey enough to feed them winter
warmer winters
1 mean I need to treat for varroa at least twice per year instead of once
2 Queen keeps laying right through

Spring

- ~~usually~~ last year very wet.
- bees not getting out
- hard to do inspections
- get treatment in

this Spring couple of frosts
lots of hives swarming later

Drier Spring -

Treat Varoa with oxalic acid strips / Bayoral
Oxalic acid vapourizing

Summer

Good amts honey last year

- late to fill boxes this summer
haven't extracted yet.
Some Hives - very strong a couple weak
- Hives swarmed early / before Nov / Q not laying well
- not well mated?

Autumn

- wrap hives polystyrene
- check stores
- Q slows laying
- remove honey leave 10 frames for bees
- treat varroa
- apivar or Apitraz followed by api Life var organic treatment over winter

Winter

- usually cold/wet
Queen ~~may~~ usually stop laying / at least slows down (winter down / plenty stores)

- this winter warmer
Queen laying
Bees active
lots + lots of varoa in hives
Started oxalic acid vapourizing

Upper Hutt
Michele
michele.vandaalen@gmail.com

4 HIVES AROUND HOME PROPERTY

ALL HIVES DOUBLE DEEP BROOD BOXES STD LANGSTROTH

VAROA CONTROL EXTENDED RELEASE QXALIC ACID 2APPS PER YEAR

JAN FEB MARCH APRIL MAY JUNE JUL AUG SEPT OCT NOV DEC

MAIN HONEY FLOW

WINTERING DOWN

SOME FEEDING

SPRING BUILD UP

VAROA CONTROL

AFB CHECK

RE QUEENING

Winter - sugar feeding and mite treat-
ment

Spring - plant flowers, take out mites.

Summer - Harvest honey

Fall - Treat for varoa;

JILL DALTON
+ JIM HEPBURN
(PORIRUA)

AUTUMN ~~SPRING~~ - - - - WINTER - SPRING → SUMMER

AUTUMN

~~RAIN DILUTED NECTAR~~

- WAX MOTH
- MORE VARROA

↓

TREATED A LOT

WINTER

- WARMER
- STRONG COLONIES
- DIDNT EAT MUCH OF STORES

SPRING → SUMMER

LOTS OF RAIN

→ INSPECTIONS DIFFICULT

VARROA ↑

→ LOTS OF SWARMS

→ SWARM CELLS MISSED

LESS HONEY – (NECTAR DILUTED)

Janine Davie - Porirua

February - treatment for varroa mite
March " " "

April Wintering down.

May - July fairly quiet

August - starting to ramp up
- varroa treatment.
- making sure there is room in the hive for queen to lay

September - Adding boxes, super, queen excluders
October swarm control

November - January
honey flow, keeping an eye on supers, any late swarms.

STEVE HEAL - RAUMATI BEACH,
PARAPARAUMU.

USUALLY ONE OR TWO HIVES.
HIVES USUALLY ARE STRONG YEAR ROUND TREATED FOR VARROA THROUGHOUT THE YEAR. OVER THE PAST FEW YEARS THE WINTERS HAVE BEEN MILDER (WARMER) THEN IN PREVIOUS YEARS. THIS HAS RESULTED IN BROOD BEING IN THE HIVES ALL THROUGH THE YEAR. IN SPRING THE HIVES ARE SPLIT TO PREVENT SWARMING, THE BEE NUMBERS INCREASE RAPIDLY BY EARLY SUMMER (DECEMBER). THE HONEY FLOW STARTS IN EARLY TO MID DECEMBER THROUGH TO THE END OF JANUARY. MAIN VARROA SYNTHETIC TREATMENTS ARE INSTALLED IN THE HIVES AROUND MID FEBRUARY. THESE ARE AN 8 WEEK TREATMENT. WHEN THAT TREATMENT HAS ENDED, OXALIC ACID VAPOUR (SUBLIMATION) IS USED EVERY 5 DAYS UNTILL THE END OF MAY WHEN APIVAR IS THEN PUT INTO THE HIVES AS A WINTER TREATMENT (10 WEEKS). IN EARLY SPRING UNTILL SUMMER BEFORE THE HONEY FLOW STARTS, OXALIC ACID SUBLIMATION IS USED — EVERY 5 DAYS. SOMETIMES DURING THE HONEY FLOW, FORMIC PRO IS USED AS A KNOCKDOWN IF VARROAS LEVELS SUDDENLY SPIKE.

THE HIVE(S) CONSIST OF 2 MAIN FULL DEPTH BOXES FOR THE BROOD AND 2X3/4 DEPTH BOXES CONTAINING HONEY ARE LEFT ON THE HIVE ALL YEAR ROUND FOR HONEY SUPPLIES FOR THE BEES.

Jan	Feb	March	April	May	
Second extract	Varroa treat	Varroa treat	Varroa treat	Varroa treat	Jonny plumater NZ
		Easter →	Winter down		
		remove supers.	feeding →		

June	July	August	Sept, Oct	Nov	Dec.
Varroa treat	Varroa treat	Varroa treat	Varroa treat, Varroa treat	flow	first extract
				add supers	
feeding	feeding.	feeding	feeding.	remove varroa treatment →	

June / July / August (Winter)

no/fewer brood breaks over Winter

→ more Varroa

- need to treat in Winter or very early in Spring

Mar / Apr / May

Autumn

?

Sept / Oct / Nov

Spring

Earlier production of drone brood

- Earlier swarms (some in August)

