Biosecurity New Zealand

Tiakitanga Pūtaiao Aotearoa

Report on the 2022 New Zealand Colony Loss Survey

Biosecurity New Zealand Technical Paper No: 2023/01

Prepared for the Ministry for Primary Industries

by P. Stahlmann-Brown, Manaaki Whenua – Landcare Research; T. Robertson

ISBN No: 978-1-991080-21-9 (online)
ISSN No: 2624-0203 (online)

February 2023

Te Kāwanatanga o Aotearoa
New Zealand Government

Ministry for Primary Industries
Manatū Ahu Matua

Disclaimer

While every effort has been made to ensure the information in this publication is accurate, the Ministry for Primary Industries does not accept any responsibility or liability for error of fact, omission, interpretation or opinion that may be present, nor for the consequences of any decisions based on this information.

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries website at:
http://www.mpi.govt.nz/news-and-resources/publications/

Reviewed by:

Pam Booth
Associate Economist
Manaaki Whenua – Landcare Research

Approved for release by:

Suzie Greenhalgh
Portfolio Leader – Society, Culture & Policy
Manaaki Whenua – Landcare Research

Manaaki Whenua – Landcare Research Contract Report: LC4247

Contents

Page

Executive Summary

The 2022 NZ Colony Loss Survey recorded colony losses incurred over the winter of 2022. This survey builds on seven previous NZ Colony Loss Surveys (2015–2021), providing an opportunity to monitor losses at both the national and regional level over time.

The survey questionnaire included a core set of questions from a standardised survey that has been conducted in at least 37 countries. It also included questions that are specific to New Zealand, reflecting our unique apicultural context. The survey comprised four distinct parts, focusing on eligibility to complete the survey, winter 2022 losses, the 2021/22 honey and pollination season, and the beekeeping environment. The survey was administered online.

Invitations to participate in the survey were sent to all New Zealand beekeepers who had registered valid email addresses with the American Foulbrood (AFB) Pest Management Agency. Participation was encouraged by industry groups, presentations of the results at Apiculture New Zealand conferences, articles in newspapers, the *New Zealand BeeKeeper*, and *The Apiarist's Advocate*. In addition, all beekeepers with more than 500 registered colonies received personal phone calls to encourage completion, targeting beekeepers who had not completed the survey at the time of the call.

In total, 3,573 beekeepers completed the 2022 NZ Colony Loss Survey, indicating a response rate of 40.6% of all registered beekeepers with living colonies at the start of winter who had valid email addresses. Among the beekeepers who completed the survey were 16 of the 20 largest operators, indicating a response rate of 80% among this group. After data cleaning, 3,499 beekeepers remained in the sample. We estimate the total share of registered hives included in the survey to be 49.1%. These response rates continue to be world leading in colony loss surveys.

The overall loss rate (i.e. total winter losses reported by survey respondents divided by the total number of colonies that entered winter) is estimated to be 13.46%, with a 95% confidence interval of 13.03–13.90%. This loss rate implies that New Zealand lost approximately 97,613 colonies over winter 2022. This is statistically unchanged from winter 2021, but is higher than that from 2015, 2016, 2017, 2018, 2019, and 2020. These losses represent a substantial impact on the profit margin of beekeepers.

As in previous years, overall loss rates show regional variation, with estimates ranging from 11.46% for the Middle South Island to 15.49% in both the Upper North Island and Lower South Island. That said, regional variation in losses over winter 2022 was considerably lower than in previous years of the survey.

Average loss rates over winter were significantly higher for non-commercial beekeepers. Nevertheless, as in previous years, the survey results indicate wide variation in individual loss rates for both commercial and non-commercial beekeepers.

We estimate that 6.4% of all living colonies entering winter were lost to suspected varroa and related complications – significantly higher than in any previous wave of the survey. We further estimate that 3.1% were lost to queen problems, 0.9% to wasps, and 0.9% to suspected starvation. An additional 0.9% of overwintering colonies were lost to other causes, such as robbing by other bees, suspected nosema and other diseases, American foulbrood, exposure to toxins, and Argentine ants. Some 0.8% of colonies were lost to natural disasters, accidents, theft or vandalism.

Varroa monitoring enables beekeepers to optimise the timing of varroa treatment, which greatly increases a colony's chances of survival. While most beekeepers undertake formal monitoring for varroa, more than one-fifth do not. Regardless of monitoring, most beekeepers treat varroa in spring and/or autumn using a combination of flumethrin (marketed in New Zealand as Bayvarol®), amitraz (marketed as Apivar® and Apitraz®), and oxalic acid. Some beekeepers also treat during summer and/or winter. The vast majority of beekeepers consider their varroa treatment to be effective and point to the timing of treatment and reinvasion as the reasons for varroa losses.

We also found that greater beekeeping experience and lower risk tolerance are associated with lower loss rates.

Additional results are available on the Manaaki Whenua – Landcare Research website: https://www.landcareresearch.co.nz/discover-our-research/environment/sustainable-society-and-policy/nz-colony-loss-survey/

1 Introduction

Domesticated honey bees (*Apis mellifera*) provide honey as well as essential pollination services in crop production, yet managed honey bees are under persistent threat from pests and diseases. These threats have compelled many countries to undertake periodic surveys of honey bee colony losses, especially losses occurring over winter. For example, winter colony losses in excess of 35% in 2005 and 2006 prompted surveys of winter colony losses in the USA (Lee et al. 2015; Seitz et al. 2015), which are annual and ongoing. Similar surveys have been undertaken in Canada (Currie et al. 2010) and across Europe (e.g. van der Zee et al. 2012, 2014, 2015; Brodschneider et al. 2016; Meixner & Le Conte 2016). Indeed, by 2008 COLOSS (Prevention of honey bee COlony LOSSes) had developed a standardised survey format to harmonise data collection on colony losses (van der Zee et al. 2014) that is regularly undertaken in at least 37 countries (Gray et al. 2022).

New Zealand did not systematically record annual wintering losses until 2015, when MPI commissioned Manaaki Whenua – Landcare Research to conduct the first NZ Colony Loss Survey. The questionnaire is based on the international COLOSS survey but has been adapted to reflect the New Zealand apiculture context. Indeed, several features distinguish the New Zealand apiculture industry from beekeeping elsewhere.

1 New Zealand spans 12 degree of latitude and has a temperate climate. The country has a diversity of native and exotic flora that provide abundant pollen and nectar resources, allowing honey bee colonies to flourish at comparatively high stocking rates (Ausseil et al. 2018). Of particular note, native trees in the Myrtaceae family (e.g. *Leptospermum scoparium* [mānuka], *Kunzea ericoides* [kānuka], *Metrosideros excelsa* [pōhutukawa], and *Metrosideros robusta* [rātā], provide substantial seasonal nectar yields and monofloral honey crops.
2 Although prices have fallen significantly in recent years, mānuka honey continues to command significant price premiums relative to other honeys (van Eaton 2014; MPI 2018; Stahlmann-Brown et al. 2022a). These price premiums have not only contributed significantly to market entry and an exponential increase in colony numbers since 2006, but have also led to the uncommon situation in which most commercial beekeepers' livelihoods depend on honey production rather than providing pollination services. New Zealand exported 11,320 tonnes of honey worth $455 million in 2021 (MPI 2022).
3 Beekeeping in New Zealand is large scale. Approximately 625 beekeepers (7.1%) have more than 150 registered colonies. In contrast, less than 0.1% of beekeepers in Germany have more than 150 colonies and just 50 out of 37,888 beekeepers in the UK have more than 150 colonies (European Parliamentary Research Service 2017). Across the European Union, approximately 2% of beekeepers had more than 300 colonies in 2013 (Chauzat et al. 2013) compared to 4.7% of New Zealand beekeepers in 2022.
4 Honey bee colonies are concentrated in the hands of relatively few operators: as of June 2022, 4% of beekeepers operated 80% of production colonies. In comparison, 20% of beekeepers maintain 80% of Canadian colonies (Canadian Honey Council 2023). At the extreme end, 10 New Zealand operators each managed more than 10,000 colonies in 2022.
5 New Zealand is geographically isolated and its strict biosecurity laws do not allow for the importation of live bees or the import of bee products, as importation may expose the national hive stock to biosecurity risks such as European foulbrood (*Melissococcus plutonius*), small hive beetle (*Aethina tumida*), *Tropilaelaps* mites (*Tropilaelaps clareae* and *T. mercedesae*), tracheal mite (*Acarapis woodi*), and Israeli acute paralysis virus (Hall et al. 2021)
6 American Foulbrood is one of only two animal diseases to have its own pest management agency (the AFB Pest Management Agency), the other being bovine tuberculosis. New Zealand beekeepers are legally obliged to register their apiaries in HiveHub[1] and to destroy colonies that are found to have AFB.
7 *Varroa destructor* is a comparatively late arrival in New Zealand, having been discovered in the North Island in 2000 and in the South Island in 2006 (Zhang 2000; Goodwin & Taylor 2007), which gives New Zealand the advantage of being able to learn from overseas experience.

[1] HiveHub is the national apiary registry held by the AFB Pest Management Agency. See https://afb.org.nz/hivehub/.

Using methods detailed below, the NZ Colony Loss Survey has been used to estimate over-winter loss rates between 2015 and 2021 as follows:

- 2015: 8.37% with a 95% confidence interval of [7.66%, 9.15%] (Brown & Newstrom-Lloyd 2016)
- 2016: 9.57% [9.10%, 10.05%] (Brown & Newstrom-Lloyd 2017)
- 2017: 9.70% [9.37%, 10.05%] (Brown & Robertson 2018)
- 2018: 10.21% [9.85%, 10.58%] (Brown & Robertson 2019)
- 2019: 10.46% [10.10%, 10.82%] (Stahlmann-Brown et al. 2020)
- 2020: 11.30% [10.95%, 11.77%] (Stahlmann-Brown et al. 2021)
- 2021: 13.59% [13.21%, 13.99%] (Stahlmann-Brown and Robertson 2022).

Colony losses result in substantial economic distress. For example, over-winter losses were valued at €32 million in Austria, €21 million[2] in Czechia, and €3 million in Macedonia for 2016/17 (Popovska Stojanov et al. 2021). In New Zealand, losses over winter 2021 were valued at more than $24 million for the subset of beekeepers who operate commercially (Stahlmann-Brown et al. 2022a).

2 Methods

2.1 Survey design

The 2022 New Zealand Colony Loss Survey was administered to beekeepers online. Electronic survey enumeration affords several advantages. In particular it reduces respondent burden via branching and ensuring the relevance of each question to each respondent. For example, only those beekeepers who lost production colonies over winter were asked to provide details of the nature of those losses. In addition, electronic enumeration eliminates data-entry error, increasing the accuracy of results for analysis.

One criticism of online surveys is that they may compromise accessibility, particularly for rural populations, including beekeepers. However, well over 99% of New Zealand's population had broadband Internet access by the end of 2022 (Crown Infrastructure Partners 2018). In addition, the survey was optimised for portable devices such as phones and tablets to increase accessibility for those without high-speed Internet access at home. The survey was also made available via telephone interview.

The 2015 survey questionnaire (Brown 2015; Brown & Newstrom-Lloyd 2016) was based on an annual survey of beekeepers developed by the international COLOSS honey bee research association. Survey topics included the number and nature of over-winter colony losses, queen health and performance, indicators of pests and diseases such as varroa and nosema, treatment of varroa, supplemental feeding, and colony management. Because the challenges facing New Zealand beekeepers differ from those facing beekeepers in the northern hemisphere, the 2015 NZ Colony Loss Survey added questions on competition for apiary sites and on losses from AFB, theft and vandalism, natural disasters, and wasps. It also adapted the question on nectar flow to reflect New Zealand's floral resources.

The 2016 NZ Colony Loss Survey was a refinement of the 2015 survey. While retaining the core international COLOSS questions to facilitate international comparisons, it incorporated feedback from scientists, beekeepers, and industry representatives to increase the relevance and accuracy of the information collected, including better accounting of the acquisition and disposal of colonies to improve accounting of winter losses, and replacing the Apiary Registry Location with well-understood geographical regions. In addition, new questions on emerging challenges to apiaries were added to quantify the threats posed by Argentine ants and giant willow aphid. Questions on methods for monitoring varroa were included, as were several new methods for treating varroa. The 2016 questionnaire also included new questions on beekeepers' estimates of the primary reasons that apiary sites had been lost or compromised and revised questions on the nectar flow of selected native monoflorals.

The 2017 questionnaire was very similar to the 2016 one to facilitate trend analysis, but it did include two important refinements. First, the international COLOSS surveys include a catch-all category of losses that generally require verification. This 'colony death' category explicitly includes suspected

[2] At the time of writing, €1 = $1.70.

toxic exposure and suspected starvation, and implicitly includes both varroa and related complications, and nosema and other diseases (Steinhauer et al. 2018). In both 2015 and 2016, New Zealand beekeepers attributed many losses to 'colony death' and later remarked that they found the category to be poorly defined. Hence, beginning in 2017 we asked about specific causes of losses associated with colony death (e.g. starvation and exposure to toxins) without first asking beekeepers to identify colony death as the cause. Second, we added other important explanations for colony loss, including suspected varroa and related complications, suspected nosema and other diseases, and robbing by other bees.

The 2018 questionnaire included additional questions on the nature of queen problems, which were the leading cause of winter colony losses reported in 2017. Specifically, the survey asked whether queens disappeared, were drone layers, or had poor brood pattern and/or poor hive build up. In addition, the questionnaire was refined to collect more detailed information about winter apiaries and where losses occurred. The 2018 survey was also transitioned to a new survey platform that supports matrix-style questions, thereby making completion of the survey faster and easier.

In 2019 new questions focused on the source of new queens, and honey that was not sellable due to tutin, a toxic compound that may be present if bees collect honeydew secreted by passion vine hoppers feeding on the sap of the native tutu plant (*Coriara genus*). The survey was also optimised for phones and tablets because approximately half of all respondents complete the survey on a mobile device.

In 2020 the questionnaire was updated to simplify recording of winter losses. Rather than asking about all forms of losses in a single page, the questionnaire categorised losses into high-level categories, specifically: unresolvable queen problems, natural disasters and accidents, theft or vandalism, and colonies that were dead upon inspection (due to AFB, varroa, wasps, disease, robbing, starvation, etc.). Beekeepers who indicated they had colonies that were dead upon inspection were then asked to specify the nature of those deaths. This reframing of the questionnaire aligns more closely with the standard COLOSS questionnaire while resolving the problems of interpreting 'colony death' noted in 2017. The 2020 questionnaire was also updated to capture detailed information on the location of seasonal activities, dependence on beekeeping for livelihoods, and perceptions of the operating environment, including the economics of beekeeping, environmental factors, biosecurity, and beekeeper lifestyle.

The 2021 questionnaire focused on varroa and its management. New questions were added to record perceptions of why colonies were lost to varroa, mite loads, timing of varroa treatment, dosage of any treatments used, and the duration of treatment. In addition, respondents were asked to reflect on the extent to which they considered these treatments to be successful. These questions added a significant response burden, so to accommodate the increased demands on respondents, selected questions from previous years (e.g. requeening strategies) were removed from the 2021 questionnaire.

The 2022 questionnaire retained key refinements pertaining to varroa from the 2021 survey, including the timing and type of varroa treatment and perceptions of why colonies were lost to varroa. It also included questions related to the timing of key management activities (e.g. splitting, uniting, providing pollination services, and taking honey off), and questions on each beekeeper's risk preferences and optimism about the future of beekeeping in New Zealand. Finally, survey answer sets were streamlined to address beekeepers' concerns about the complexity of the survey.

2.2 Categories of colony loss used in the 2022 survey

Colony losses, in general, were attributed to queen problems (including drone-laying queens or no queen), natural disasters or accidents, theft or vandalism, AFB, wasps, robbing by other bees, Argentine ants, suspected starvation, suspected toxic exposure, suspected varroa and related issues, and suspected nosema and other diseases. Losses due to varroa mites, insecticides or plant toxins, and other pathogens and pests may be difficult to diagnose, hence the caveat 'suspected'. As noted above, several of these categorisations were added to the 2017 questionnaire at the suggestion of beekeepers. We acknowledge that in many cases it may be difficult to definitively determine the underlying causes of colony loss outside of a laboratory and that some colonies may be lost to multiple causes; nevertheless, we report beekeepers' own understanding of what caused their colony losses.

2.3 Sampling strategy

Our sampling strategy aimed for inclusiveness while targeting New Zealand's largest beekeeping operations. To achieve this, we followed a two-pronged approach to recruiting respondents, first implemented in 2016.

Under the Biosecurity Act 1993 all New Zealand beekeepers are legally obliged to register colony numbers and apiaries with the AFB Management Agency and to complete an Annual Disease Return by 1 June. More than 95% of registered New Zealand beekeepers provided email addresses in HiveHub. In turn, the AFB Management Agency provided these email addresses to Manaaki Whenua – Landcare Research to conduct the 2022 NZ Colony Loss Survey.

Manaaki Whenua – Landcare Research sent personalised email invitations to participate in the survey to 8,844 registered New Zealand beekeepers who had reported having at least one living colony at the start of winter in HiveHub. In total, 50 emails bounced, probably due to invalid email addresses and/or overly aggressive spam filters. Non-respondents received up to four email reminders between 15 September 2022 and 1 November 2022.

Participation was encouraged by industry groups, presentations of the results at Apiculture New Zealand conferences, articles in newspapers, the *New Zealand BeeKeeper*, and *The Apiarist's Advocate*, and by the opportunity to win supermarket vouchers. In addition, all beekeepers with more than 500 registered colonies received personal phone calls to encourage completion; phone calls began in mid-October, targeting beekeepers who had not completed the survey at the time of the call.

In total, 3,573 beekeepers completed the 2022 NZ Colony Loss Survey, a response rate of 40.6% of all registered beekeepers with valid email addresses. Among the beekeepers who completed the survey were 16 of the 20 largest operators, indicating a response rate of 80% among this group. After data cleaning, 3,499 beekeepers remained in the sample. These response rates are significantly higher than those obtained for any European country (Gray et al. 2022).

Beekeepers reported on 352,419 colonies in the 2022 NZ Colony Loss Survey, some 49.1% of all colonies registered in HiveHub managed by beekeepers with valid email addresses. In comparison, the share of colonies included in US calculations is approximately 9.9% (Bee Informed Partnership 2021). Table 1 describes the sample for each year the NZ Colony Loss Survey has been conducted.

Table 1: NZ Colony Loss Survey Sample, 2015–2022.

Year	No. of respondents	% of all registered beekeepers	No. of colonies reported	% of all registered colonies*
2022	3,573	40.60%	352,419	49.10%
2021	4,355	49.10%	381,148	47.20%
2020	2,863	32.00%	304,143	34.70%
2019	3,456	36.70%	297,377	36.20%
2018	3,655	42.30%	365,986	41.60%
2017	2,066	30.90%	242,926	30.10%
2016	2,179	37.90%	275,356	40.30%
2015	366	6.70%	225,660	39.60%

* Registered colonies with valid email addresses

Table 2 describes the 2022 sample by operation size and by the region in which colonies were overwintered. Given the small number of beekeepers with more than 3,000 colonies, locations are not provided for the largest operators.

Table 2: Number of beekeepers responding to the 2022 NZ Colony Loss Survey, by region and operation size.

Region	1–10 colonies	11–50 colonies	51–250 colonies	251–500 colonies	501–3,000 colonies	3,001+ colonies
Upper North Island	692	58	24	7	22	29
Middle North Island	590	54	33	14	29	
Lower North Island	598	46	20	7	18	
Upper South Island	174	19	7	3	9	
Middle South Island	440	27	12	4	13	
Lower South Island	363	28	9	3	10	
Total	**2,854**	**229**	**102**	**37**	**93**	29

Notes: To preserve anonymity, beekeepers with 3,001+ colonies are not reported by region. Also, some beekeepers winter colonies in multiple regions. The total shown in the last row therefore reflects the total number of beekeepers in each size class and is not a column total. Beekeepers who operate in the Chatham Islands are not included in this figure.

2.4 Estimating colony losses and confidence intervals

Van der Zee et al. (2012) note two ways to calculate loss rates. The 'overall loss rate' is calculated as the total number of winter losses by survey respondents divided by the total number of colonies that were alive at the beginning of winter. The 'average loss rate' is the average of the individual loss rates (i.e. the average of each respondent's total winter losses divided by the number of living colonies at the beginning of winter). Although the loss rates experienced by beekeepers with different-sized operations are not equally variable, the latter approach weights losses equally. In addition, the average loss rate is strongly influenced by operation size. For these reasons, van der Zee et al. (2012 advocate reporting overall loss rates rather than average loss rates. This approach has been adopted by COLOSS for reporting wintering losses in Europe (Brodschneider et al. 2016, 2018) and by the Bee Informed Partnership for reporting wintering losses in the US (Lee et al. 2015; Seitz et al. 2015). We also adopt this approach.