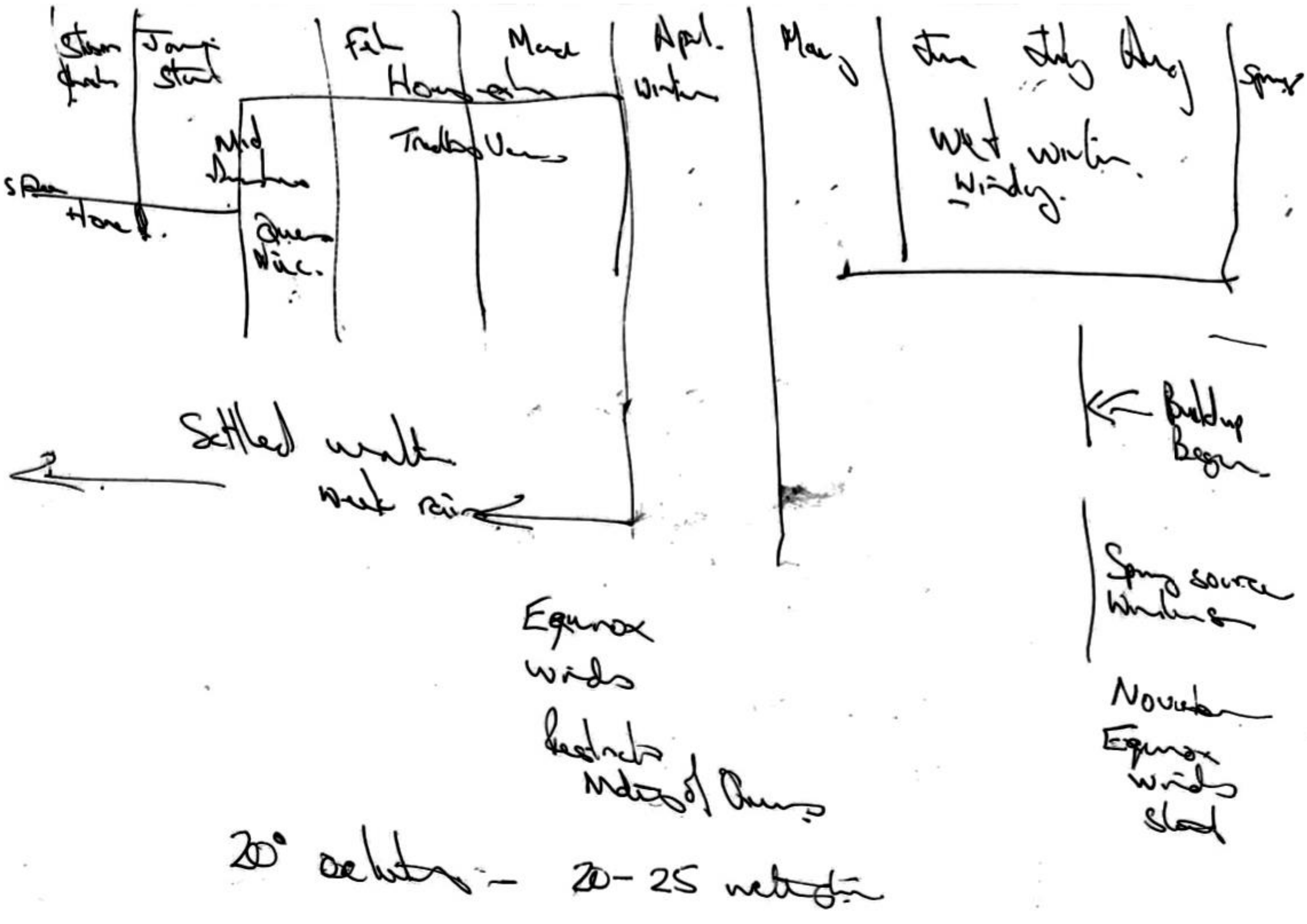
usually swarming Nov → Dec

Dec / Jan / Feb

Summer

Earlier / longer honey flows though no necessarily more honey

Lower Hutt
Richard
richardm.brazek@gmail.com


Feb
March
Apr.
winter
May
June
July
Aug
Spring
wet winter
windy.
Settled weather
Build up
Begin
Spring source
November
Equinox
winds
start
Equinox
winds
Mating of Queens
20° or below – 20-25 weather

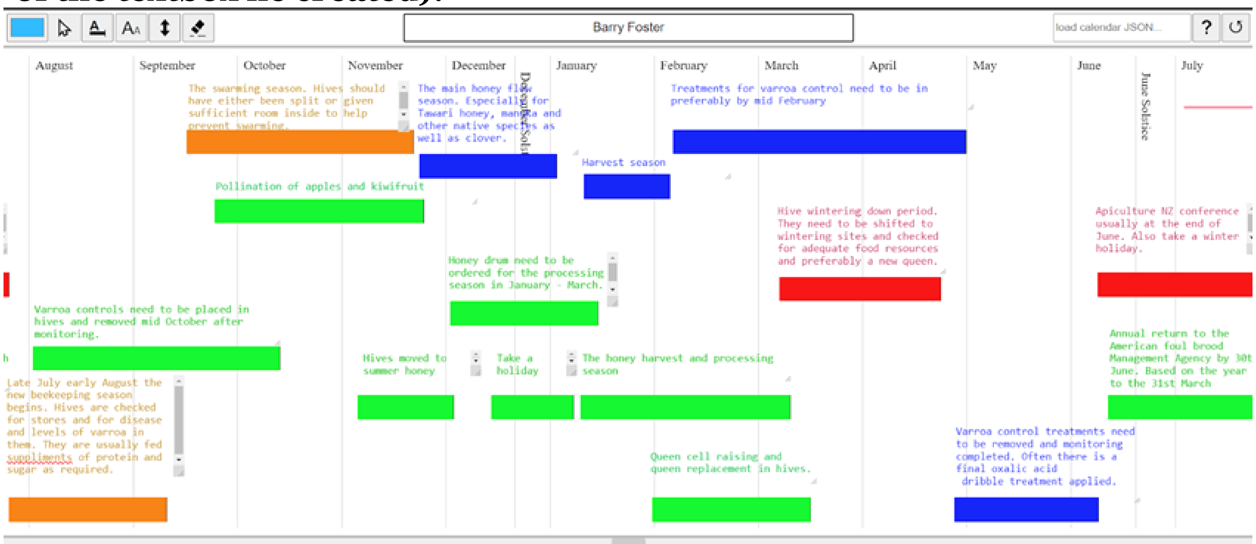
APPENDIX E: INTERPRETATIONS OF HAND DRAWN CALENDARS USING THE ONLINE CALENDAR TOOL

Unless a specific name is mentioned all calendars are taken from hand-drawn calendars from the Wellington Beekeeping Association Conference that have been interpreted into the Calendar Tool, labeled 1-9.

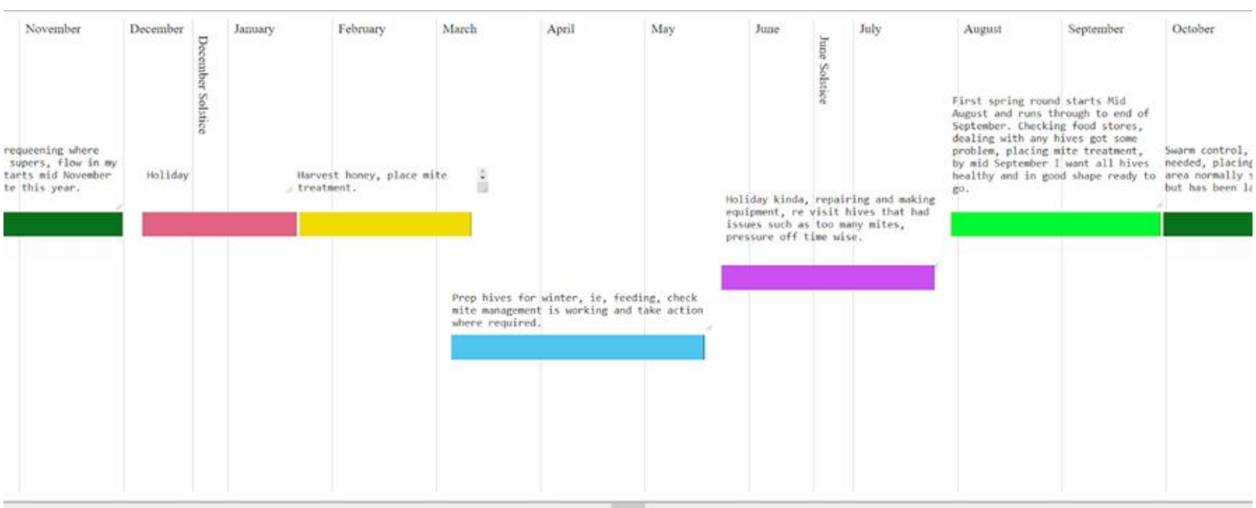
Color Coded Calendar Events Key	
(yellow)	Honey Events
(purple)	Spring Build Up
(blue)	Wintering Down
(magenta)	Swarming Events
(cyan)	Supers and Boxes
(green)	Brood Events
(lime green)	Queen Events
(light blue)	Weather Events
(red)	Feeding Events
(orange)	Varroa Events

Edited Calendar Tool Submissions by Key Informants

Barry Foster Calendar Tool Submission (we extended the bars to the size of the textbox he created):

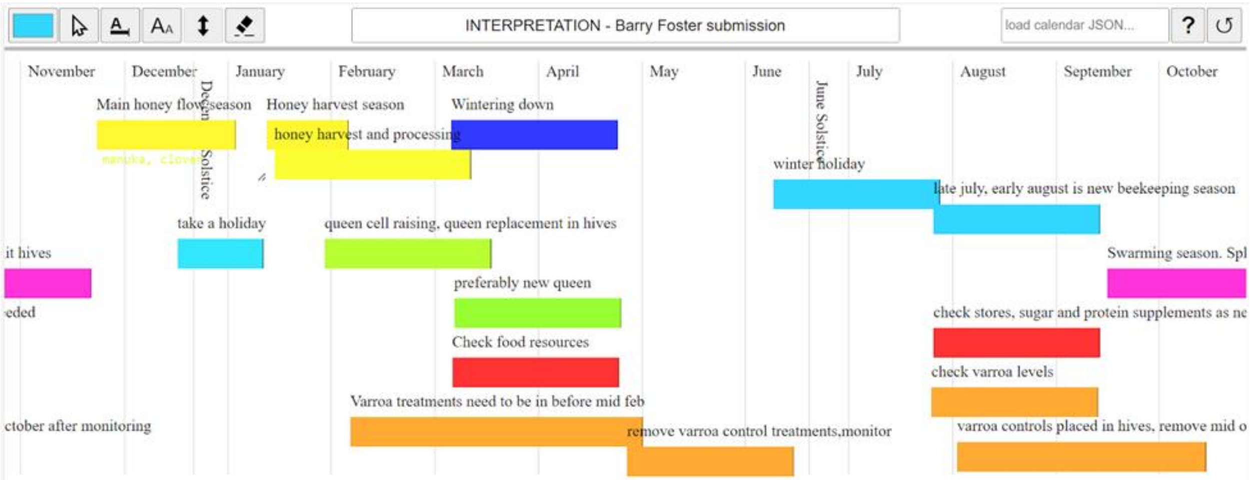


Alistair Little Calendar Tool Submission (we extended the bars to the size of the textbox he created and added the different colors):

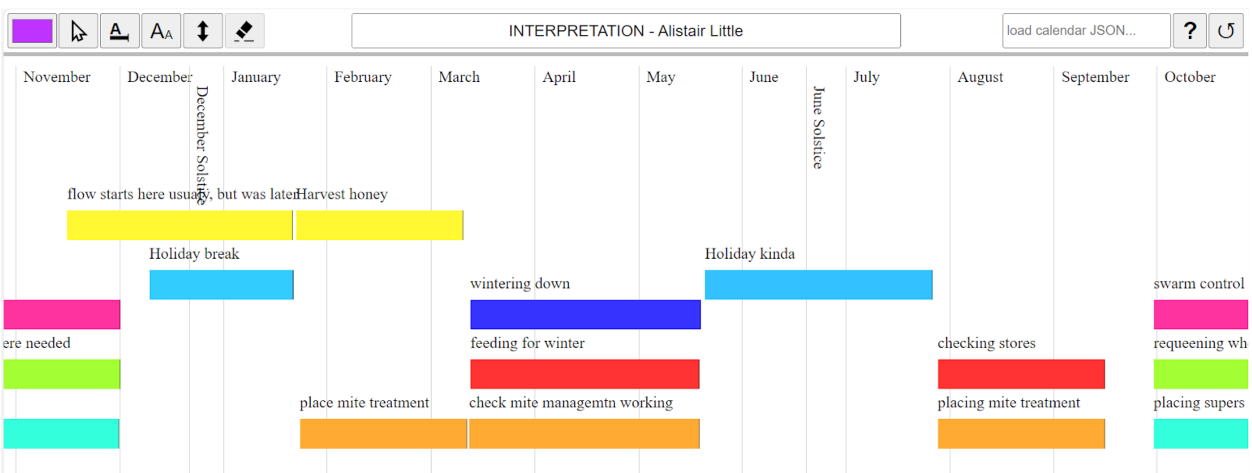


Interpretation of Calendar Data with Online Calendar Tool

Online Interpretation of Barry Foster's Calendar Tool Submission:

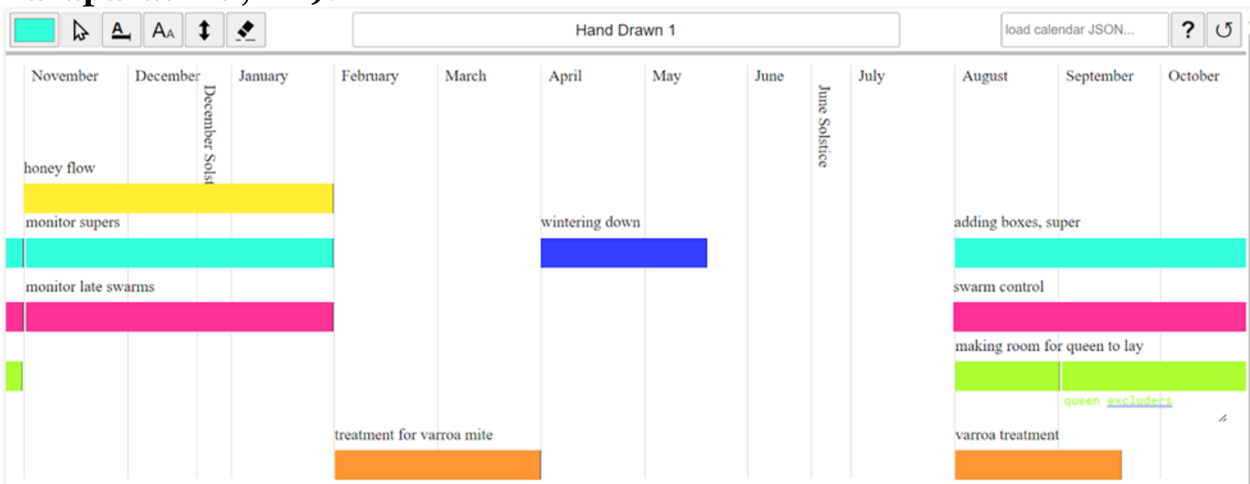


Online Interpretation of Alistair Little's Calendar Tool Submission:

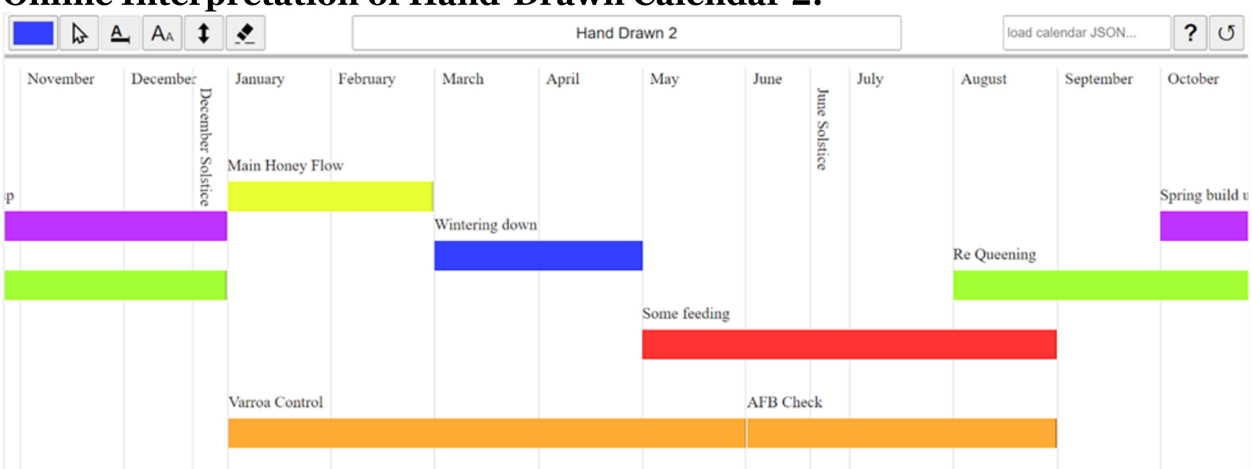


Interpretations from Hand-Drawn Beekeeping Calendars

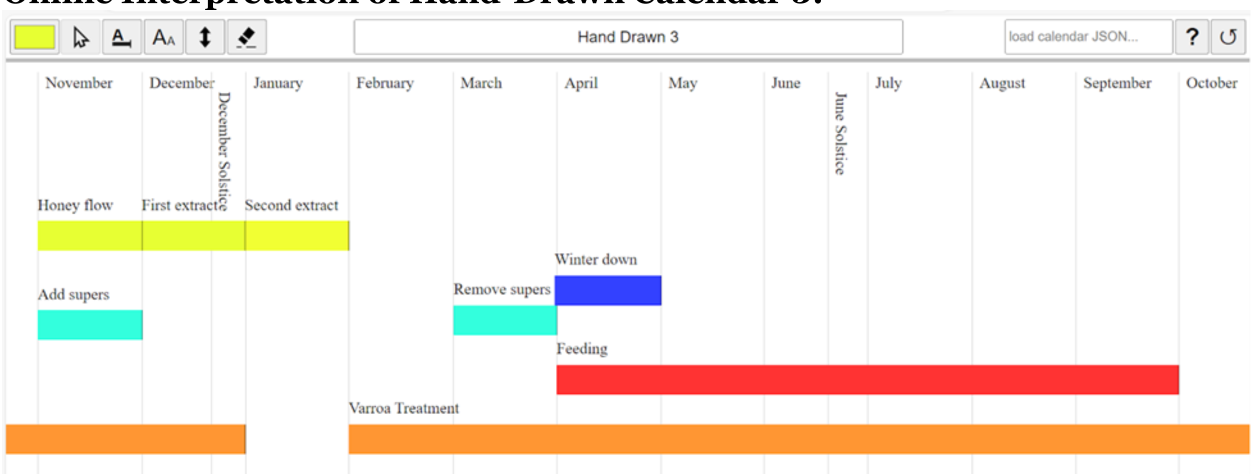
Online Interpretation of Hand-Drawn Calendar 1 (Steve Heal, Paraparaumu, NZ):



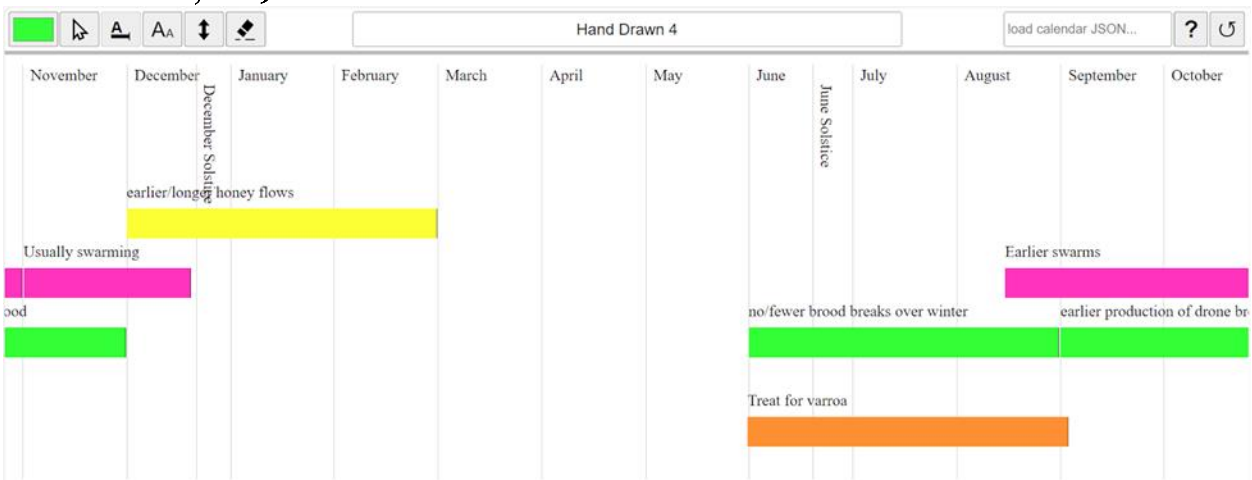
Online Interpretation of Hand-Drawn Calendar 2:



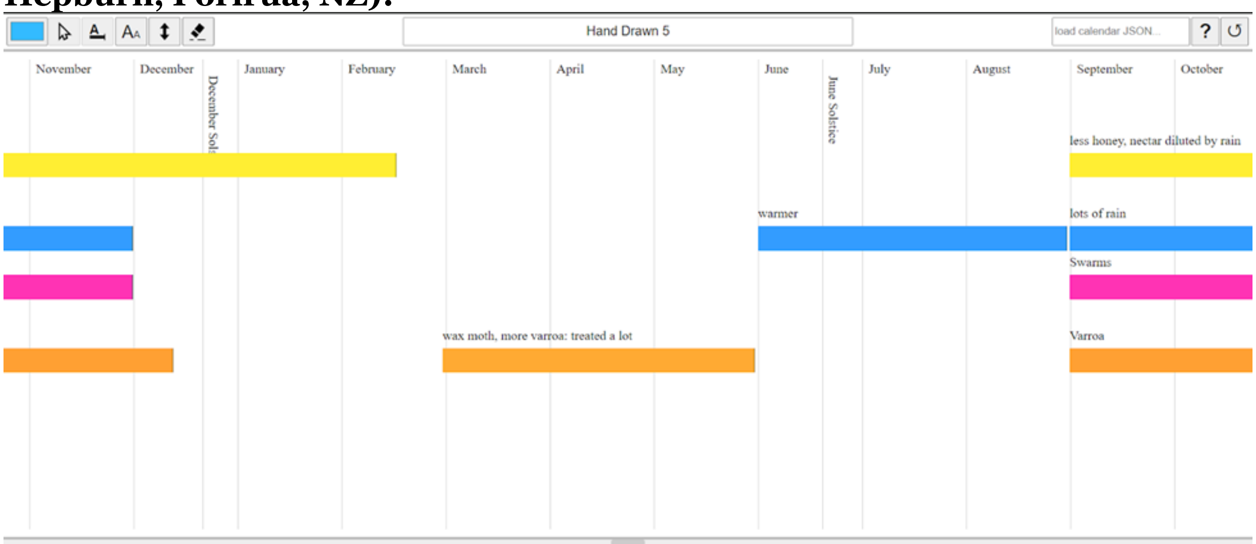
Online Interpretation of Hand-Drawn Calendar 3:



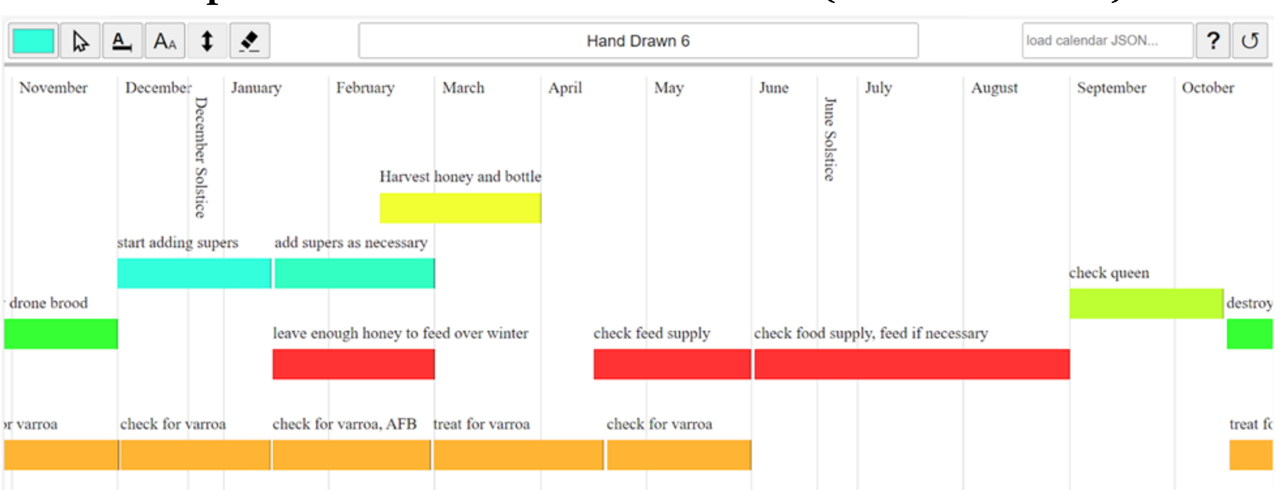
Online Interpretation of Hand-Drawn Calendar 4 (Richard Braczek, Lower Hutt, NZ):



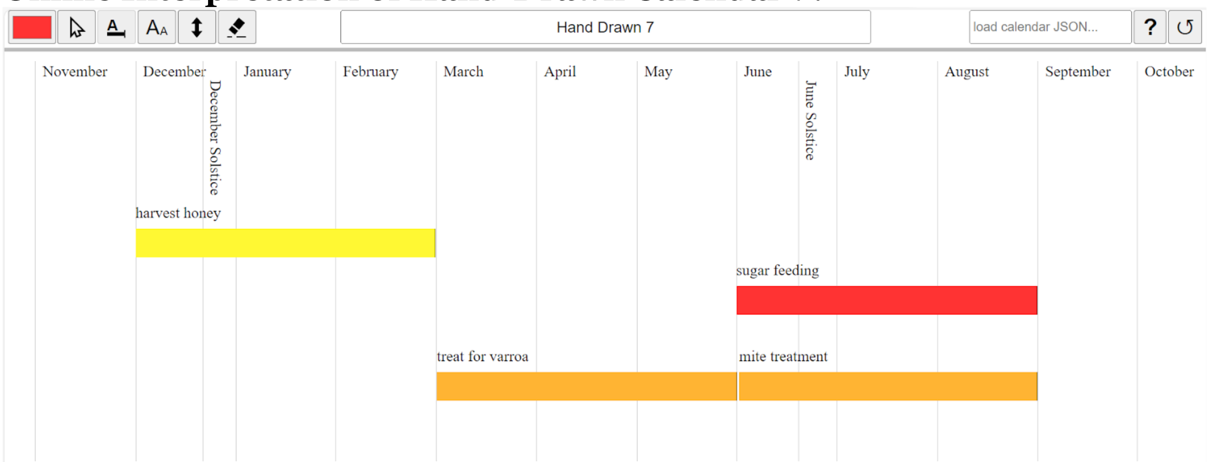
Online Interpretation of Hand-Drawn Calendar 5 (Jill Dalton & Jim Hepburn, Porirua, NZ):



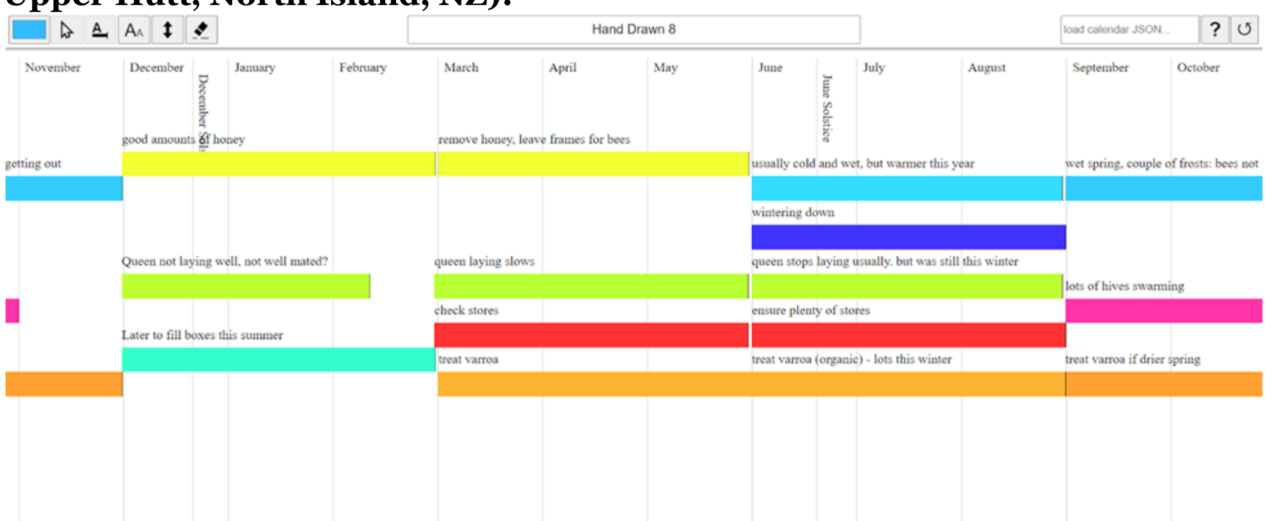
Online Interpretation of Hand-Drawn Calendar 6 (Dave Henderson):