Confidence intervals (interpreted as the true value falling within this range 95% of the time a new sample of beekeepers is drawn from the population) are generally calculated using a binomial distribution, which in this case implies that the likelihood of survival for any given colony is independent of that for any other colony, and that the probability of survival is the same for all colonies (van der Zee et al. 2013).

However, the performance of one colony in an apiary often depends on the performance of other colonies in the same apiary (McCullagh & Nelder 1989). Location-specific impacts, such as disease and disaster, can have similar impacts. Such clustering of losses often leads to under- or over-dispersion in the data (McCullagh & Nelder 1989), which can affect standard errors and confidence intervals (Brodschneider et al. 2016). Thus, beginning in 2018, standard errors reported in the NZ Colony Loss Survey were calculated using a quasi-binomial distribution and a logit-link function, which derives a confidence interval for the overall loss rate based on the standard error of the estimated intercept in a model with only an intercept (McCullagh & Nelder 1989; vanEngelsdorp et al. 2012; van der Zee et al. 2012). This approach is consistent with that undertaken in Europe (Brodschneider et al. 2016, 2018) and the US (Lee et al. 2015; Seitz et al. 2015).

3 Survey questionnaire

The main questions from the standard international COLOSS survey were included to enable international comparison. Additional questions were added to reflect both the New Zealand context and feedback on the previous NZ Colony Loss Surveys provided by scientists, beekeepers, and other end users. The survey was available online between 1 September and 15 November 2022.

The 2022 NZ Colony Loss Survey comprised four distinct parts. The first part obtained each respondent's consent and ensured that he or she was well positioned to complete the survey. The main part of the survey recorded the number of living colonies at the beginning of winter, the number of living colonies during the first spring round, and the attributions of any losses in between those periods. The third part focused on topics such as varroa monitoring and treatment, brood comb replacement, migration, floral resources, supplemental feeding, overcrowding during the honey and pollination season, and colony management. The fourth part included questions about beekeeping experience, perceptions of the current beekeeping climate, and risk preferences. Apart from obtaining consent, and recording colony numbers at the beginning of winter and during the first spring round, all questions were optional.

The entire text of the survey questionnaire is included as an appendix at the end of this report.

4 Highlighted results

Results are presented as bar charts, pie charts, histograms, and tables. Histograms are especially useful for highlighting the range of reported values, but we also include averages to facilitate making comparisons across groups.

Most information is reported at an aggregated level (hereafter called a 'region'). Specifically, beekeepers recorded the political regions in which they operated; these political regions were then aggregated and categorised into six geographical regions: Upper North Island, Middle North Island, Lower North Island, Upper South Island, Middle South Island, and Lower South Island.

Most information is also reported by the total number of colonies comprising each beekeeping operation as at the beginning of winter. Operation size is categorised into six size classes: 1–10 colonies, 11–50 colonies, 51–250 colonies, 251–500 colonies, 501–3,000 colonies, and operators with more than 3,000 colonies. Beekeepers whose colony numbers changed between the 2021/22 season and the beginning of winter are classified according to the latter date.[3] Because most figures report beekeeper averages, figures reported by region restrict the sample to beekeepers with more than 250 colonies, unless noted.[4] Figures reported by operation size include all respondents.

4.1 National-level estimates of colony losses during winter 2022

We report overall loss rates and standard errors based on quasi-binomial distributions with a logit-link function in order to maintain consistency and to facilitate international comparisons. (Refer to the Methods section for detail.)

The overall loss rate during winter 2022 was 13.46%, with a 95% confidence interval of [13.03%, 13.90%].

Table 3 reports the overall loss rates and 95% confidence intervals for winter from 2015 to 2022. To compare overall loss rates between years, we paired the loss data for every two consecutive years and ran a quasi-binomial model on each data set. A dummy variable was included to distinguish between years, with statistical significance of the coefficient indicating a statistical difference between overall loss rates (at the 0.05 level).[5] The overall loss rate for winter 2022 is statistically indistinguishable from the overall loss rate for winter 2021, but it is 19.1% higher than it was in 2020,

---

[3] For example, if a beekeeper with 600 colonies in January sold 300 colonies in May, that operation would be classified as having 251–500 colonies for all reporting.

[4] Beekeepers who have more than 250 colonies were included in such reporting even if those colonies were distributed across multiple regions.

[5] We apply the same threshold for statistical significance throughout the report. Thus, whenever we refer to results being statistically significant, we mean that they are significant at the 0.05 level or higher.

a difference that is statistically significant. Overall loss rates for winter 2022 are also substantially higher than for winter 2015, 2016, 2017, 2018, and 2019.

Table 3: Overall winter loss rates, 2015–2022.[6]

Winter	Overall loss rate	95% confidence interval
2022	13.46%	[13.03%, 13.90%]
2021	13.59%	[13.21%, 13.99%]
2020	11.30%	[10.95%, 11.66%]
2019	10.40%	[10.05%, 10.77%]
2018	10.20%	[9.85%, 10.57%]
2017	9.70%	[9.37%, 10.05%]
2016	9.53%	[9.07%, 10.02%]
2015	8.37%	[7.66%, 9.15%]

Overall loss rates over winter 2022 were also calculated by region. Loss rates over winter 2022 vary by region, as shown in Figure 1.

[6] In preparing this report we reviewed data collected in previous years to ensure consistency and data integrity. The table has been updated to reflect the correct figures on overall loss rates, confidence intervals, and colony numbers for each year; none of the changes substantively change the results reported in earlier reports.

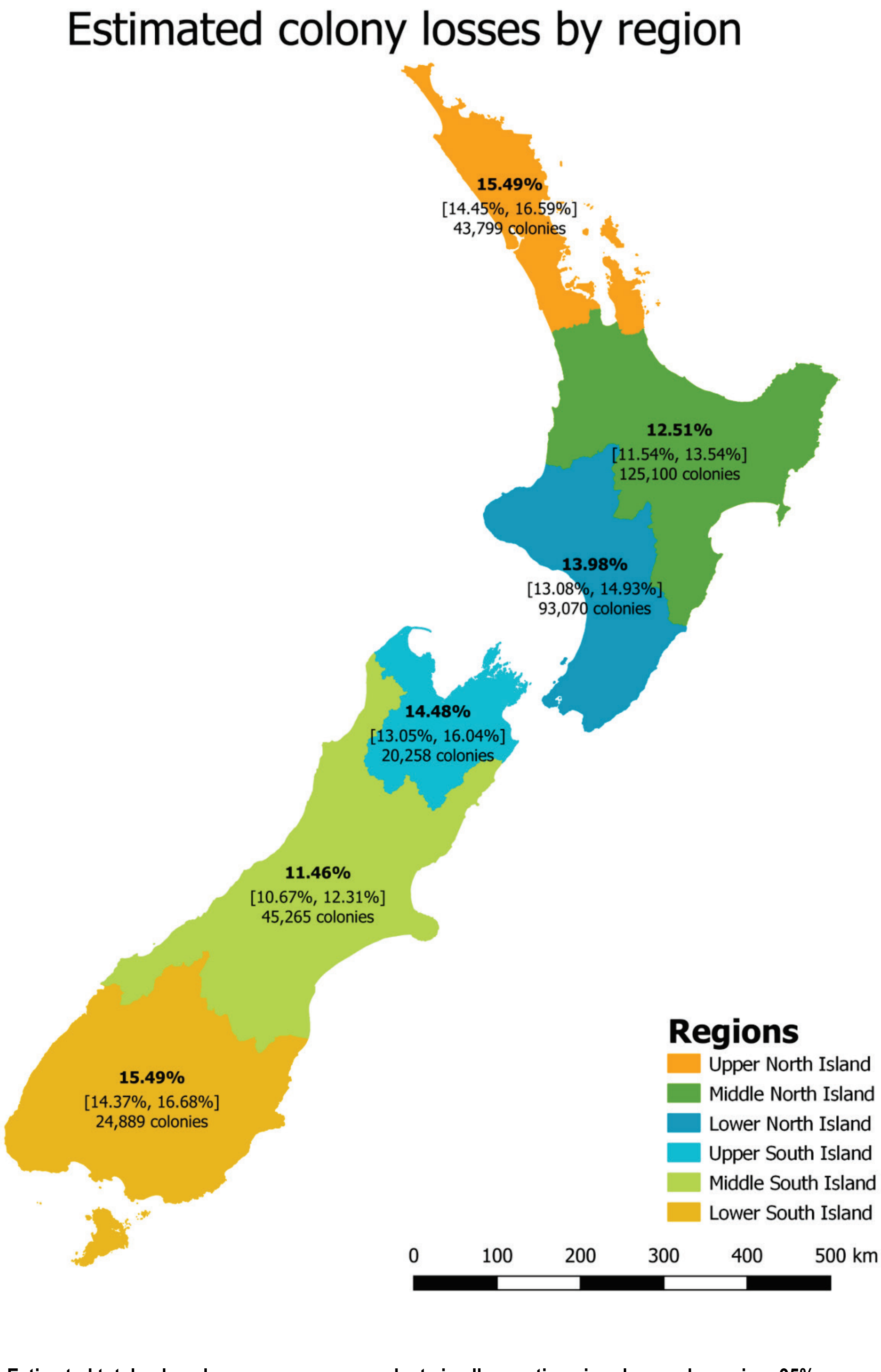

Figure 1: Estimated total colony losses among respondents in all operation size classes, by region; 95% confidence intervals and number of colonies reporting are shown below estimated total colony losses.

Overall loss rates by region for winter from 2016 to 2022 are reported in Table 4.[7,8] Notably, regional variation in loss rates was much lower in 2022 than in previous years.

Table 4: Overall winter loss rates, by year and region.[9]

Region	Winter	Overall loss rate	95% confidence interval	Reported colonies
Upper North Island	2022	15.49%	[14.45%, 16.59%]	43,799
	2021	13.08%	[12.26%, 13.95%]	59,127
	2020	11.07%	[10.32%, 11.86%]	47,092
	2019	10.67%	[9.85%, 11.56%]	49.593
	2018	12.82%	[12.00%, 13.68%]	61,401
	2017	9.71%	[9.05%, 10.41%]	54,297
	2016	8.06%	[7.20%, 9.03%]	45,434
Middle North Island	2022	12.51%	[11.54%, 13.54%]	125,100
	2021	18.70%	[17.78%, 19.66%]	131,442
	2020	13.94%	[13.20%, 14.71%]	96,695
	2019	11.99%	[11.32%, 12.70%]	97,447
	2018	9.92%	[9.17%, 10.72%]	110,561
	2017	10.37%	[9.70%, 11.07%]	83,922
	2016	10.65%	[9.77%, 11.59%]	96,451
Lower North Island	2022	13.98%	[13.08%, 14.93%]	93,070
	2021	8.71%	[8.11%, 9.35%]	95,051
	2020	9.34%	[8.80%, 9.90%]	95,964
	2019	7.99%	[7.43%, 8.59%]	58,509
	2018	8.06%	[7.45%, 8.71%]	84,239
	2017	9.11%	[8.30%, 9.98%]	50,584
	2016	11.63%	[10.28%, 13.14%]	63,221
Upper South Island	2022	14.48%	[13.05%, 16.04%]	20,258
	2021	14.02%	[12.76%, 15.39%]	21,962
	2020	12.79%	[11.19%, 14.57%]	17,430
	2019	8.01%	[6.93%, 9.23%]	29,982
	2018	9.99%	[9.06%, 11.02%]	39,782
	2017	5.27%	[4.49%, 6.17%]	12,741
	2016	5.49%	[4.56%, 6.61%]	15,382
Middle South Island	2022	11.46%	[10.67%, 12.31%]	45,265
	2021	9.99%	[9.25%, 10.78%]	47,266
	2020	7.84%	[6.94%, 8.86%]	31,614
	2019	10.64%	[9.40%, 12.02%]	31,573
	2018	11.36%	[10.41%, 12.39%]	43,526
	2017	11.28%	[10.20%, 12.45%]	18,636
	2016	7.67%	[6.81%, 8.63%]	30,805

[7] Regions were defined slightly differently in our 2015 reporting so are not available for comparison; see section 2.1.

[8] As noted above, the numbers provided in the table include any colonies that were either acquired or sold/given away over winter and remove any colonies for which loss information was not provided. As such, they differ slightly from the number of colonies presented in Figure 1, which reflects colonies at the beginning of winter.

[9] Similar to Table 3, we reviewed data collected in previous years to ensure consistency and data integrity. Table 4 has thus been updated to reflect the correct figures for overall loss rates, confidence intervals, and colony numbers for each year.

Region	Winter	Overall loss rate	95% confidence interval	Reported colonies
Lower South Island	2022	15.49%	[14.37%, 16.68%]	24,889
	2021	13.02%	[12.00%, 14.11%]	26,220
	2020	12.93%	[11.63%, 14.35%]	17,005
	2019	11.87%	[10.82%, 13.00%]	26,411
	2018	10.58%	[9.14%, 12.22%]	26,390
	2017	9.79%	[8.80%, 10.87%]	18,083
	2016	7.35%	[6.50%, 8.31%]	24,882

- The overall loss rate in winter 2022 in the Upper North Island was estimated to be 15.5%, statistically higher than in any previous wave of the survey.
- In the Middle North Island the overall winter 2022 loss rate was 12.5%, considerably lower than the 18.7% figure reported for winter 2021, when the region was especially hard hit by both suspected varroa and wasps.
- In the Lower North Island the overall loss rate for winter 2022 was 14.0%, far and away the highest it has been since 2017. The 2022 overall loss rate is not statistically distinguishable from the 2016 overall loss rate.
- The 2022 overall loss rate in the Upper South Island was 14.5%, statistically indistinguishable from the 2020 and 2021 overall loss rates in this region.
- In the Middle South Island the overall loss rate for winter 2022 was 11.5%. This figure is higher than the overall loss rates for 2016 and 2020 but statistically indistinguishable from the overall loss rates in other survey years.
- In the Lower South Island overall loss rates reached 15.5%, tied with the Upper North Island and the first time that any South Island region has experienced such high loss rates. These Lower South Island loss rates are statistically higher than in any previous wave of the survey.

The share of overall losses attributed to specific causes of colony loss is shown in Figure 2. Some 47.3% of total losses over winter 2022 were attributed to suspected varroa and related complications compared to 38.9% for winter 2021. Queen problems was the second most common attributed cause of loss at 23.0%. Wasps were the attributed cause for 6.8% of over-winter losses compared to 12.0% for 2021. Suspected starvation was the attributed cause of 6.4% of losses compared to 6.8% for 2021. Natural disasters (e.g. flooding) and accidents (e.g. livestock overturning hives) accounted for 5.6% of overwinter loss attributions in 2022. Robbing by bees accounted for 3.0% of loss attributions, and 2.1% of total colony losses were attributed to suspected nosema and other diseases. Attributions to American foulbrood, Argentine ants, suspected toxicity, and theft or vandalism were negligible in comparison. Beekeepers report being unsure about the cause of 2.1% of losses.

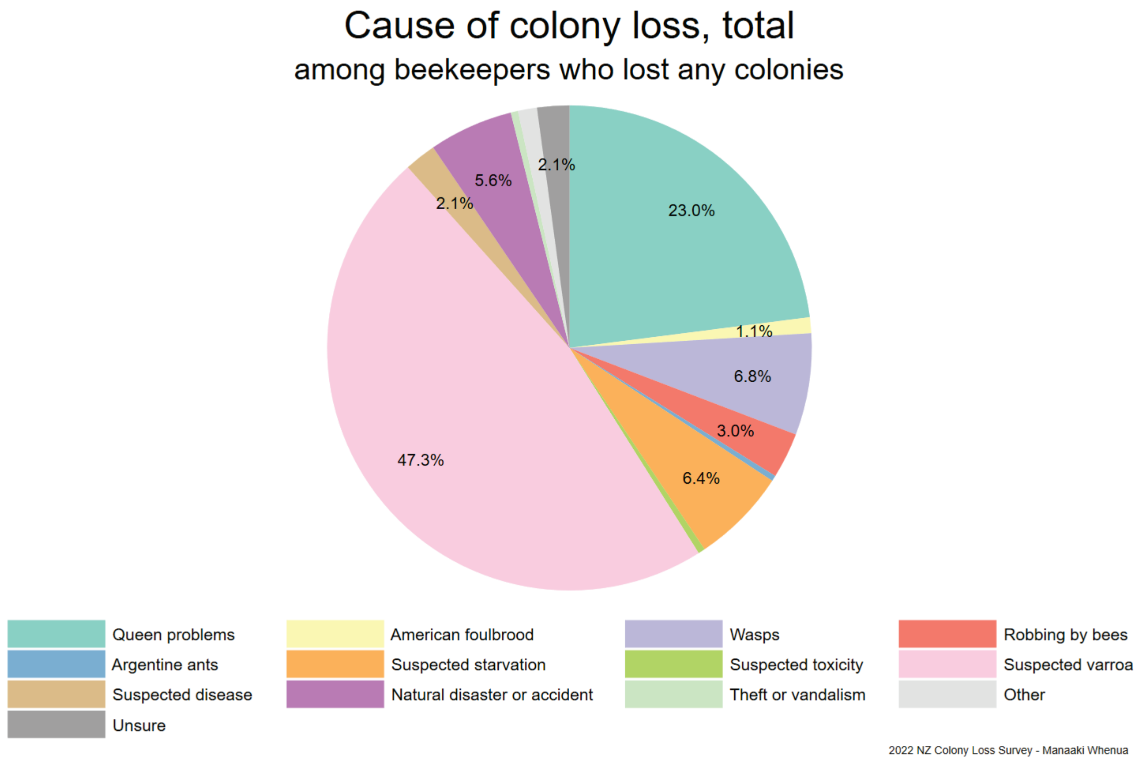

Figure 2: Share of total colony losses over winter 2022 attributed to various causes among beekeepers who lost any colonies.

4.2 Respondents by region and operation size

In line with previous years and with colony registration on HiveHub, more beekeepers reported operating in the Upper North Island than in any other region (Figure 3). The Middle South Island has the highest number of respondents in the South Island.

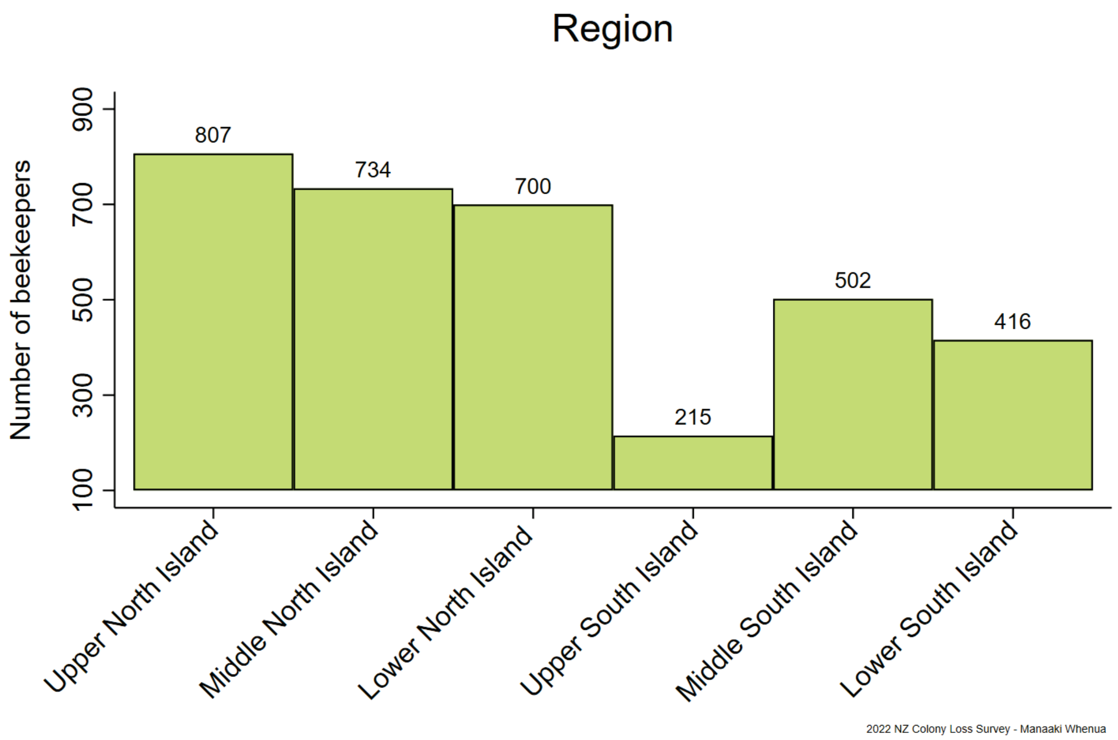

Figure 3: Number of respondents who operate in each region (regardless of operation size).

Figure 4 shows the operation size reported by each respondent as at the beginning of winter. Operations with:

- 1–10 colonies comprised 85.4% of the sample
- 11–50 colonies comprised 6.9% of the sample
- 51–250 colonies comprised 3.1% of the sample
- 251–500 colonies comprised 1.1% of the sample
- 501–3,000 colonies comprised 2.3% of the sample
- more than 3,000 colonies comprised 0.9% of the sample.

Compared with HiveHub registrations, our sample is over-represented by beekeepers with 1–10 colonies and by beekeepers with more than 3,000 colonies.

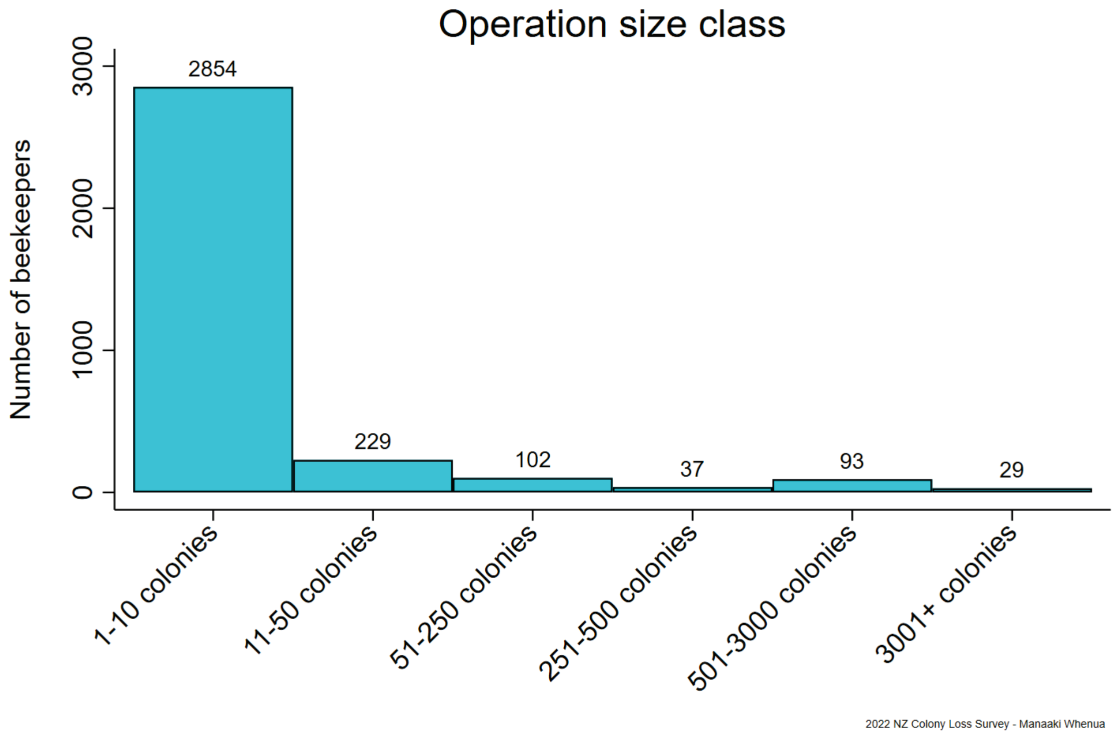

Figure 4: Operation size.

4.3 Average loss rates over winter 2022

For the remainder of this report, unless otherwise stated, numbers reported in figures are interpreted as averages within groups. For example, whereas Figure 2 shows overall loss rates (combining all colonies reported), Figure 5Figure 5 reports the average loss rates for beekeepers within each region. To clarify with an example, consider a region that consists of two beekeepers, one with 500 colonies and one with 5,000 colonies. Assume that the smaller beekeeper lost 8% of their colonies and the larger beekeeper lost 12% of their colonies. The overall loss rate for the region would be 11.6%, but the average loss rate would be 10.0%.

While overall loss rates are useful for estimating total losses, average loss rates enable individual beekeepers to better understand the relative performance of their own operations. However, as noted above, loss rates experienced by beekeepers with different-sized operations are not equally variable, and average loss rates are strongly influenced by operation size. Loss rates are also strongly influenced by region; for example, wasps are problematic in certain parts of New Zealand and largely absent elsewhere. For these reasons it makes little sense to compare averages for a large commercial operator in the one region with those of a small, non-commercial beekeeper elsewhere. Hence, the following results are presented by region (restricting the sample to beekeepers with more than 250 colonies, unless otherwise stated) and by operation size (without regard to apiary location). These and all subsequent questions were optional, and many beekeepers chose not to provide these details; hence the number of respondents (*n*) is shown in each figure.

Among beekeepers with more than 250 colonies, the mean reported colony loss over winter 2022 was 14.2% (Figure 5), compared with 15.7% in 2021 and 11.2% in 2020. The average shares of colonies lost among beekeepers with more than 250 colonies in the North Island and South Island were 15.1% and 12.2%, respectively, compared to 17.7% and 11.2% for 2021. The highest average losses occurred in the Upper North Island at 17.5%. Three North Island beekeepers with more than 250 colonies reported losing more than 70% of their colonies over winter 2022. Six beekeepers with more than 250 colonies reported having no losses over winter 2022.

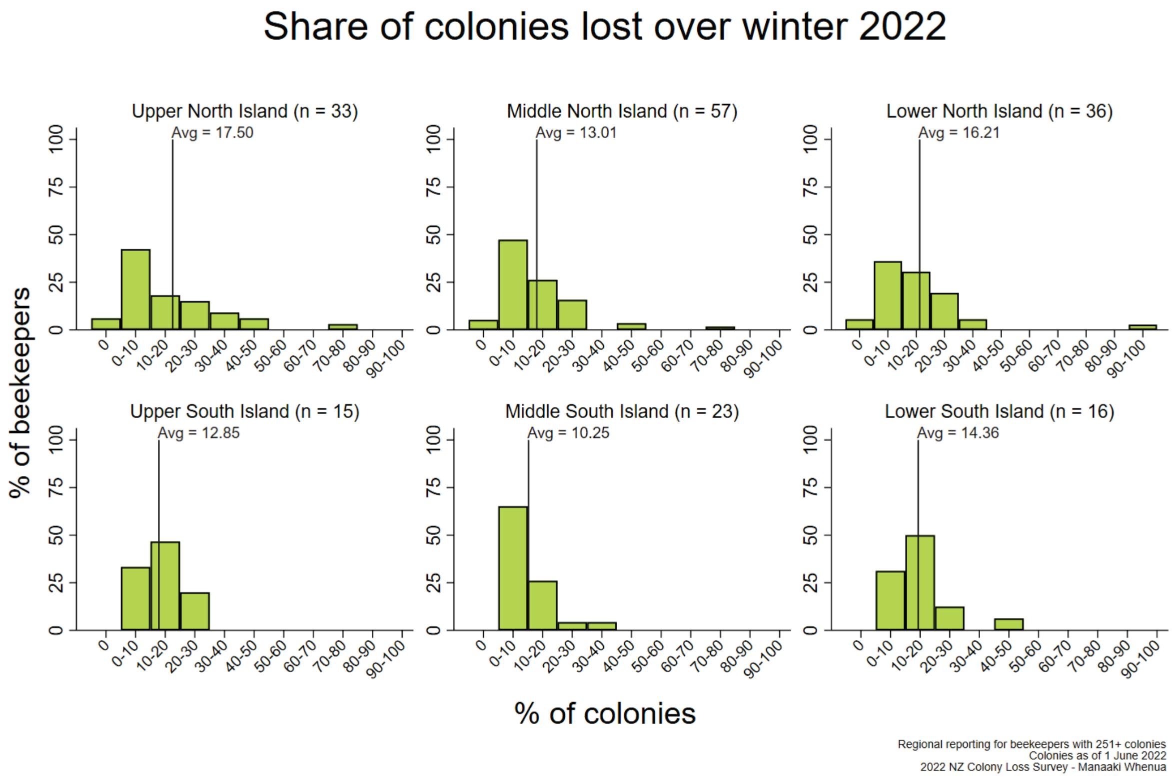

Figure 5: Winter 2022 colony losses as a share of total winter colonies among beekeepers with more than 250 colonies, by region.

Figure 6 shows the distribution of colony losses by operation size, including those with fewer than 251 colonies. Operations with 1–10 colonies lost the highest share of colonies, on average, at 32.7% (cf. 29.3% in 2021), although the distribution was bimodal and approximately half of operations with 1–10 colonies reported having no losses. Operations with 11–50 colonies lost 28.1% (26.9%) of their colonies, on average, with approximately 10% reporting no losses. Operations with 51–250 colonies lost 21.4% (23.8%), on average, while operations with 251–500 colonies lost 17.3% (19.5%), on average. Operations with 501–3,000 colonies had average losses of 13.9% (15.4%) and those with over 3,000 colonies lost 11.7% (10.5%), on average.

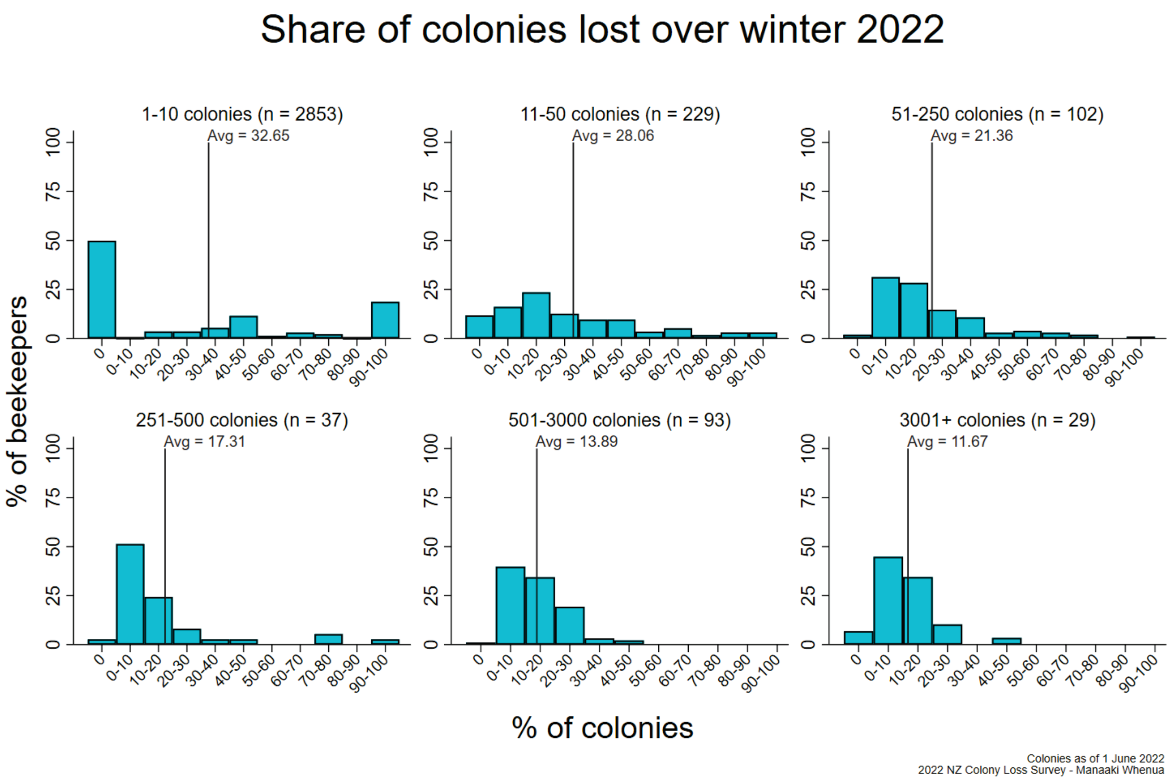

Figure 6: Winter 2021 colony losses as a share of total winter colonies, by operation size.

4.4 Colony losses by categories of loss

Figure 7 and Figure 8 report the average share of colonies lost by region for beekeepers with more than 250 colonies and by operation size, *among beekeepers who experienced any losses*, respectively. For example, among beekeepers with 1–10 colonies, 24.0% of losses were attributed to suspected varroa and related complications, on average, as were 22.7% of losses among beekeepers with 11–50 colonies.

In 2022 the average share of losses attributed to suspected varroa and related complications among beekeepers with more than 250 colonies ranged from 28.8% in the Upper South Island to 54.1% in the Lower South Island. Among beekeepers with more than 250 colonies the average share of losses attributed to queen problems was also high in 2022, ranging from 26.3% in the Lower South Island to 40.4% in the Middle South Island. As in previous years of the survey, wasps were most problematic in the Middle North Island (8.4% of loss attributions) and Upper North Island (6.8% of loss attributions). Attributions of losses to suspected starvation ranged from 4.5% of losses in the Lower North Island to 13.3% in the Upper South Island. Natural disasters and accidents were most prevalent in the Upper South Island (15.7%) and the Upper North Island (9.6%). Suspected nosema and other diseases were most prevalent in the Lower North Island (4.4%).

Beekeepers across all size classes reported that suspected varroa and related complications and queen problems accounted for more losses than any other causes. For example, among beekeepers with 501–3,000 colonies, 44.7% of losses were attributed to suspected varroa and related complications, on average, as were 29.9% to queen problems.

Starvation was identified as an underlying cause of losses across operation sizes. For example, beekeepers with 501–3,000 colonies attributed 6.9% of losses to suspected starvation; beekeepers with 11–50 colonies attributed 12.7% of losses to suspected starvation.

Wasps were also identified as a major problem across size classes: for example, beekeepers with more than 3,000 colonies attributed 7.6% of colony losses to wasp attacks, while beekeepers with 1–10 colonies attributed 11.3% of colony losses to wasp attacks. Robbing is a common cause of loss among beekeepers with 1–10 colonies, accounting for 9.7% of attributed losses, on average.

Colonies weakened by varroa are more susceptible to wasp attack and robbing by other bees (Goodwin et al. 2006), so losses attributed to wasps and robbing may reflect varroa infestation.

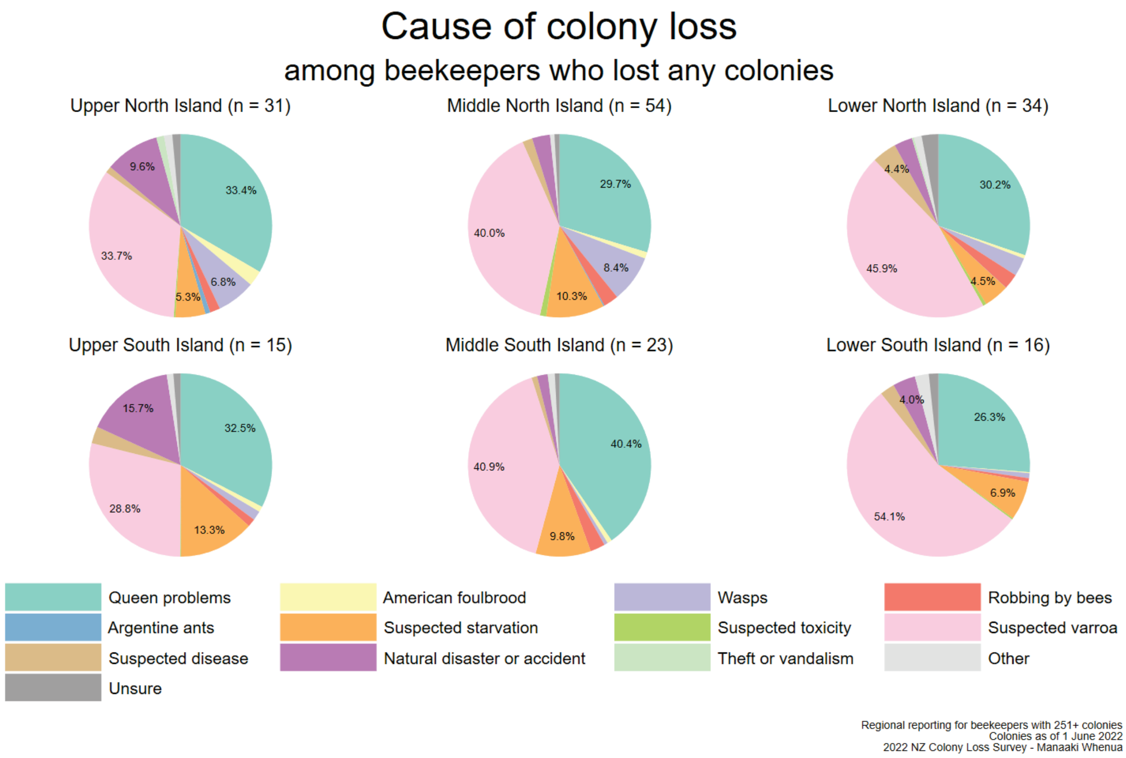

Figure 7: Share of colony losses attributed to various causes over winter 2022 among beekeepers with more than 250 colonies who lost any colonies, by region.

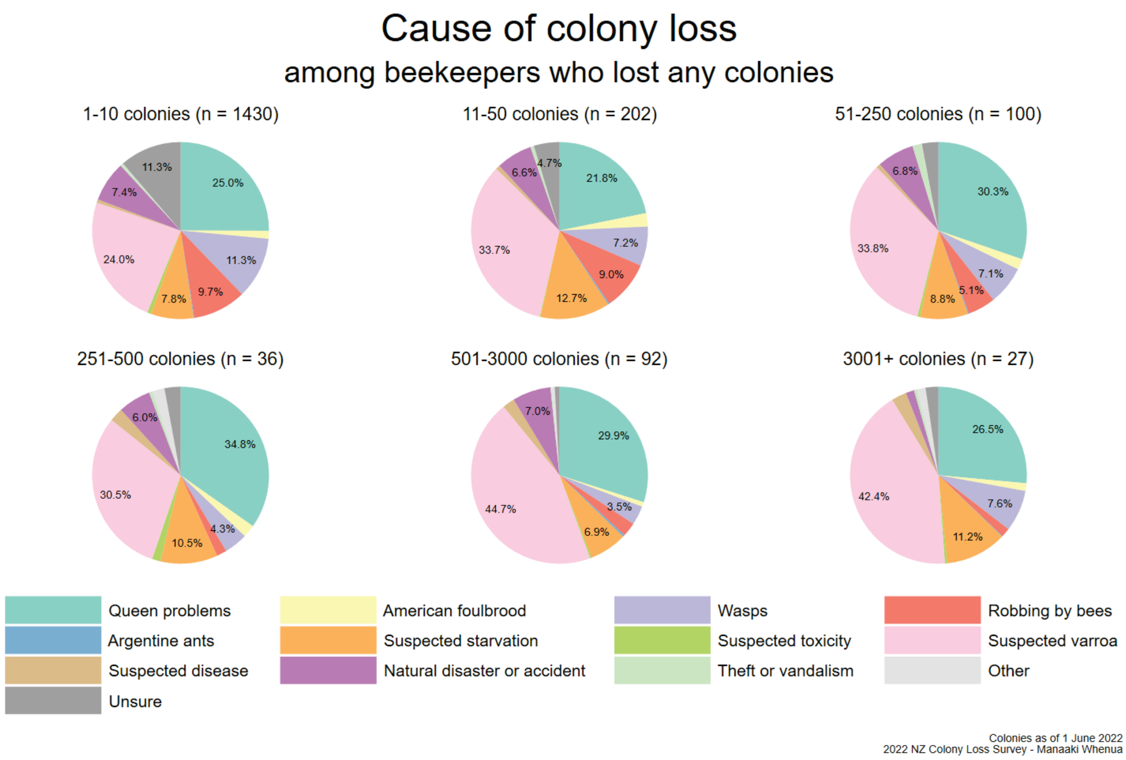

Figure 8: Share of colony losses attributed to various causes over winter 2022 among beekeepers who lost any colonies, by operation size.