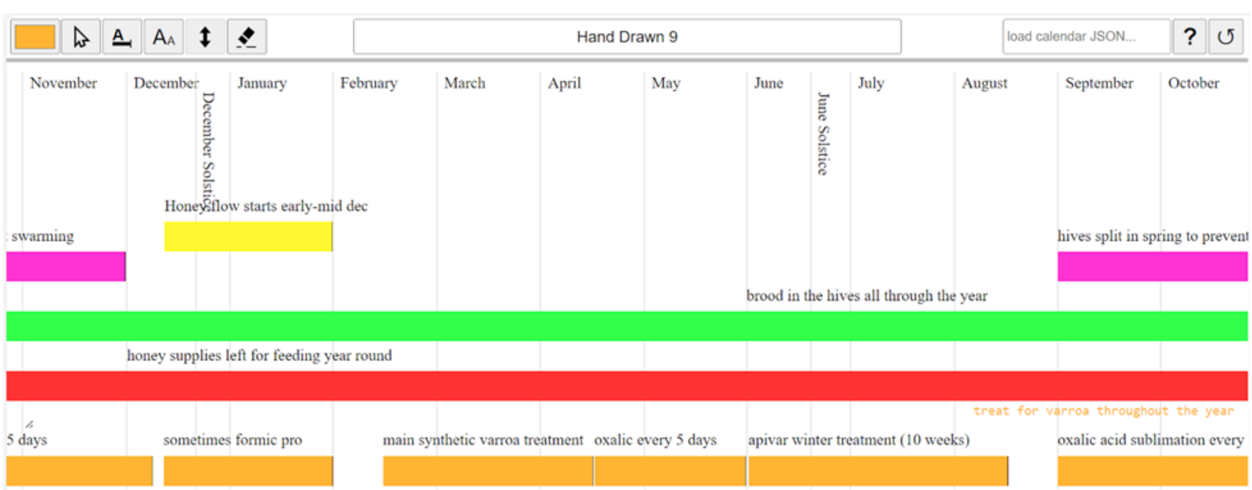
Online Interpretation of Hand-Drawn Calendar 7:



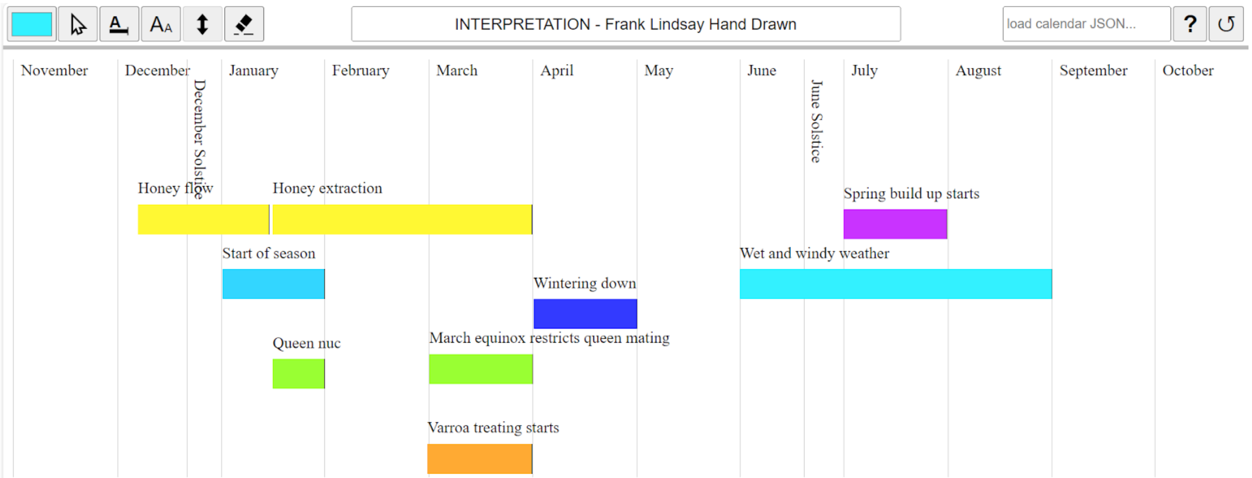
Online Interpretation of Hand-Drawn Calendar 8 (Michele Vandaalen, Upper Hutt, North Island, NZ):



Online Interpretation of Hand-Drawn Calendar 9 (Janine Davie, Porirua, North IslandNZ) :



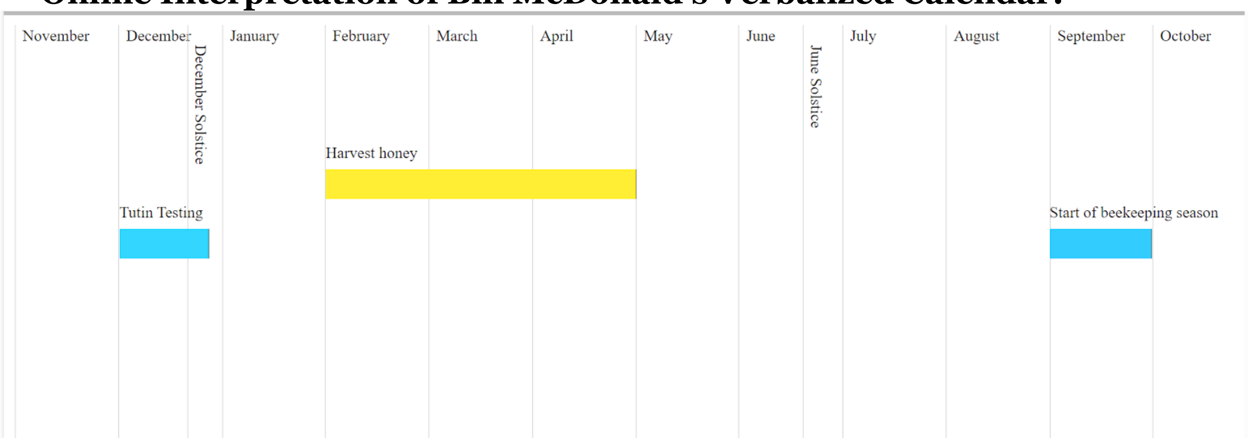
Online Interpretation of Hand-Drawn Calendar by Frank Lindsay:



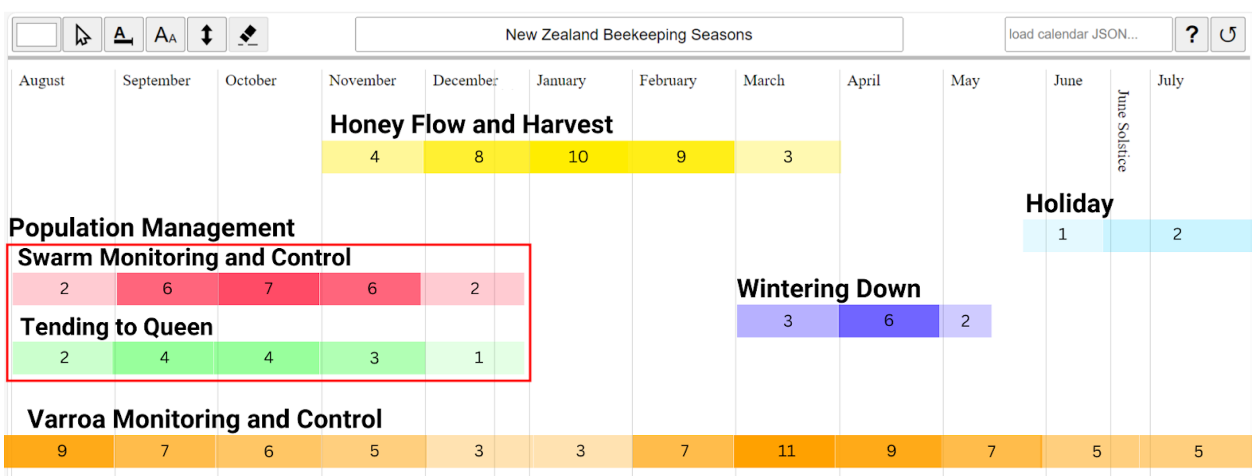
Interpretations from Verbalized Beekeeping Calendars During Interviews

Online Interpretation of Rae Butler's Verbalized Calendar:

Online Interpretation of Bill McDonald's Verbalized Calendar:

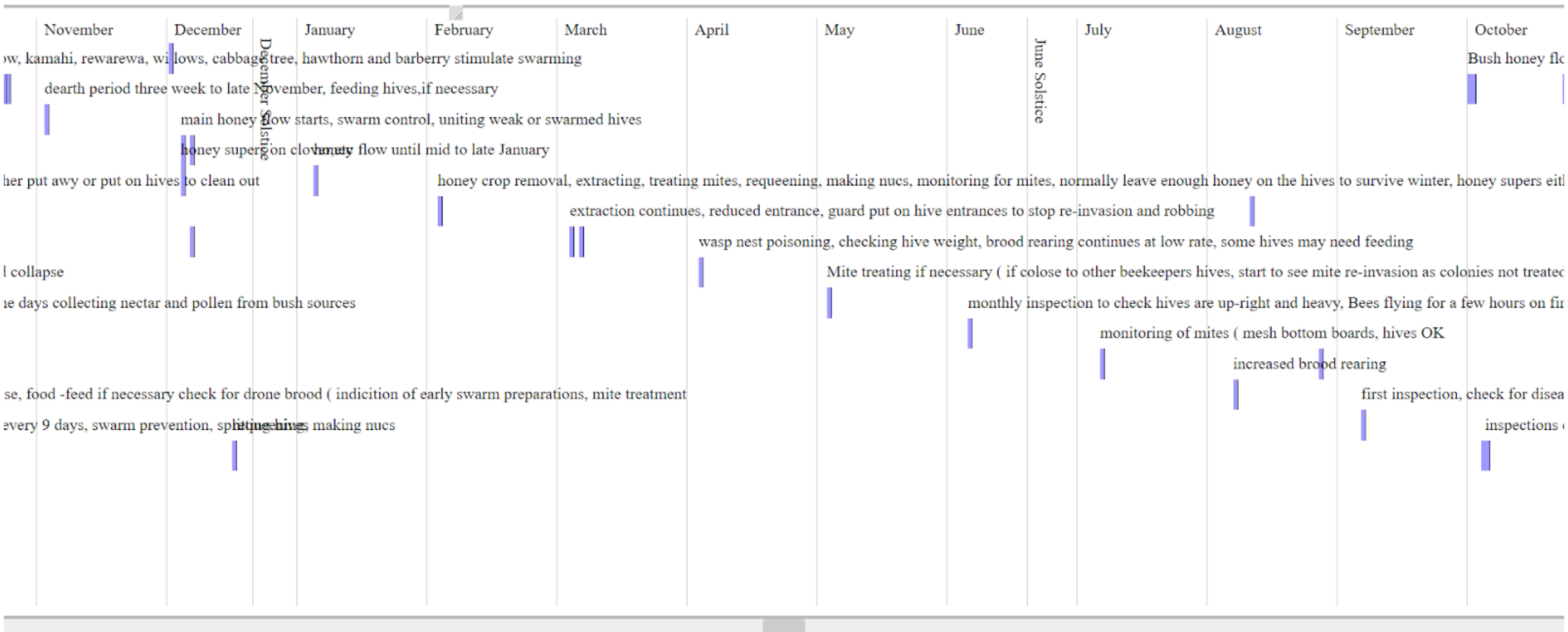


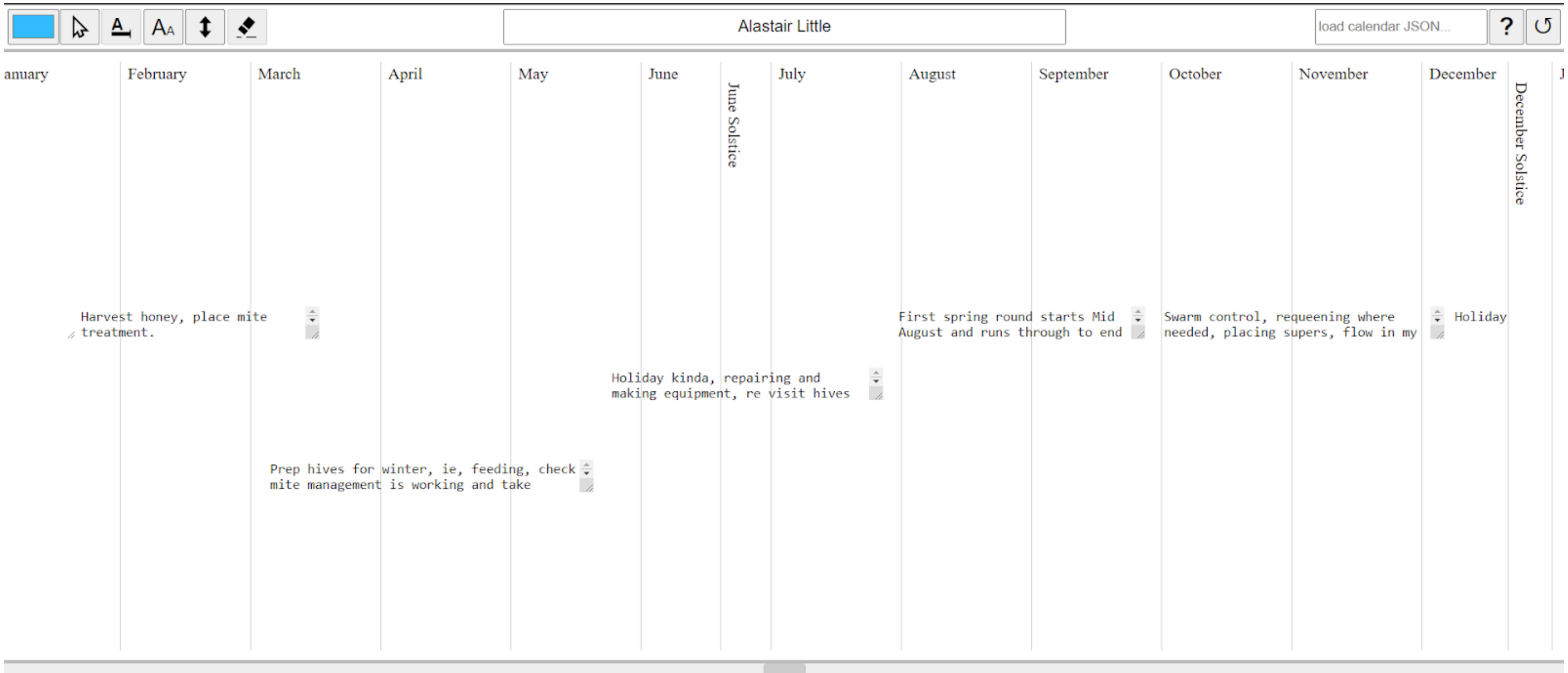
Number of interpreted calendars that noted each beekeeping event by month:



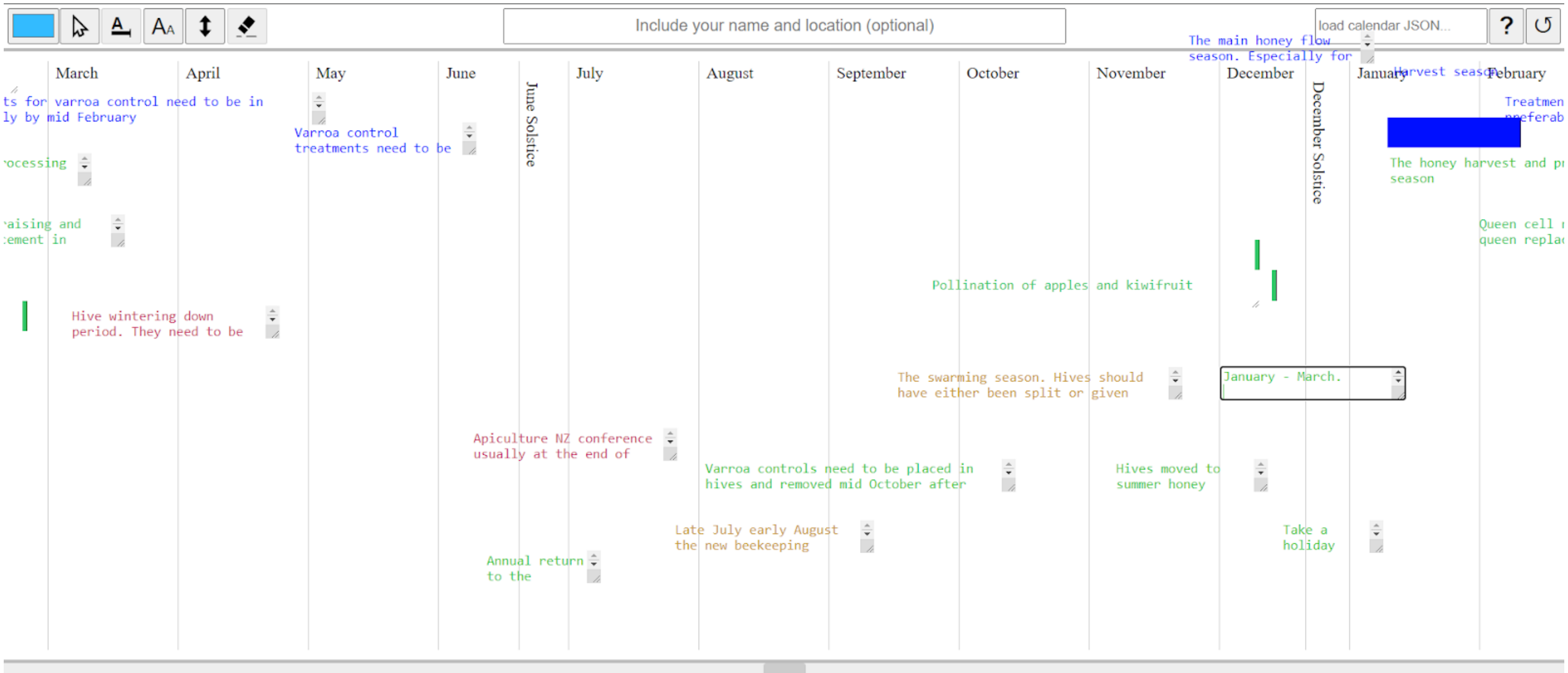
APPENDIX F: CALENDAR TOOL SUBMISSION BY BEEKEEPERS

These submissions were submitted by beekeepers that we reached out to.
In Order: **Frank Lindsay, Alistair Little, Barry Foster**


November
December
January
February
March
April
May
June
July
August
September
October
December Solstice
June Solstice
ow, kamahi, rewarewa, willows, cabbage tree, hawthorn and barberry stimulate swarming
Bush honey flo
dearth period three week to late November, feeding hives,if necessary
main honey flow starts, swarm control, uniting weak or swarmed hives
honey super on clover
honey flow until mid to late January
her put awy or put on hives to clean out
honey crop removal, extracting, treating mites, requeening, making nucs, monitoring for mites, normally leave enough honey on the hives to survive winter, honey supers eit
extraction continues, reduced entrance, guard put on hive entrances to stop re-invasion and robbing
wasp nest poisoning, checking hive weight, brood rearing continues at low rate, some hives may need feeding
l collapse
Mite treating if necessary (if colose to other beekeepers hives, start to see mite re-invasion as colonies not treatec
ne days collecting nectar and pollen from bush sources
monthly inspection to check hives are up-right and heavy, Bees flying for a few hours on fi
monitoring of mites (mesh bottom boards, hives OK
increased brood rearing
se, food -feed if necessary check for drone brood (indicition of early swarm preparations, mite treatment
first inspection, check for disea
every 9 days, swarm prevention, splitting hives making nucs
inspections



Alastair Little
load calendar JSON...
anuary
February
March
April
May
June
June Solstice
July
August
September
October
November
December
December Solstice
J
Harvest honey, place mite treatment.
Prep hives for winter, ie, feeding, check mite management is working and take
Holiday kinda, repairing and making equipment, re visit hives
First spring round starts Mid August and runs through to end
Swarm control, requeening where needed, placing supers, flow in my
Holiday


Include your name and location (optional)
load calendar JSON...
March
April
May
June
June Solstice
July
August
September
October
November
December
December Solstice
January
February
The main honey flow season. Especially for
Varroa control treatments need to be
Hive wintering down period. They need to be
Apiculture NZ conference usually at the end of
Annual return to the
Late July early August the new beekeeping
Varroa controls need to be placed in hives and removed mid October after
Pollination of apples and kiwifruit
The swarming season. Hives should have either been split or given
January - March.
Hives moved to summer honey
Take a holiday
The honey harvest and pr season

APPENDIX G: RESPONSE TO ADDITIONAL RESEARCH QUESTIONS: WHO IS IN CHARGE, THE BEES OR THE BEEKEEPER?