Tables 5 and 6 present the estimated share of all living colonies going into winter that were lost due to the attributions discussed above, by region and operation size, respectively. For example, 3.4% of all living colonies in the Upper North Island were estimated to be lost to queen problems over winter 2022, 0.3% of all living colonies in the Upper North Island were estimated to be lost to AFB over winter 2022, and 5.5% of all living colonies in the Upper North Island were estimated to be lost to suspected varroa and related complications.

Table 5: Estimated share of all colonies lost to various causes over winter 2022, by region.

	National	Upper North Island	Middle North Island	Lower North Island	Upper South Island	Middle South Island	Lower South Island
Queen problems	3.09% [2.93%, 3.26%]	3.41% [2.98%, 3.90%]	2.28% [2.01%, 2.59%]	3.41% [3.08%, 3.78%]	4.66% [3.76%, 5.76%]	3.86% [3.50%, 4.25%]	2.74% [2.35%, 3.20%]
AFB	0.14% [0.11%, 0.18%]	0.32% [0.24%, 0.42%]	0.13% [0.08%, 0.22%]	0.09% [0.05%, 0.18%]	0.22% [0.06%, 0.79%]	0.10% [0.05%, 0.19%]	0.07% [0.01%, 0.49%]
Wasps	0.91% [0.79%, 1.05%]	2.08% [1.66%, 2.60%]	1.30% [1.04%, 1.63%]	0.47% [0.32%, 0.69%]	0.41% [0.21%, 0.82%]	0.09% [0.01%, 0.54%]	0.46% [0.26%, 0.81%]
Robbing	0.41% [0.34%, 0.50%]	0.42% [0.25%, 0.73%]	0.46% [0.32%, 0.67%]	0.45% [0.32%, 0.64%]	0.44% [0.22%, 0.89%]	0.21% [0.12%, 0.38%]	0.27% [0.13%, 0.56%]
Argentine ants	0.05% [0.04%, 0.07%]	0.18% [0.15%, 0.21%]	0.07% [0.05%, 0.11%]	0.01% [0.00%, 1.90%]	0% [-, -]	0% [-, -]	0% [-, -]
Suspected starvation	0.86% [0.78%, 0.94%]	0.98% [0.82%, 1.19%]	0.67% [0.57%, 0.78%]	0.43% [0.30%, 0.61%]	1.64% [1.21%, 2.22%]	1.41% [1.17%, 1.70%]	1.53% [1.21%, 1.93%]
Suspected toxicity	0.06% [0.04%, 0.09%]	0.06% [0.01%, 0.29%]	0.10% [0.07%, 0.15%]	0.06% [0.03%, 0.13%]	0.02% [0.00%, 1.14%]	0.01% [0.00%, 46.62%]	0.01% [0.00%, 0.09%]
Suspected varroa	6.37% [6.09%, 6.66%]	5.55% [5.02%, 6.13%]	6.35% [5.65%, 7.13%]	7.40% [6.85%, 7.98%]	4.21% [3.58%, 4.94%]	4.88% [4.37%, 5.44%]	8.55% [7.85%, 9.29%]
Suspected disease	0.28% [0.25%, 0.32%]	0.16% [0.10%, 0.25%]	0.21% [0.17%, 0.27%]	0.49% [0.42%, 0.57%]	0.53% [0.33%, 0.85%]	0.07% [0.03%, 0.15%]	0.27% [0.20%, 0.36%]
Natural disaster/accidents	0.76% [0.65%, 0.88%]	1.58% [1.24%, 2.01%]	0.71% [0.54%, 0.93%]	0.46% [0.31%, 0.68%]	1.88% [1.34%, 2.63%]	0.32% [0.13%, 0.79%]	0.53% [0.32%, 0.89%]
Theft/vandalism	0.06% [0.04%, 0.10%]	0.25% [0.16%, 0.38%]	0.05% [0.01%, 0.22%]	0.03% [0.01%, 0.15%]	0% [-, -]	0.06% [0.02%, 0.14%]	0.01% [0.00%, 0.14%]

Note: Bracketed values indicate 95% confidence intervals. Calculations included all beekeepers, not just those with more than 250 colonies.

Table 6: Estimated share of all colonies lost to specific causes over winter 2022, by operation size.

	1–10 colonies	11–50 colonies	51–250 colonies	251–500 colonies	501–3,000 colonies	+3,001 colonies
Queen problems	7.34% [6.71%, 8.04%]	4.28% [3.39%, 5.38%]	6.13% [4.10%, 9.07%]	4.92% [2.71%, 8.76%]	3.37% [2.83%, 4.01%]	2.43% [1.71%, 3.44%]
AFB	0.51% [0.34%, 0.74%]	0.76% [0.37%, 1.59%]	0.26% [0.08%, 0.85%]	0.46% [0.13%, 1.59%]	0.12% [0.08%, 0.19%]	0.09% [0.05%, 0.18%]
Wasps	4.35% [3.80%, 4.98%]	2.09% [1.33%, 3.28%]	1.66% [1.13%, 2.43%]	0.87% [0.27%, 2.79%]	0.57% [0.36%, 0.92%]	0.89% [0.22%, 3.46%]
Robbing	3.21% [2.75%, 3.73%]	2.13% [1.42%, 3.18%]	0.87% [0.57%, 1.34%]	0.35% [0.15%, 0.78%]	0.31% [0.22%, 0.44%]	0.28% [0.14%, 0.58%]
Argentine ants	0.04% [0.01%, 0.20%]	0.06% [0.01%, 0.35%]	0.02% [0.00%, 0.13%]	0% [-, -]	0.12% [0.05%, 0.27%]	0.02% [0.01%, 0.07%]
Suspected starvation	2.38% [2.01%, 2.82%]	2.41% [1.81%, 3.20%]	1.52% [1.01%, 2.28%]	1.30% [0.67%, 2.52%]	0.94% [0.59%, 1.47%]	0.64% [0.37%, 1.11%]
Suspected toxicity	0.25% [0.13%, 0.45%]	0.08% [0.03%, 0.26%]	0.11% [0.05%, 0.24%]	0.39% [0.11%, 1.39%]	0.06% [0.02%, 0.17%]	0.03% [0.00%, 0.31%]
Suspected varroa	8.21% [7.51%, 8.98%]	11.39% [9.18%, 14.05%]	6.77% [5.35%, 8.54%]	6.58% [3.39%, 12.39%]	6.34% [5.09%, 7.88%]	6.15% [3.91%, 9.54%]
Suspected disease	0.14% [0.06%, 0.29%]	0.28% [0.12%, 0.64%]	0.20% [0.10%, 0.41%]	0.53% [0.23%, 1.21%]	0.37% [0.21%, 0.64%]	0.23% [0.08%, 0.63%]
Natural disaster/accidents	2.50% [2.08%, 3.00%]	2.85% [1.77%, 4.56%]	2.09% [1.20%, 3.60%]	2.23% [0.77%, 6.29%]	1.11% [0.66%, 1.84%]	0.26% [0.10%, 0.68%]
Theft/vandalism	0.22% [0.11%, 0.44%]	0.28% [0.08%, 0.94%]	0.49% [0.16%, 1.50%]	0.05% [0.01%, 0.31%]	0.04% [0.02%, 0.11%]	0.04% [0.01%, 0.17%]

Note: Bracketed values indicate 95% confidence intervals.

4.4.1 Suspected varroa and related complications

The varroa mite is an ectoparasite that feeds off the fat body tissue of honey bees[10] and is generally regarded as the biggest threat to beekeeping worldwide (Rosenkrantz et al. 2010; Ramsey et al. 2019). The varroa mite transmits and activates several single-stranded RNA viruses; specifically, acute bee paralysis virus, black queen cell virus, Israeli acute paralysis virus (which has not been found in New Zealand), Kashmir bee virus, sacbrood virus, and deformed wing virus (Chen & Siede 2007; Runckel et al. 2011; Grozinger & Flenniken 2019). The varroa mite arrived in the North Island in 2000 and spread to the South Island in 2006, resulting in more frequent colony losses and increased labour and control costs.

An estimated 6.4% of all winter 2022 colonies were lost to suspected varroa and related complications, compared with 5.5% in winter 2021, 3.5% in winter 2020, 3.0% in winter 2019, 2.3% in winter 2018, and 1.6% in winter 2017. That is, overall losses attributable to varroa have increased both dramatically and consistently over the last 6 years.

Over winter 2022 varroa was most problematic in the Lower South Island, where 8.6% of all living colonies entering winter were estimated to have been lost to suspected varroa and related complications. The estimated impact of varroa is lowest for the Upper South Island, where 'only' 4.4% of living colonies entering winter 2022 were estimated to have been lost.

We estimate that suspected varroa and related complications resulted in the loss of (Table 6):

- 8.2% of all colonies among beekeepers with 1–10 colonies
- 11.4% of all colonies among beekeepers with 11–50 colonies
- 6.8% of all colonies among beekeepers with 51–250 colonies
- 6.6% of all colonies among beekeepers with 251–500 colonies
- 6.3% of all colonies among beekeepers with 501–3,000 colonies
- 6.2% of all colonies among beekeepers with more than 3,000 colonies.

In 2022 respondents who attributed colony losses to suspected varroa and related complications were asked to identify the single largest factor underlying those losses. Seven out of 10 respondents specified that ineffective varroa management led to their losses, which can be broken down to:

- 2.1% of respondents attributed their losses due to varroa to the fact that they simply did not treat for varroa (down from 2.4% in 2021)
- 12.9% attributed their losses to varroa to winter weather conditions (up from 11.3% in 2021)
- 13.5% stated that they treated for varroa at the wrong time (down from 32.1% in 2021)
- 3.1% reported using an ineffective dosage (down from 8.1% in 2021)
- 18.9% reported that the treatment was ineffective (cf. 18.7% in 2021)
- 52.7% reported reinvasion after treatment (up from 27.4% in 2021).

Figures 9 and 10 present results across regions and operation sizes, respectively.

[10] Ramsey et al. (2019) conclude that 'Varroa are exploiting the fat body as their primary source of sustenance: a tissue integral to proper immune function, pesticide detoxification, overwinter survival, and several other essential processes in healthy bees'.

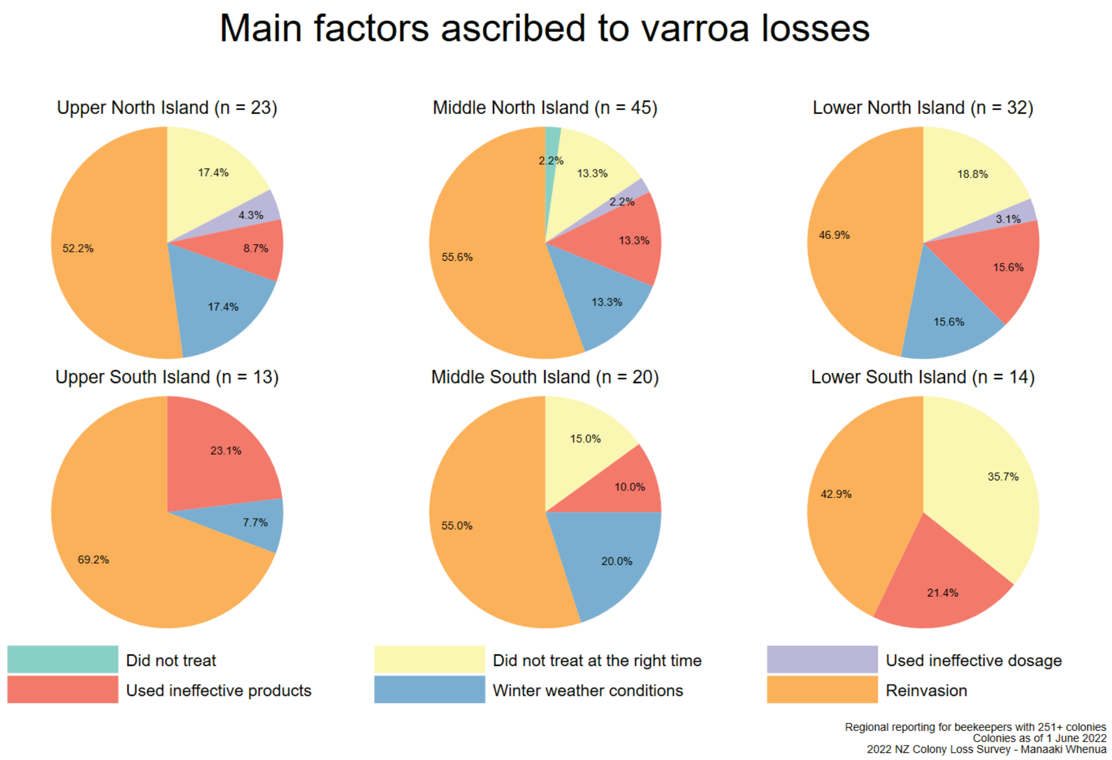

Figure 9: Factors explaining varroa loss over winter 2022 among beekeepers with more than 250 colonies, by region.

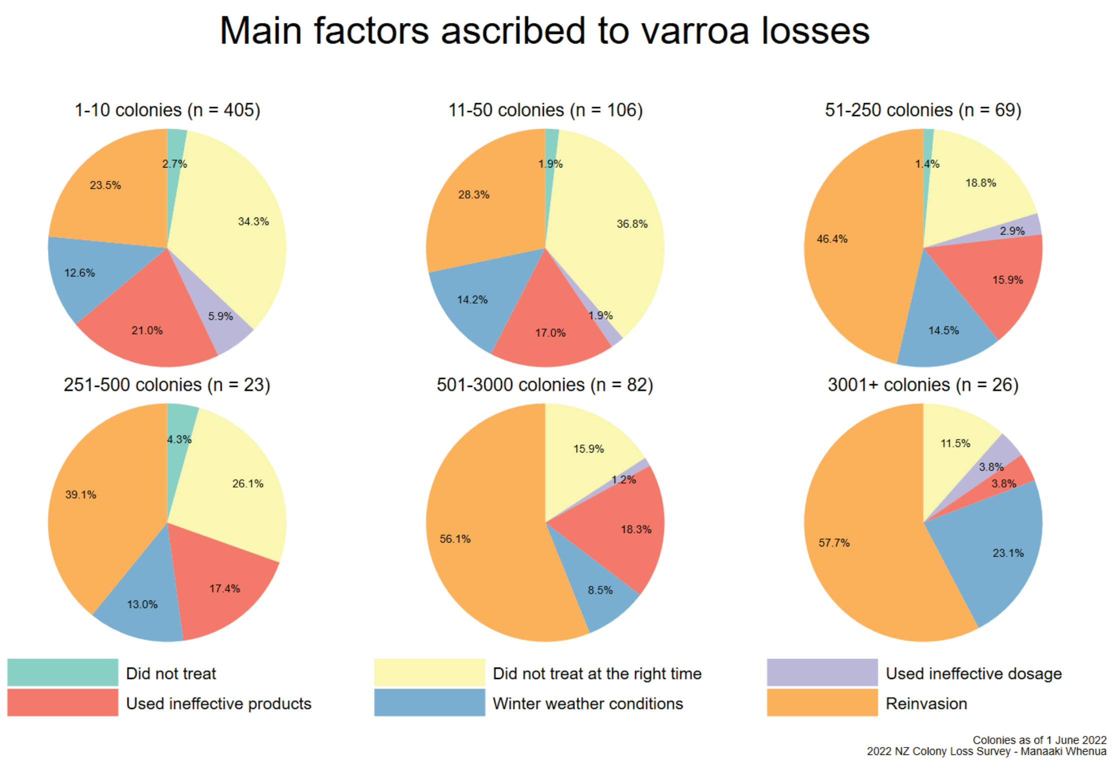

Figure 10: Factors explaining varroa loss over winter 2022, by operation size.

4.4.2 Queen problems

Queen problems are difficult to diagnose because many bee health problems may present as queen problems (Lee et al. 2019). Nevertheless, many beekeepers attribute losses to perceived queen problems, and we record those attributions here.

Because colonies function as ‘superorganisms’, any disruption in the replenishment of each cohort can cause a colony to fail (Pettis et al. 2016). A well-mated, healthy queen is integral to drive the reproduction and growth of the colony, but she needs nurse bees to feed her, who in turn need foragers to bring pollen and nectar to make royal jelly. The queen also needs healthy drones for mating to produce worker bees.

Consistent with international studies (Brodschneider et al. 2016; Pettis et al. 2016; Gray et al. 2019; Lee et al. 2019), perceived queen problems were a major contributor to colony losses across all regions and all operation sizes.[11] Indeed, we estimate that 3.1% of all colonies were lost to what beekeepers classified as queen problems during winter 2022. That said, the share of all colonies lost to queen problems has been relatively stable since 2017, when the current suite of loss categories was first implemented in our survey. Between 2017 and 2021 the share of all living colonies lost to queen problems fluctuated between 3.1% and 3.9%.

Among beekeepers with more than 250 colonies (Table 5), queen problems accounted for more losses than any other reason in the Upper South Island, with loss rates of 4.7%. Queen problems were the second-highest loss attribution in all other regions after varroa. Queen problems were also the largest contributor to estimated losses across size classes (Table 6) after varroa, accounting for between 2.4% (more than 3,000 colonies) and 7.4% (1–10 colonies) of losses.

It is generally accepted that younger queens outperform older queens (Rangel et al. 2013), and re-queening is a common strategy for reducing potential queen problems, especially among commercial beekeepers. Indeed, among beekeepers with more than 250 colonies, 50.5% of colonies were re-queened during the 2021/22 season (compared with 54.7% of colonies during the 2020/21 season and 46.6% of colonies during the 2019/20 season). Re-queening was most common in the Lower North Island, as shown in Figure 11. Operators with more than 3,000 colonies re-queen the majority of colonies, whereas operators with 1–10 colonies re-queen about 29% of colonies (Figure 12).

[11] Queens may fail for several reasons, including poor mating and pathogen infection (drones can transmit viruses to queens via semen) (Pettis et al. 2016). In addition, temperatures during queen shipment affect sperm viability and thus the quality of mated queens (Pettis et al. 2016).

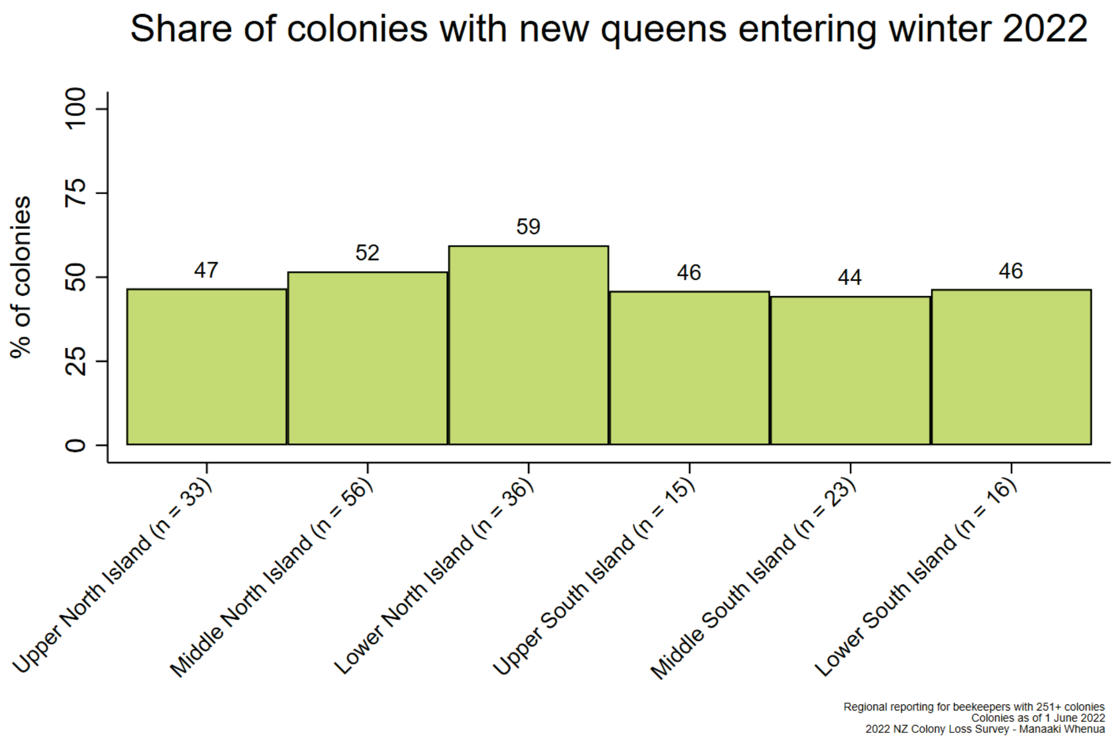

Figure 11: Share of colonies that were re-queened during the 2021/22 season among beekeepers with more than 250 colonies, by region.

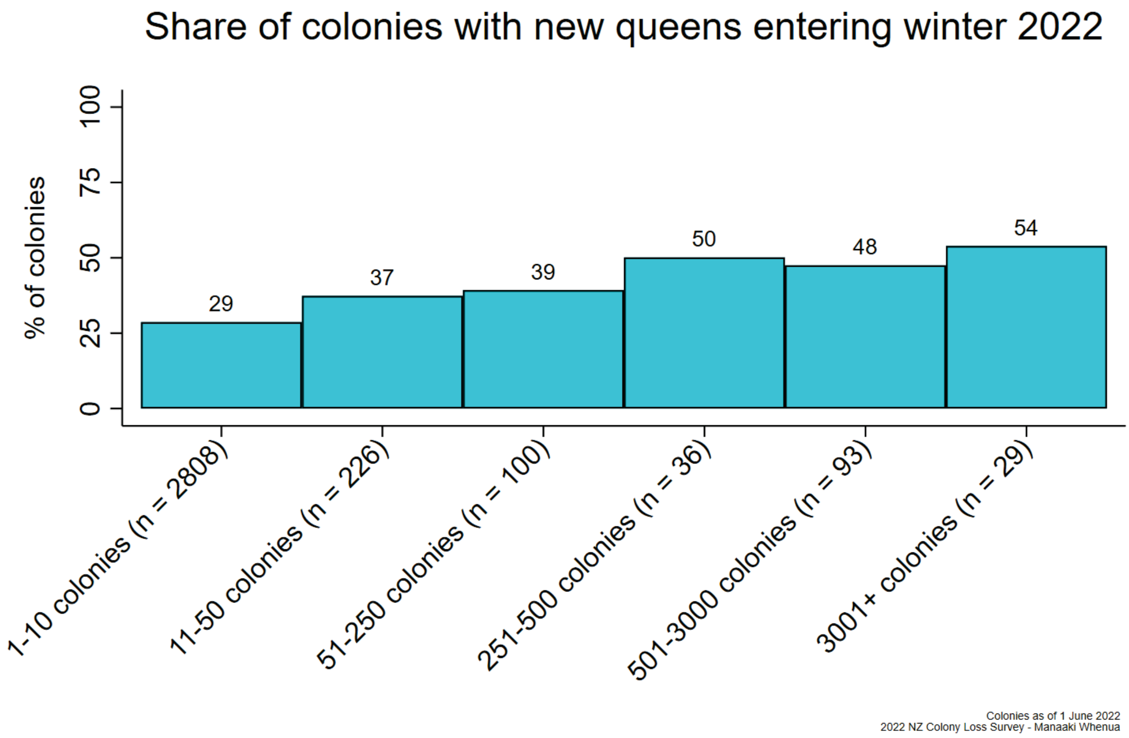

Figure 12: Share of colonies that were re-queened during the 2021/22 season, by operation size.

4.4.3 Wasps

Wasps debilitate honey bee colonies in winter by robbing their honey stores and by seeking protein (including both adult bees and brood) to feed their own young, which can lead to starvation and a reduced workforce of foragers.

Beekeepers lost an estimated 0.9% of all living colonies entering winter 2022 to wasps, compared to 1.7% of colonies over winter 2021, 0.8% of colonies over winter 2020, and 1.0% of colonies over winter 2019. In contrast to previous years in which the Middle North Island had the highest incidence of wasp attacks, wasps were most problematic in the Upper North Island over winter 2022: we estimate that 2.1% of all living colonies in the Upper North Island entering winter 2022 were lost to wasp attacks. In the Middle North Island approximately 1.3% of colonies were estimated to have been lost to wasps in 2022.

Protection against wasps can be achieved by maintaining strong colonies and reducing hive entrances in autumn to facilitate more effective defence by the bees. Pesticides such as Vespex® have also been shown to be effective for wasp control but safe for use near honey bee colonies (Edwards et al. 2017).

Small operators were most affected by wasps: beekeepers with 1–10 colonies lost an estimated 4.4% of all winter 2022 colonies to wasps, and beekeepers with 11–50 colonies lost an estimated 2.1% of all winter 2022 colonies to wasps. In contrast, beekeepers with more than 500 colonies lost an estimated 0.6–0.9% of wintering colonies to wasps.

In 2022 commercial beekeepers with more than 250 colonies were asked to describe wasp activity in their region (Figure 13). One-quarter of respondents with colonies wintering in the Upper North Island described wasp activity as being ‘extreme’ or ‘a lot’. Approximately two-thirds of respondents across the North Island described wasp activity as ‘extreme’, ‘a lot’, or ‘some’. The lowest prevalence of wasps was in the Lower South Island, although 34.3% of beekeepers there nevertheless reported at least ‘some’ wasp activity.

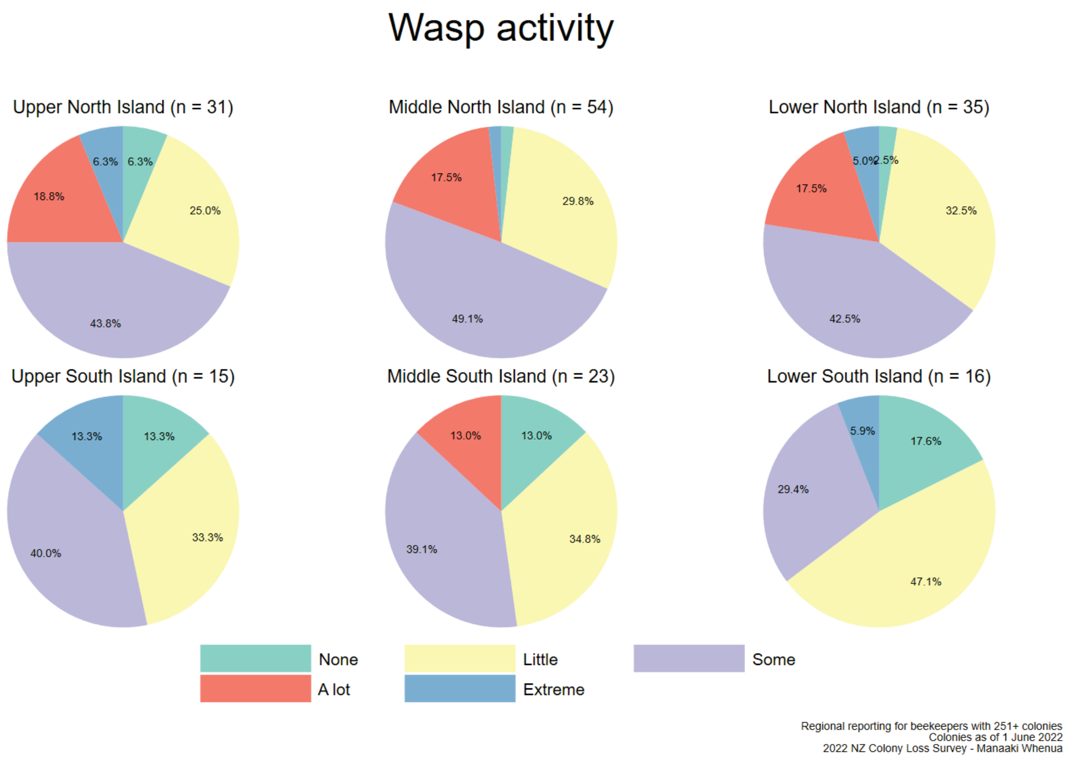

Figure 13: Wasp activity over winter 2022 as described by beekeepers with more than 250 colonies, by region.

4.4.4 Suspected starvation

Dead worker bees in cells with no food present in the colony is indicative of starvation. An estimated 0.9% of all winter 2022 colonies were lost to suspected starvation, compared with 1.0% in winter 2021, 0.9% in winter 2020, and 1.0% in winter 2019. Suspected starvation was pronounced in the South Island and Middle South Island, where we estimate that approximately 1.5% of all colonies entering winter 2022 were lost to starvation. Estimated loss rates attributed to starvation generally decreased as operation size increased, from 2.4% of all winter 2021 colonies for beekeepers with 0–50 colonies to 0.6% of all winter 2021 colonies for beekeepers with more than 3,000 colonies. This follows a similar pattern to winters 2019, 2020, and 2021. Supplemental feeding has been associated with reduced varroa infestations (Giacobino et al. 2014), and supplemental feeding has obvious benefits when colonies are facing starvation (Ahmad et al. 2021). However, the effects of supplementation are complex, and the wider effects on colony health remain unclear (Steinhauer et al. 2021; Mortensen et al. 2019).

4.4.5 Robbing by other bees

Weak hives are susceptible to robbing from strong hives, particularly when there is a dearth of nectar sources. An estimated 0.4% of all winter 2022 colonies were lost due to robbing by other bees, compared with 0.6% in winter 2021, 0.5% in winter 2020, and 0.5% in winter 2019. As in previous years, robbing was more common in the North Island and the Upper South Island (where mānuka honey production is dominant). Robbing was more frequently observed among small operators: beekeepers with 1–10 colonies had estimated loss rates due to robbing of 3.2% compared to 0.3% for beekeepers with more than 500 colonies.

4.4.6 Natural disasters and accidents

Estimates of losses due to natural disasters and accidents over winter 2022 ranged from 0.3% in the Middle South Island to 1.9% in the Upper South Island, which was badly affected by winter flooding. Beekeepers with fewer colonies are estimated to have lost a greater share of colonies to natural disasters and accidents: for example, among beekeepers with 1–10 colonies, 2.5% of colonies were estimated to have been lost to natural disasters and accidents; among beekeepers with more than 3,000 colonies, the figure is 0.3%.

4.4.7 Suspected nosema and other diseases

Nosema apis and *Nosema ceranae* are microsporidian parasites that invade the intestinal tracts of honey bees, causing nosemosis. *Nosema apis* had been in New Zealand historically, whereas *Nosema ceranae* was only identified internationally in 2006 (Higes et al. 2006) as a pathogen in *Apis mellifera* and was first identified in New Zealand in 2010 (MAF 2011). Nosemosis is exacerbated when bees cannot leave their colonies to eliminate waste (e.g. during cold and wet winters).

Symptoms of nosemosis may include dysentery, and colonies suffering from nosema tend to dwindle rapidly, with no dead bees present in or outside the hive. However, these symptoms are not syndromic, meaning they may be confused with other honey bee diseases (including parasitic mite syndrome) or with poor queen quality (Borowik 2019).

An estimated 0.3% of all colonies over winter 2022 were lost due to causes attributed to suspected diseases, compared to 0.2% in both 2020 and 2021. This figure ranged from 0.1% in the Middle South Island to 0.5% in the Upper South Island. Losses attributed to suspected disease range between 0.1% for beekeepers with 1–10 colonies and 0.5% for beekeepers with 251–500 colonies.

4.4.8 American foulbrood disease (AFB)

New Zealand has a Pest Management Plan (PMP) under the Biosecurity Act 1993 that aims to eliminate AFB nationwide. Measures to control AFB under the PMP include colony registration, beekeeper training, annual inspections, and a requirement to burn colonies and associated equipment with any symptoms of AFB infection.

Among the 352,419 colonies reported on by all beekeepers, 501 cases of AFB were reported for winter 2022 (cf. 518 cases out of 381,148 colonies for winter 2021, 216 cases out of 304,143 colonies for winter 2020, and 331 cases out of 297,345 colonies for winter 2019). AFB losses were highest in the Upper North Island, where 0.32% of all colonies were estimated to have been lost to AFB.

Estimated losses were highest among beekeepers with 11–50 colonies, who are estimated to have lost 0.8% of all colonies to AFB over winter 2022. In contrast, beekeepers with more than 500 colonies are estimated to have lost less than 0.1% of colonies to AFB.

Beekeepers reported that AFB affected 0.06% of the colonies included in the 2015 NZ Colony Loss Survey, with figures of 0.21% in 2016, 0.27% in 2017, 0.12% in 2018, 0.11% in 2019, 0.07% in 2020, and 0.14% in 2021. An estimated 0.14% of all wintering 2022 colonies were lost due to AFB.

4.4.9 Suspected toxic exposure

Having a large number of dead bees in or in front of the colony may indicate exposure to chemicals such as insecticides, fungicides, and surfactants and naturally occurring toxins such as karaka (Palmer-Jones & Line 1962).

Over winter 2022 an estimated 0.06% of all colonies were lost to suspected toxic exposure, compared with 0.08% in 2021, 0.15% in 2020, and 0.11% in 2019. All regions had low loss rates from suspected toxicity. Exposure to toxicity was highest among beekeepers with 1–10 colonies, who lost 0.4% of all living colonies entering winter to suspected toxicity.

4.4.10 Theft or vandalism

Theft and vandalism were rare overall, with just 0.06% of all living colonies entering winter 2022 estimated to have been lost due to theft or vandalism (c.f. 0.1% for 2019, 2020, and 2021). Theft and vandalism were most common among hobbyist beekeepers and rare for operators with more than 50 colonies.

4.5 State of surviving colonies

Production colonies may survive winter but enter spring in a weakened state. In spring 2022 beekeepers with more than 250 colonies reported that 20.9% of their colonies were weak but queenright, on average (cf. 22.0% in spring 2021, 24.4% in spring 2020, and 19.8% in spring 2019) (Figure 14). In contrast with spring 2021, smaller operators reported lower shares of weak colonies in spring 2022, on average (Figure 15).

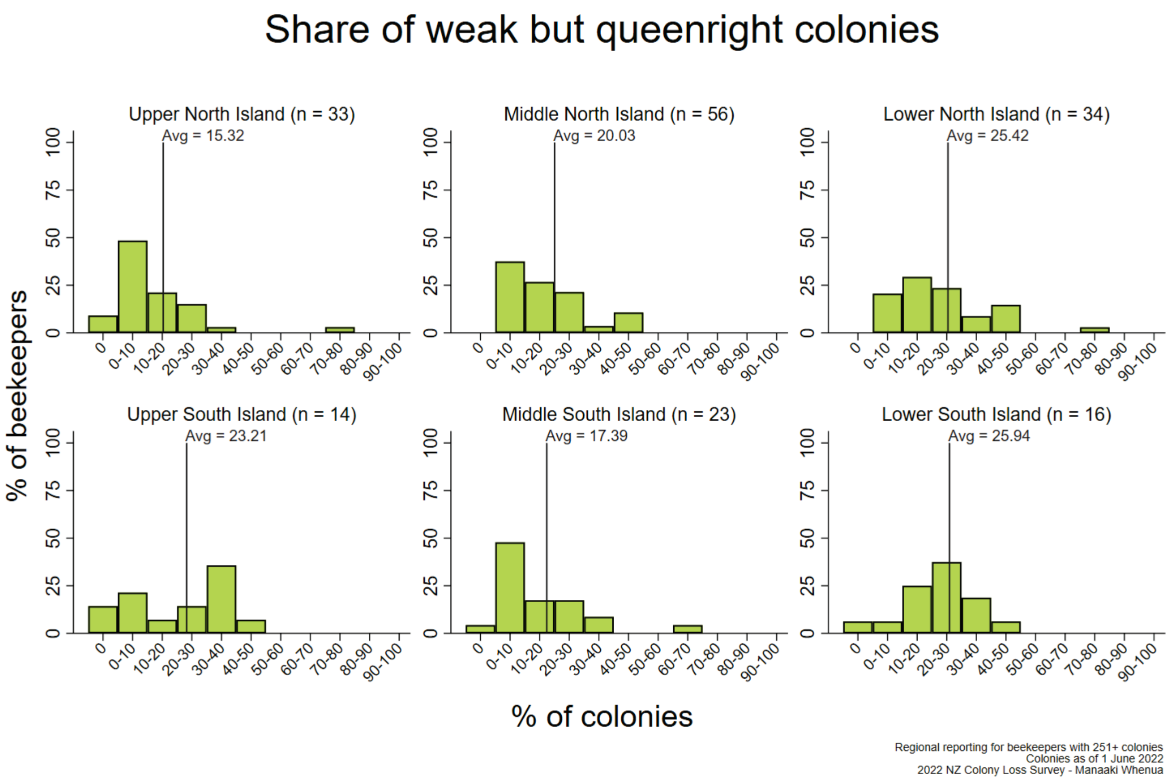

Figure 14: Share of colonies that were weak but queenright at the beginning of spring 2022 among beekeepers with more than 250 colonies, by region.

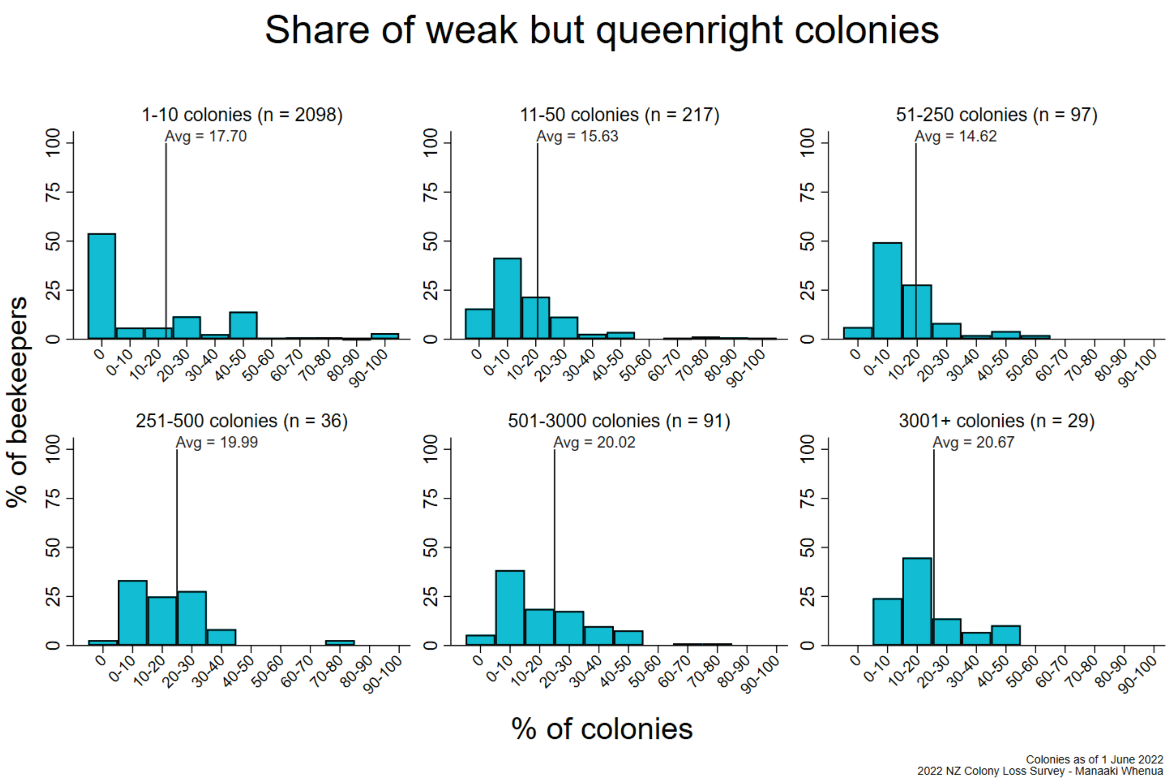

Figure 15: Share of colonies that were weak but queenright at the beginning of spring 2022, by operation size.

4.6 2021/22 season

The third part of the 2022 NZ Colony Loss Survey asked respondents to reflect on the previous season. The 2021 survey focused on varroa and its management, and many of these questions (e.g. regarding the type and timing of treatment) were retained for 2022. Other questions focused on brood comb replacement, colony use, colony migration, floral resources, supplemental feeding, tutin contamination, compromised/lost apiary sites during the 2021/22 season, and the timing of management activities. Complete results are available on the Manaaki Whenua – Landcare Research website.

4.6.1 Varroa monitoring

Deformed wing virus (DWV) is the most prominent virus related to varroa (van der Steen & Vejsnæs 2021). The virus causes deformities in adult honey bees, including stubby wings, malformed abdomens, discolouration, and paralysis; infected bees showing symptoms are often unable to forage (Kielmanowicz et al. 2015). Indeed, detection of just 11 malformed bees in a 15,000-bee colony in autumn has been associated with a low probability of winter survival in Europe (Dainat & Neumann 2013).

Prior to 2022 beekeepers were asked if they had *noticed* DWV in their hives at any time during the season. The proportion of beekeepers who reported DWV hovered between 75% and 80% each year between 2016 (when the question was first included) and 2021 (Stahlmann-Brown & Robertson 2022). Beginning in 2022 beekeepers were instead asked about the *prevalence* of DWV in their hives.

The vast majority of beekeepers with more than 250 colonies described the prevalence of DWV as 'limited' (Figure 16). Only in the Upper North Island did more than 25% of beekeepers describe 'extensive' prevalence of DWV. Beekeepers with 1–10 colonies were more than twice as likely as other operators to indicate that they had no DWV (Figure 17).

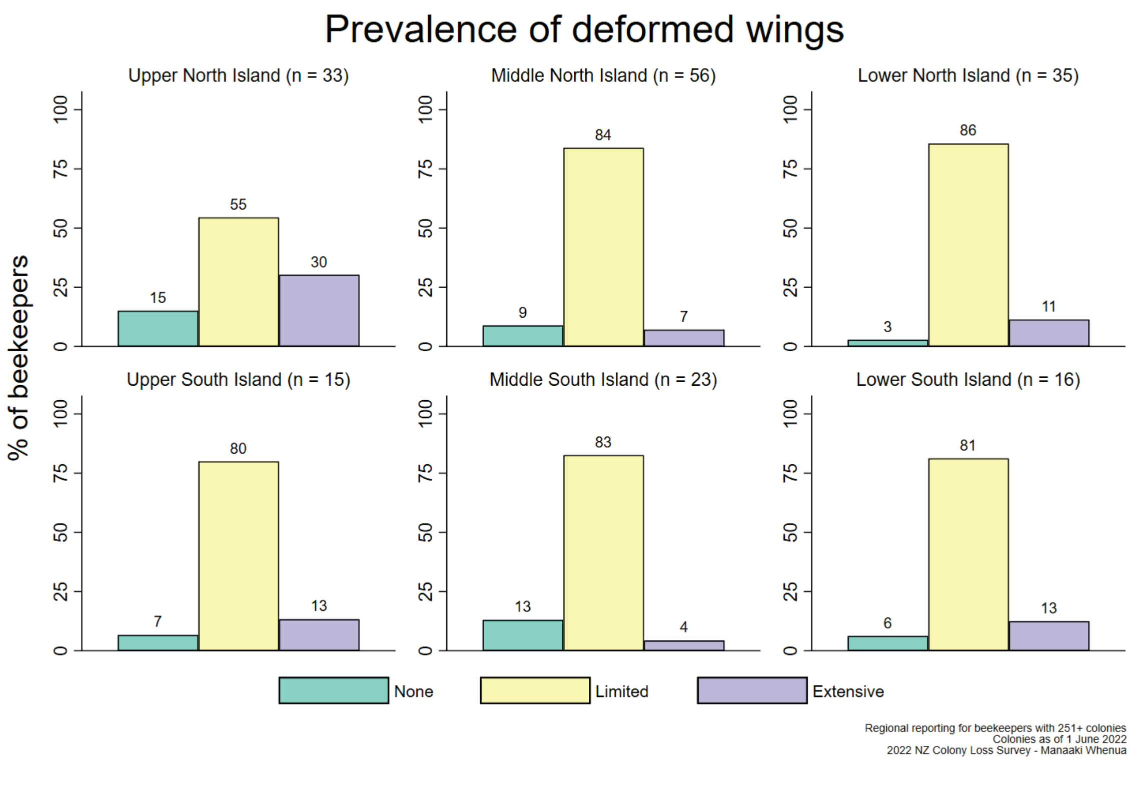

Figure 16: Prevalence of deformed wings reported by beekeepers with more than 250 colonies, by region.

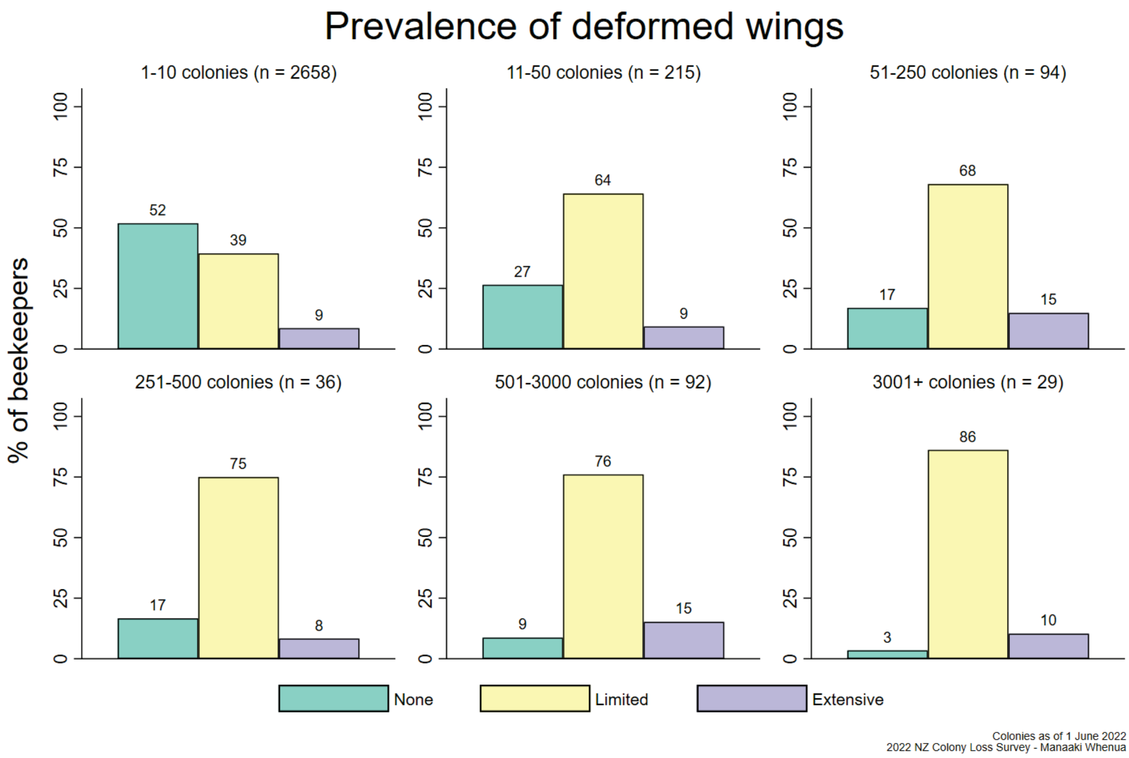

Figure 17: Prevalence of deformed wings, by operation size.

Parasitic mite syndrome (PMS) presents with spotty brood patterns and sunken, dark, or perforated cell cappings, although only larvae and prepupae are affected. PMS only occurs with infestations of varroa mites. Prior to 2022 beekeepers were asked if they had *noticed* PMS in their hives at any time during the season. The proportion of beekeepers who reported PMS was approximately 62% in 2017 and 2018, increasing to approximately 75% in 2019, 2020, and 2021 (Stahlmann-Brown & Robertson 2022). Beginning in 2022, beekeepers were instead asked about the *prevalence* of PMS in their hives.

Among beekeepers with more than 250 colonies, the prevalence of PMS (Figure 18) is similar to that of deformed wings (Figure 16), although fewer beekeepers (and none in the Upper South Island and Lower South Island) indicated that they had no PMS. Beekeepers in the Lower North Island and Middle South Island reported 'extensive' PMS more frequently than 'extensive' DWV, while beekeepers in the Upper South Island and Lower South Island reported the opposite.

Although the share of beekeepers who describe PMS as 'extensive' varies from 7.1% for beekeepers with 1–10 colonies to 15.3% for beekeepers with more than 3,000 colonies (Figure 19), the share of beekeepers who indicate that they have no PMS was inversely related to operation size. For example, 60.0% of beekeepers with 1–10 colonies indicated that they had no PMS, compared to 37.9% of beekeepers with 11–50 colonies, 20.0% of beekeepers with 51–250 colonies, 20.0% of beekeepers with 251–500 colonies, 7.1% of beekeepers with 501–3000 colonies, and just 3.8% of beekeepers with more than 3,000 colonies.

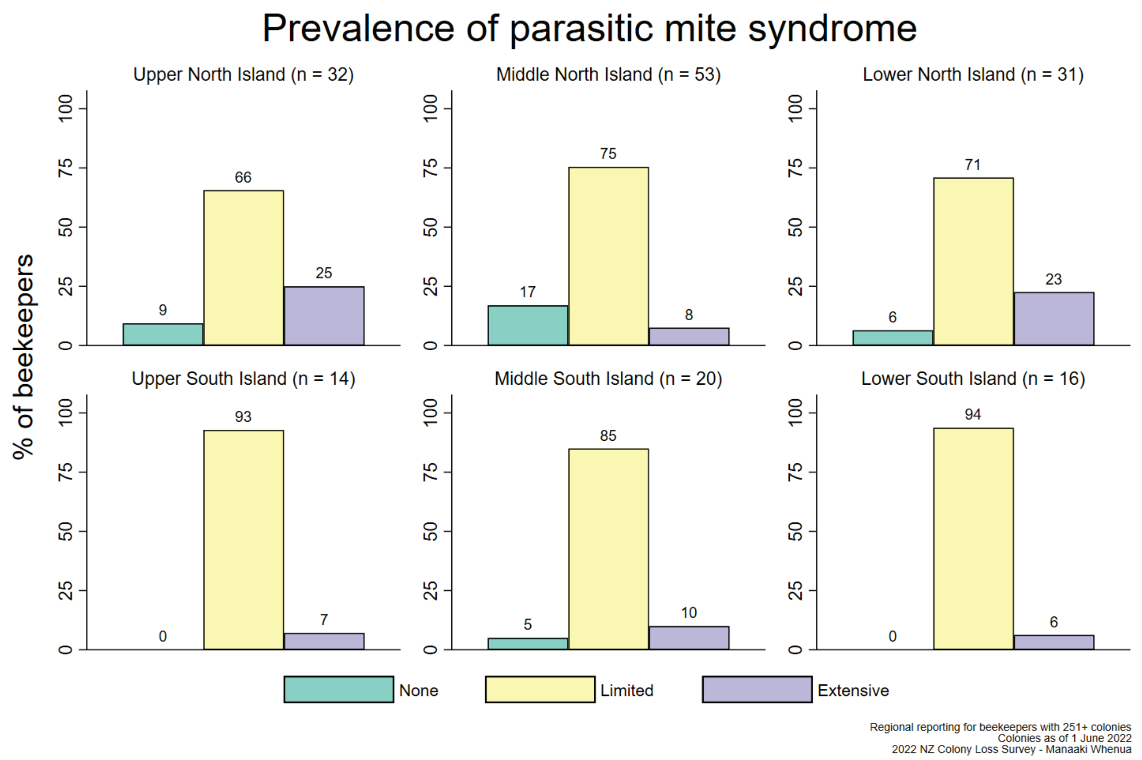

Figure 18: Prevalence of parasitic mite syndrome reported by beekeepers with more than 250 colonies, by region.

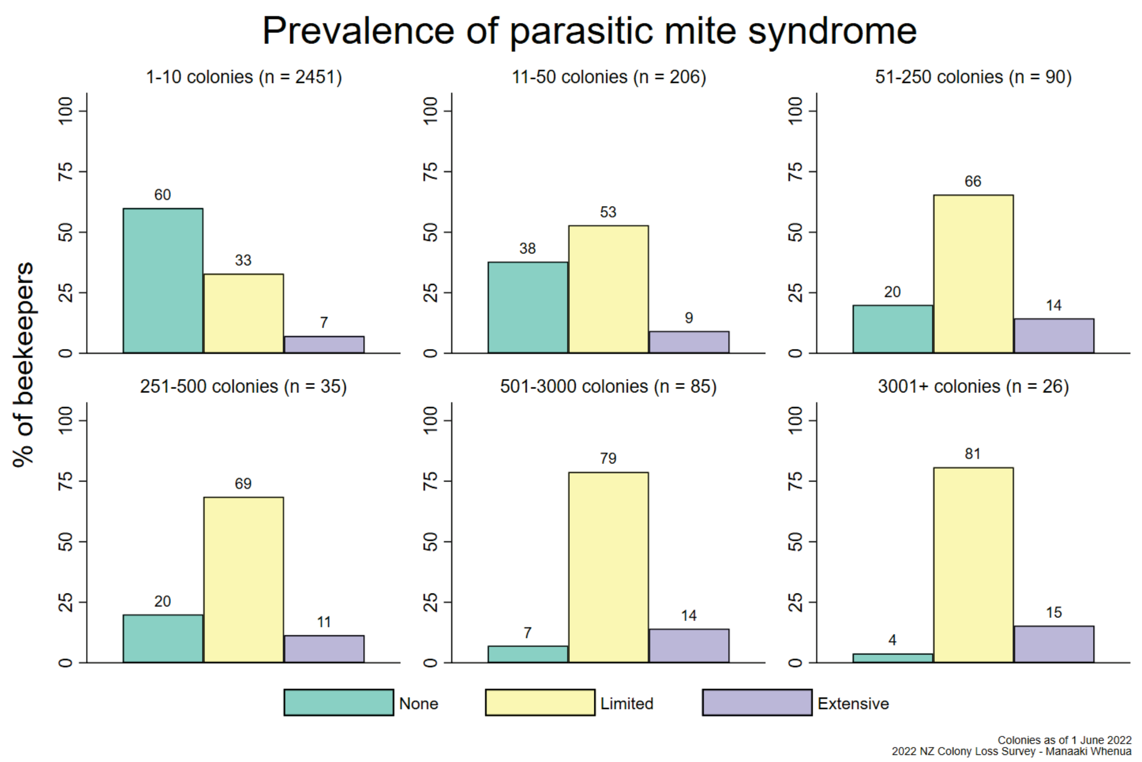

Figure 19: Prevalence of parasitic mite syndrome, by operation size.

A lower reported incidence of both DWV and PMS among beekeepers with 1–10 colonies may indicate that smaller operators have more time to manage their colonies for optimal health. However, it is perhaps more likely that smaller operators miss signs of DWV and PMS, particularly as this category includes many hobbyists with less beekeeping experience. Indeed, as shown in Figure 20, the likelihood of reporting no DWV and PMS declines sharply as beekeeper experience increases.

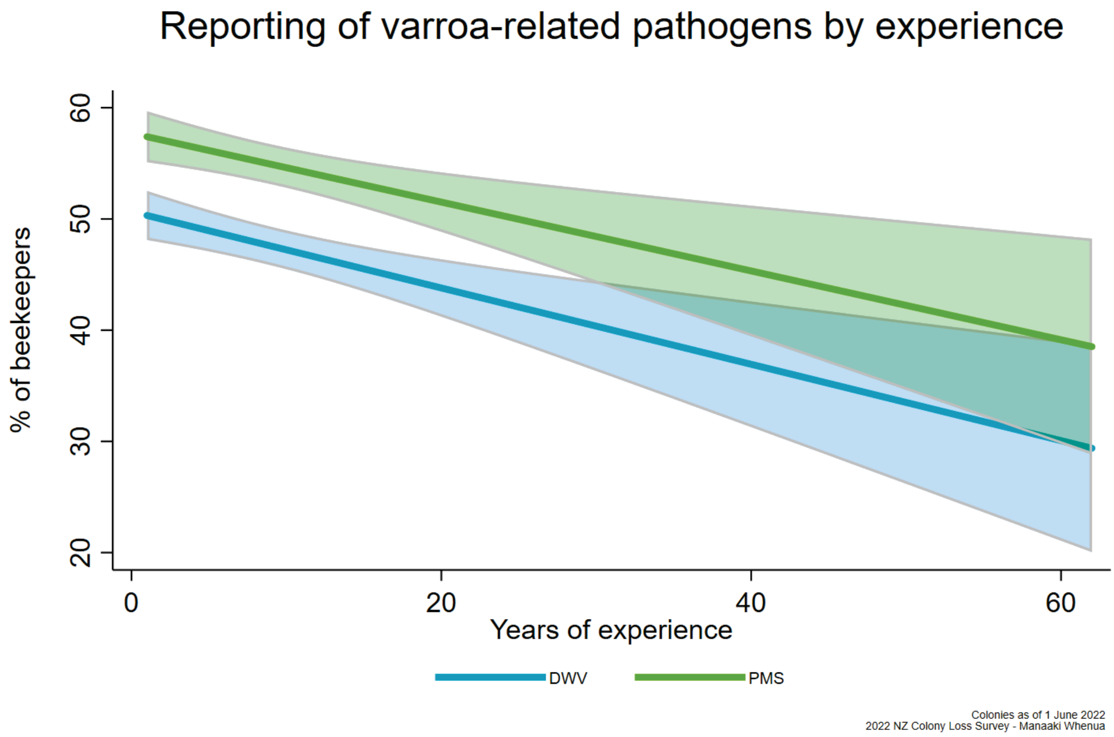

Figure 20: Share of beekeepers who reported no deformed wing virus or parasitic mite syndrome, by years of beekeeper experience. Linear prediction with 95% confidence intervals.

Monitoring for varroa enables timely treatment (Imdorf et al. 1996) as part of an integrated pest management plan. Failing to monitor substantively increases the likelihood of colony loss (Honey Bee Health Coalition 2015).

Three monitoring methods are recognised internationally as providing reliable estimates of mite populations: the sugar shake (or powdered sugar shake), alcohol wash (or soap wash), and CO_2 injection (Azizi et al. 2008; De Jong et al. 1982; de Feraudy et al. 2019; Fakhimzadeh 2000; Lee et al. 2010; Macedo et al. 2002). Each of these methods requires placing approximately half a cup of bees (about 300) into a jar with a perforated lid. In the sugar shake method, beekeepers add approximately 2 tablespoons of powdered sugar to the jar and vigorously shake the jar for at least 1 minute to cover the bees and dislodge the mites. After 3–5 minutes the jar is inverted and any mites are shaken out. An additional tablespoon of sugar is added, the jar is re-shaken, and after an additional 3–5 minutes the jar is inverted and the mites are shaken out.

In the alcohol wash method, sufficient alcohol or liquid soap is added to the jar to completely cover the bees. The jar is vigorously shaken for at least 1 minute to dislodge any mites from the bees. After shaking, the liquid is poured through a mesh screen, and the process is repeated. In the CO_2 injection method, bees are rendered unconscious before being shaken to dislodge mites onto a screen. In all cases, beekeepers count the number of mites on the screen to assess infestation levels. As an alternative, bee samples can be sent to a lab.

Field trials undertaken in New Zealand by Taylor et al. (2023) indicate that the alcohol/detergent wash and sugar shake methods are equally reliable, as two sugar shakes and three alcohol/detergent washes each resulted in >95% of mites being extracted. They note, however, that there are pros and cons for each method. For example, alcohol/detergent washes kill the bees and varroa, so the results may be more consistent across beekeepers than sugar shakes, but the washes require liquids to be managed in the apiary. Sugar shakes do not kill the bees but cannot be used to monitor varroa levels during wet weather or the honey flow. Also, the number of shakes/washes determines how effective the methods are at extracting the varroa from the bees.

Other methods for monitoring varroa include placing sticky boards beneath the hive, assessing drone brood, and visual inspection of mites on adults. These methods are considered to be less accurate than those described above. In assessing drone brood, for example, it can be difficult to interpret the results of the percentage of brood infected (Honey Bee Health Coalition 2015). It has also been observed that beekeepers do not uncap enough drone brood to make an accurate assessment of infestation rates (pers. comm., Richard Hall, Principal Scientist, Honey Bee Health, Biosecurity New Zealand, February 2023) because 200 drones must be uncapped to provide an assessment. Also, drone brood uncapping cannot be done during all seasons because drones are not present in colonies all year round.

With sticky boards, other insects may remove mite bodies, interfering with estimates. In addition, because mites collect on sticky boards over time and because colony sizes vary, it is difficult to interpret infestation rates or even mite loads at a specific point in time (Honey Bee Health Coalition 2015).

Visual inspection of adult bees is considered to be wholly ineffective because mites are not easily seen unless they are present on the thorax or top of the abdomen, and findings of mites on adults likely indicates that a high mite population already exists (Hall et al. 2021). For this reason, beekeepers who reported that their only form of varroa monitoring is visual inspection of adult bees are re-classified for this report as not having undertaken any monitoring at all.

While many beekeepers monitor for varroa using multiple methods, 32.8% of beekeepers monitored for varroa using at least one of the four recommended processes (alcohol wash, sugar shake, CO_2 injection, and sending samples to the lab) during the 2021/22 season (cf. 31.5% during the 2020/21 season). Among beekeepers with more than 250 colonies, the uptake of these monitoring methods was lowest in the Lower South Island (43.8%), Middle North Island (46.7%) and Upper North Island (47.4%) and highest in the Upper South Island (70.6%). Some 23.7% of beekeepers with more than 250 colonies undertook no mite monitoring in 2021/22, including 43.8% in the Lower South Island (Figure 21). Without claiming causal inference, we note that over-winter colony losses attributed to suspected varroa and related complications were significantly higher in the Lower South Island than elsewhere.

The use of such methods varies from 30.8% among beekeepers with 1–10 colonies to 58.6% of beekeepers with more than 3,000 colonies. At 36.1%, beekeepers with 251–500 colonies were less likely to employ these monitoring methods than beekeepers in all other size classes, apart from those with 1–10 colonies. Smaller beekeepers who undertook monitoring were more likely to rely on visual inspection of drone brood (Figure 22). More than one-fifth of beekeepers across all size classes do not undertake varroa monitoring.

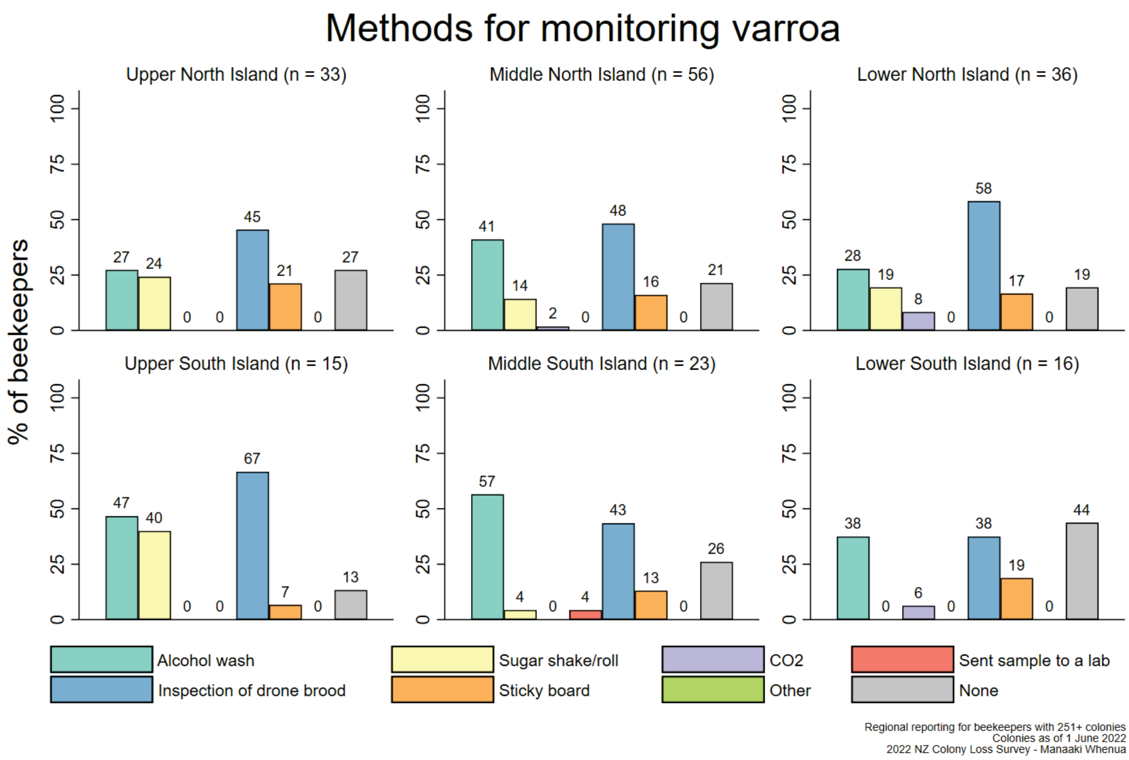

Figure 21: Methods for monitoring varroa during the 2021/22 season among beekeepers with more than 250 colonies, by region.

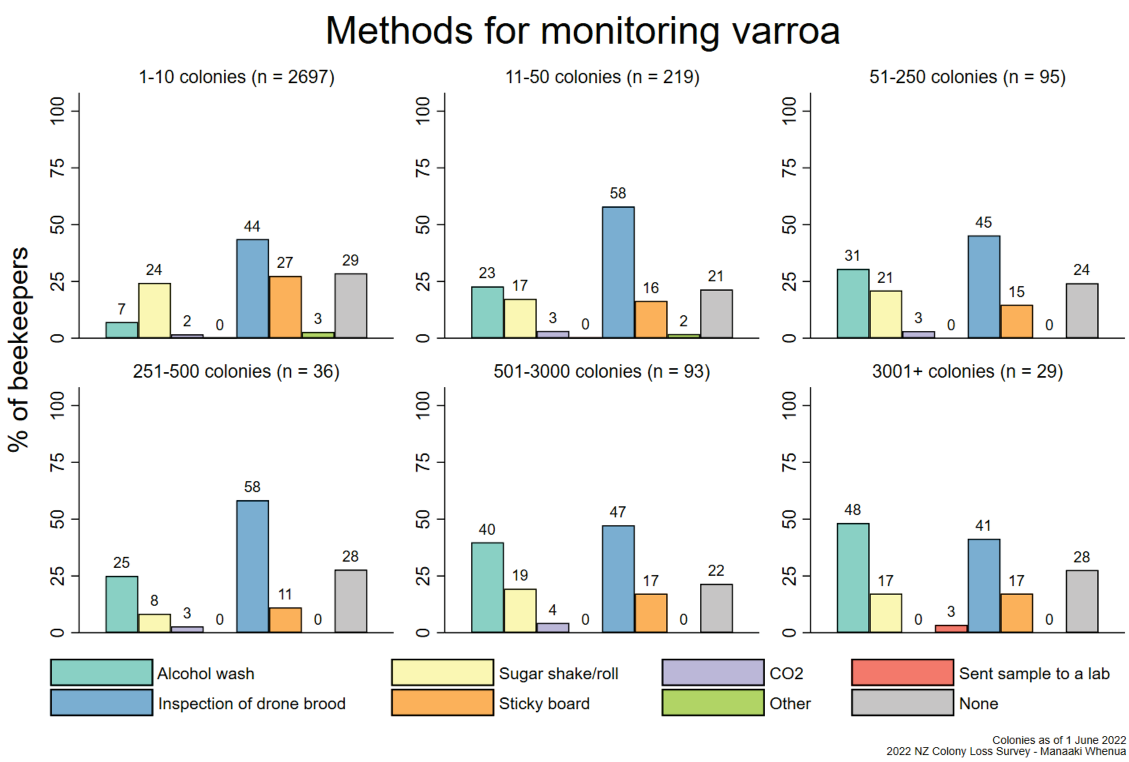

Figure 22: Methods for monitoring varroa during the 2020/21 season, by operation size.

There is no consensus on the damage threshold for varroa in the scientific literature, but a 3% infestation rate (nine mites per 300 bees) is generally considered a threshold in which colony damage could be sustained (Hall et al. 2021). Thus, beekeepers with at least 51 colonies[12] who monitored for varroa using an alcohol wash or sugar shake were subsequently asked to report the share of colonies meeting this threshold. Among beekeepers with more than 250 colonies, mite loadings were highest in the Upper North Island and Lower South Island (Figure 23). Beekeepers with 251–500 colonies were less likely to monitor using sugar shakes or alcohol washes; moreover, conditional on monitoring using these methods, they experienced higher mite loads than beekeepers in other size classes (Figure 24).

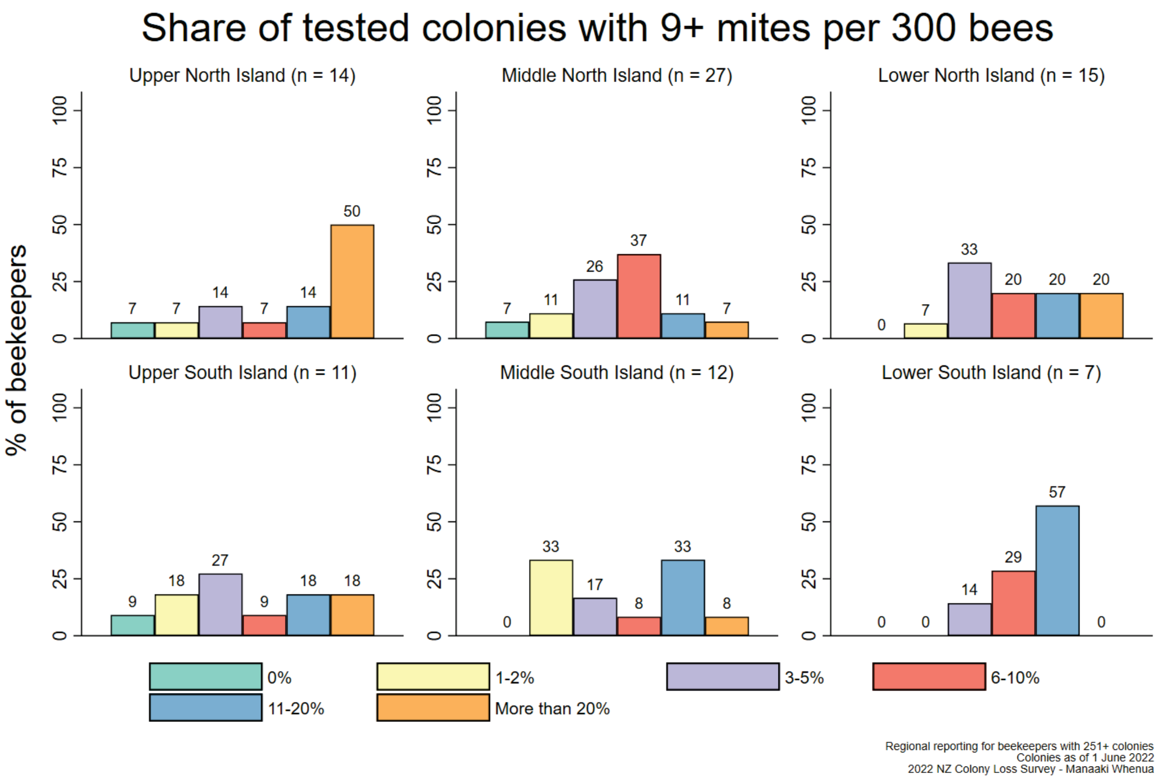

Figure 23: Share of autumn colonies tested with 9+ mites per 300 bees among beekeepers with more than 250 colonies, by region.

[12] To shorten the questionnaire for smaller operators, this question was only asked of those with at least 51 colonies.

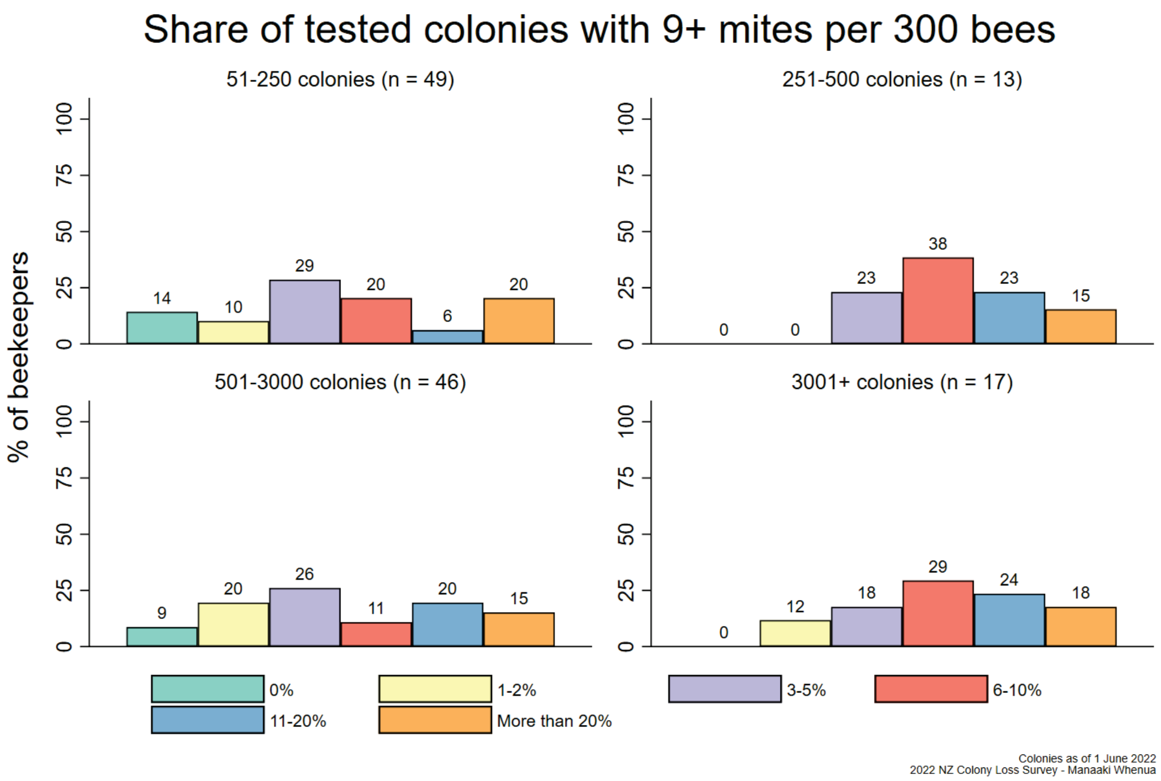

Figure 24: Share of autumn colonies tested with 9+ mites per 300 bees among beekeepers with more than 50 colonies, by operation size.

While many New Zealand beekeepers treat varroa based on evidence of its presence (a 'need-based strategy', according to van der Steen and Vejsnæs [2021]), others treat varroa regardless of the infection rate ('systematic treatment'). Hence, a lack of monitoring does not necessarily reflect a lack of treatment. Indeed, 28.2% who treated for varroa did not undertake any formal monitoring during the 2021/22 season (cf. 22.4% for the 2020/21 season).

4.6.2 Varroa treatment

Regardless of monitoring, varroa treatment is critical for reducing winter losses (Le Conte et al. 2010; Rosenkrantz et al. 2010; Dainat et al. 2012). Fortunately, beekeepers have a variety of varroacides and other management tools for helping to control varroa, ranging from synthetic to organic miticides such as essential oils.

Different varroacides affect biological systems in different ways. For example, flumethrin (marketed in New Zealand as Bayvarol®) and tau-fluvalinate (marketed as Apistan®) cause cell dysfunction by changing the mite's sodium channels (van der Steen & Vejsnæs 2021). Amitraz (marketed as Apivar® and Apitraz®) affects neural transmission by increasing the cell's octopamine receptor (Strachecka et al. 2012). Oxalic acid binds to minerals such as calcium, iron, and sodium, inhibiting their dietary function (Aliano et al. 2006). Thymol (including Thymovar®, Apiguard®, and ApilifeVAR®) and other essential oils disrupt neural functioning (Blenau et al. 2012), while formic acid reduces the availability of oxygen to the mite's body (van der Steen & Vejsnæs 2021).

Active management also plays a role in controlling varroa. For example, because varroa mites prefer drone brood over worker brood for reproduction (Fuchs 1990), removing drone brood significantly reduces the ratio of mites to bees in the colony (Charrière et al. 2003). Similarly, removing all capped brood from the colony in mid-summer ensures that all remaining mites are phoretic (i.e. attached to adult bees); if adults are treated with other methods, then subsequent generations will grow under low varroa loads. Finally, because varroa mites die at temperatures about 41°C while brood can withstand temperatures of up to 45°C for up to 45 minutes (Komissar 1985), hyperthermia is another possibility for non-chemical treatment.

As in past waves of the survey, treatment with flumethrin, amitraz (whether Apivar® or Apitraz®), and oxalic acid (whether in the form of sublimation/vaporisation, dribbling/trickling, or glycerine strips/staples) far surpasses any other form of treatment. Thus, Figure 25 In contrast to the 2021 NZ Colony Loss Survey, no beekeeper with more than 51 colonies reported forgoing varroa treatment during the 2021/22 season.

Figure 25 reports the share of all reporting beekeepers who treat with flumethrin, amitraz, oxalic acid, and any other treatment, alone or in combination. An additional 1.5% of beekeepers did not treat at all between the first day of spring 2021 and the last day of winter 2022 (cf. 4.4% in 2020/21).

Between spring 2021 and winter 2022, 12.3% of beekeepers treated with flumethrin only, 9.7% treated with amitraz only, 6.3% used oxalic treatments only, and 5.9% relied exclusively on other forms of treatment. Among beekeepers who used more than one treatment type, the most common combination was flumethrin and amitraz, with 28.4% of beekeepers reporting this combination. Some 6.0% of beekeepers reported treating with flumethrin, amitraz, and oxalic acid, and 1.7% reported using flumethrin, amitraz, oxalic acid, and other treatments. Among beekeepers with more than 250 colonies, 60.7% treated varroa with both flumethrin and amitraz and 27.3% treated with flumethrin, amitraz, and oxalic acid. In contrast to the 2021 NZ Colony Loss Survey, no beekeeper with more than 51 colonies reported forgoing varroa treatment during the 2021/22 season.

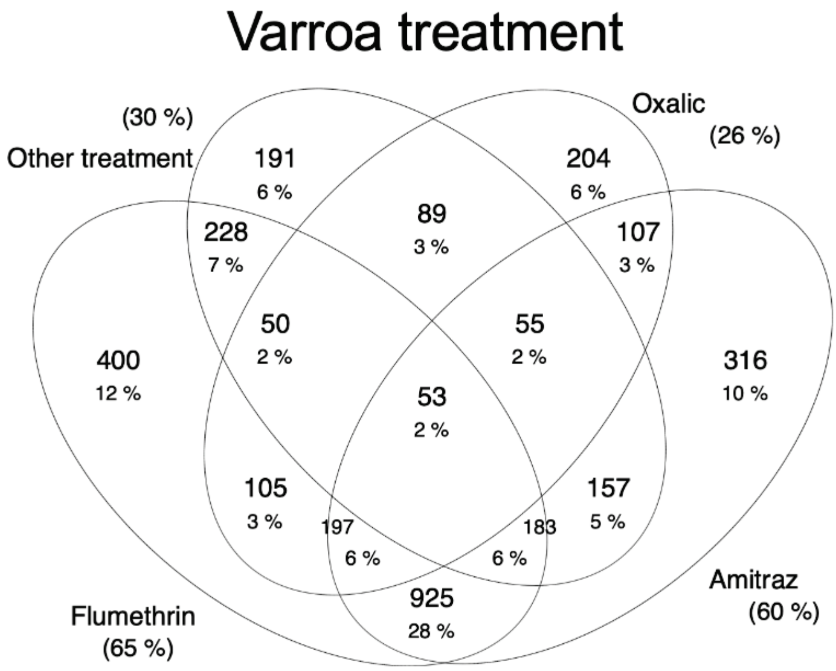

Figure 25: Varroacide treatments used between the first day of spring 2021 and the last day of winter 2022, all beekeepers.

Figure 26 shows the 95% confidence intervals for over-winter loss rates among beekeepers with more than 50 colonies by 2021/22 treatment regime. It focuses exclusively on treatment with flumethrin, amitraz, and oxalic acid, omitting beekeepers who treat with other products, whether alone or in combination. It shows that beekeepers who used multiple synthetic treatments experienced lower over-winter loss rates than those who used a single synthetic treatment. This is especially true for beekeepers who augmented treatment with flumethrin and amitraz with oxalic acid[13]. We hasten to add that these relationships are correlative rather than causal as we cannot rule out, for example, the possibility that beekeepers who use a greater diversity of varroa treatments have different management practices in general from those who use few treatment methods.

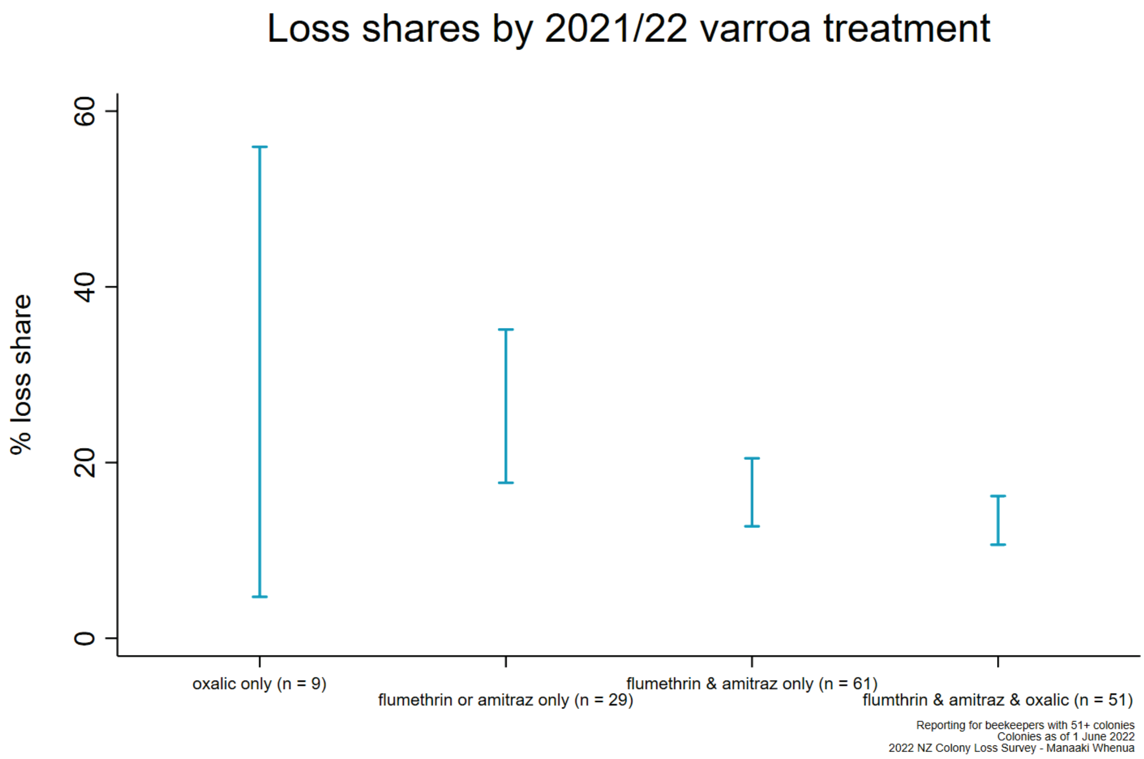

Figure 26: 95% confidence intervals of over-winter loss rates by treatment with flumethrin, amitraz, and oxalic acid (other treatments excluded) among beekeepers with more than 50 colonies.

Beekeepers who used each treatment were asked to describe how successful the product or technique was for managing varroa, answering ‘not at all successful’, ‘partly successful’, ‘mostly successful’, or ‘completely successful’. The results are presented in Table 7.

Across treatments, approximately half of beekeepers described the efficacy as being ‘mostly successful’. At least 80% of users described amitraz (85.7%), tau-fluvalinate (83.3%), and flumethrin (82.1%) as being ‘mostly successful’ or ‘completely successful’. In addition, 76.5% of formic acid users, 73.0% of thymol users, and 72.6% of glycerine strip/staples users described the treatment as being ‘mostly successful’ or ‘completely successful’. The reported success rate of oxalic sublimation/vaporisation and dribbling/trickling was considerably lower.

[13] Using a multiple comparison test with the Bonferroni normalisation, we found that beekeepers who treated with both flumethrin and amitraz experienced lower loss rates than those who treated with just one of these synthetics ($p < 0.10$). Those who treated with oxalic acid as well as flumethrin and amitraz experienced lower loss rates than those who treated with oxalic acid alone ($p < 0.05$) and those who treated with just one synthetic ($p < 0.01$).

Table 7: Reported effectiveness of varroa treatments, all beekeepers.

	Amitraz	Flumethrin	Formic acid	Tau-fluvalinate	Thymol	Oxalic: sublimation/ vaporisation	Oxalic: dribbling/ trickling	Oxalic: glycerine strips/ staples
Not at all successful	2.1%	3.1%	3.9%	4.2%	7.4%	6.2%	6.6%	3.2%
Partly successful	12.3%	14.7%	19.6%	12.4%	19.6%	30.9%	36.1%	24.3%
Mostly successful	49.7%	49.2%	46.1%	51.4%	47.9%	43.0%	44.2%	45.9%
Completely successful	36.0%	32.9%	30.4%	31.9%	25.1%	19.9%	13.1%	26.7%
N	1,974	2,122	306	354	434	356	61	536

4.6.3 Colony management among beekeepers with more than 250 colonies

Nearly 80% of colonies managed by beekeepers with more than 250 colonies are primarily used for honey production (Figure 27). In addition, 10.5% are primarily used for pollination, 4.4% are primarily used for the production of queens, and 3.8% are primarily used for the production of products such as bee venom, royal jelly, and propolis.

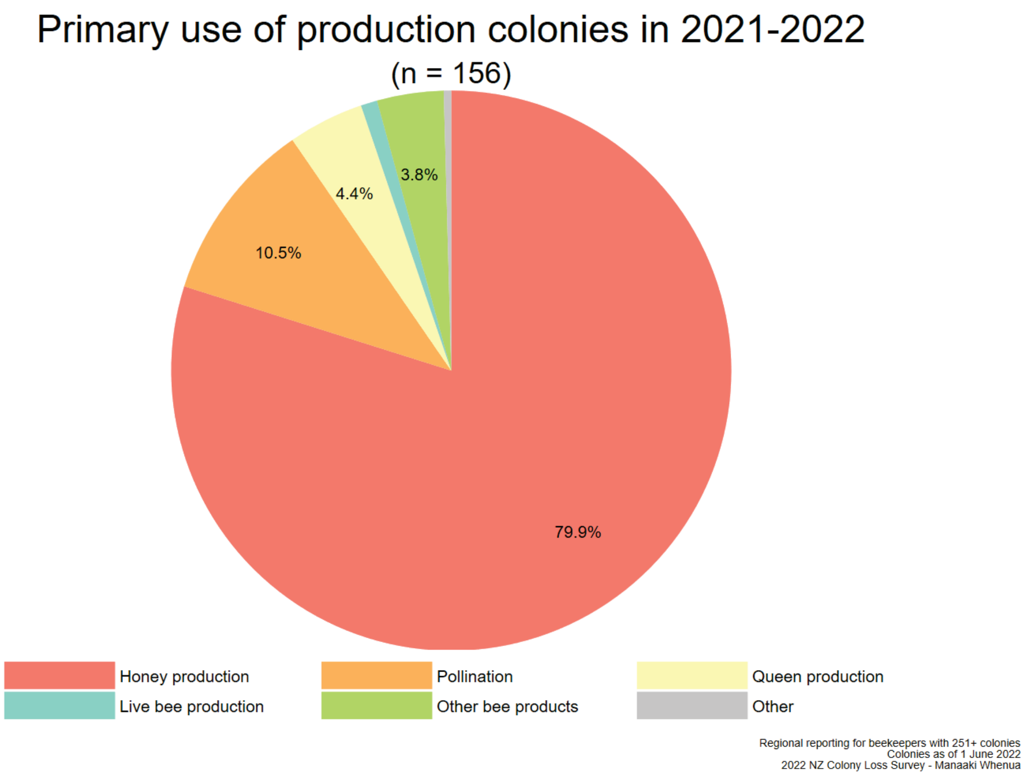

Figure 27: Primary use of production colonies among beekeepers with more than 250 colonies, nationally.

Most beekeepers with more than 250 colonies target mānuka honey (Figure 28), which continues to command significant prices premiums over other honey types (e.g. van Eaton 2014; MPI 2018; Stahlmann-Brown et al. 2022a). The dominance of mānuka diminishes in more southern latitudes, where clover/pasture is the main nectar flow among beekeepers who overwinter their colonies in the lower South Island.

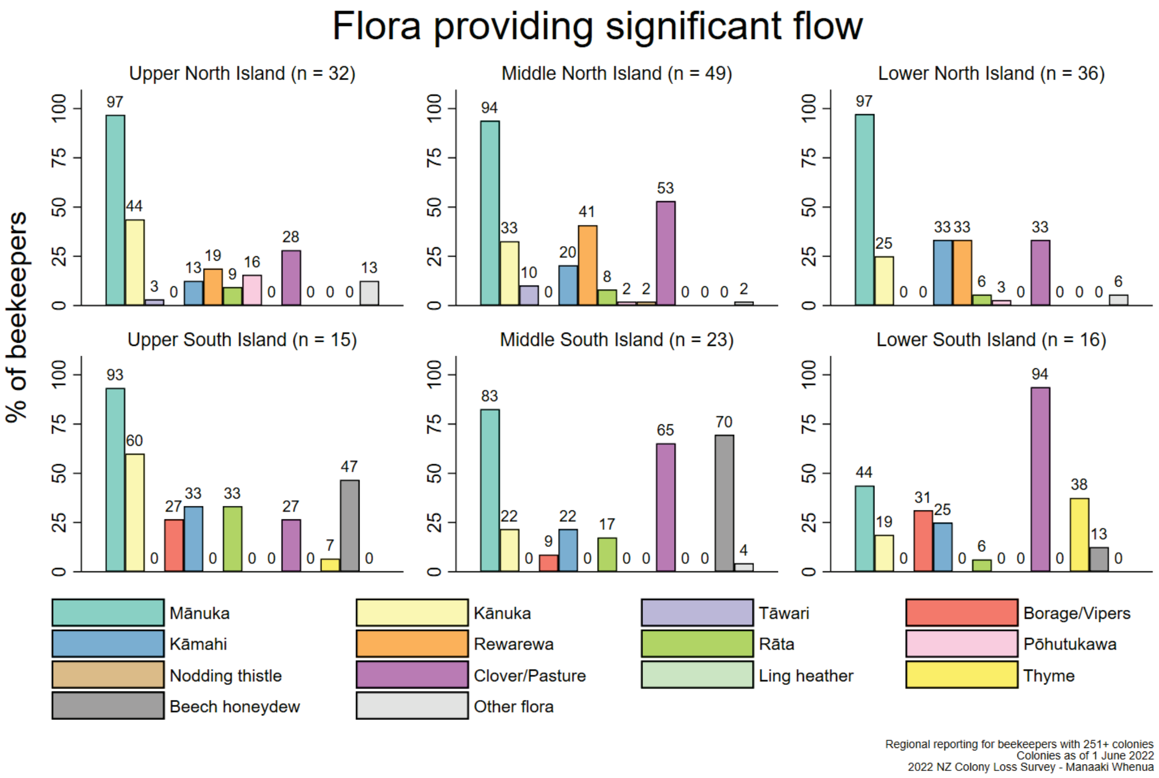

Figure 28: Sources of significant nectar flow among beekeepers with more than 250 colonies, by region.

Figure 29 shows the crops that were pollinated under contract by beekeepers with more than 250 colonies who primarily allocate colonies to pollination services. Avocados were the main crop for pollination services in the Upper North Island. More than 75% of North Island beekeepers providing pollination services under contract provisioned bees to kiwifruit orchards. In the South Island, vegetables and stone fruits were pollinated by the majority of beekeepers.

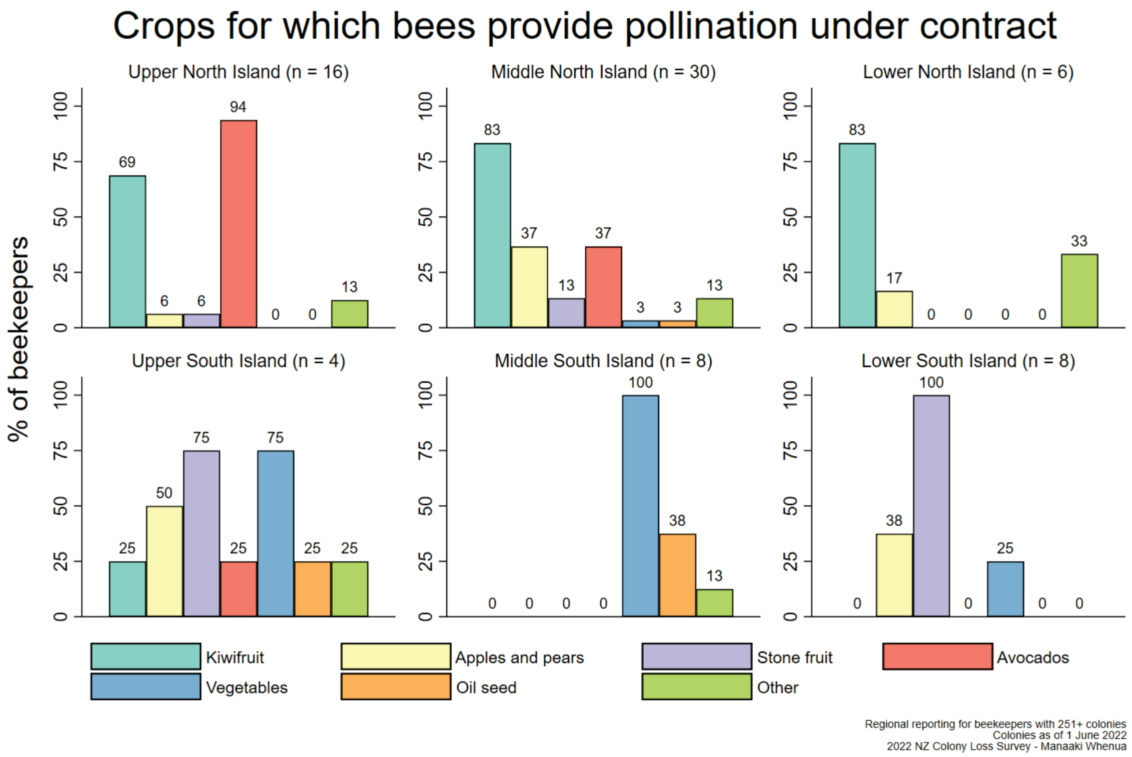

Figure 29: Crops that were provided pollination under contract by beekeepers with more than 250 colonies, by region.

Figure 30 shows the timing of key management activities among beekeepers with more than 250 colonies not discussed above. Beekeepers most frequently added supers at the start of honey flow, between October and January. Re-queening most frequently took place in October, although re-queening in autumn was also common. Most splits were undertaken in spring, most often in October, although uniting colonies was undertaken year round. For most beekeepers the honey harvest began in earnest in December and concluded by March. And among beekeepers who provided pollination services, peak demand was for early-flowering crops such as avocados, kiwifruit, and cherries, which are in pollination between September and November.

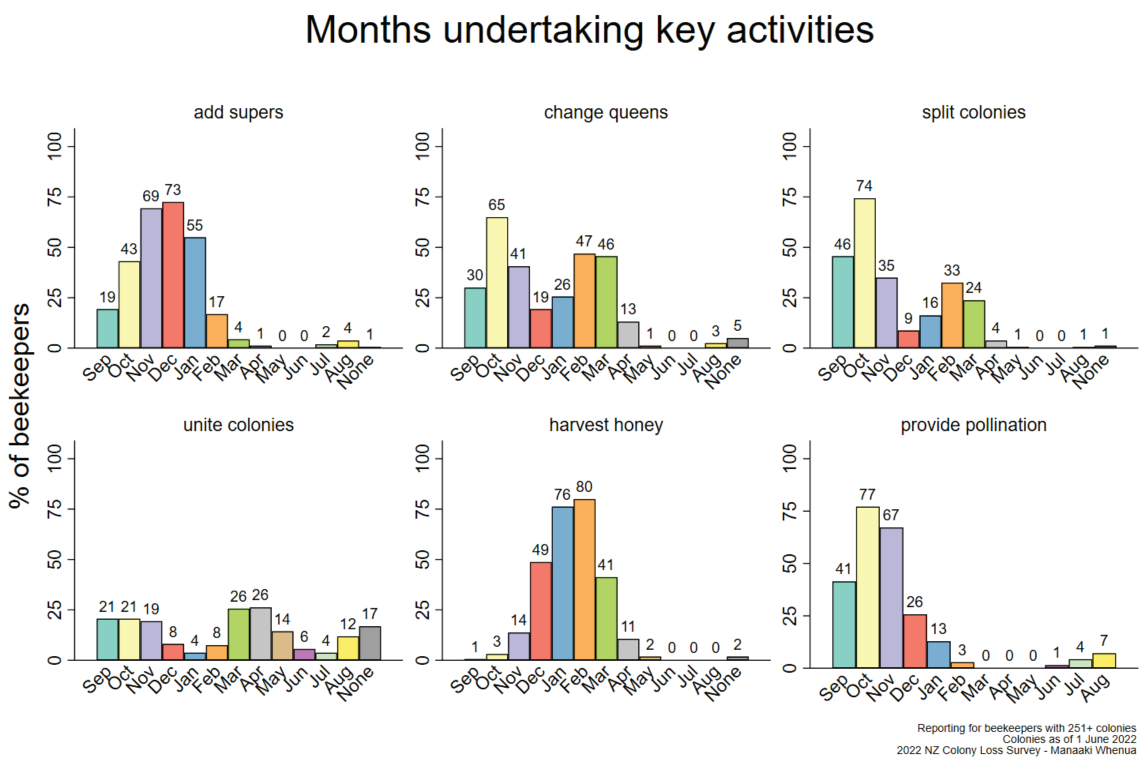

Figure 30: Timing of management activities among beekeepers with more than 250 colonies, nationally.

While beekeepers with more than 250 colonies experience colony losses year round, the majority reported that losses are most common during winter (Figure 31).

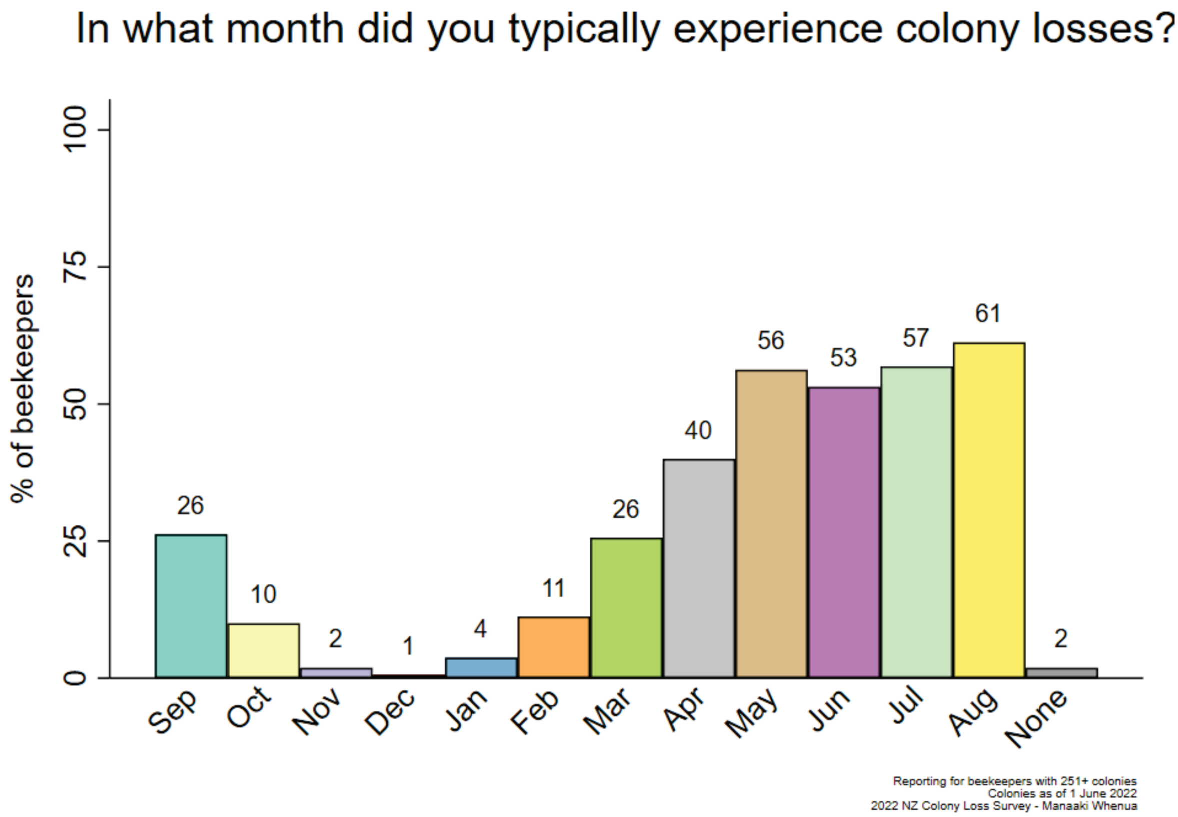

Figure 31: Months in which beekeepers with more than 250 colonies typically experienced colony losses, nationally.

4.6.4 Supplemental feeding

If pollen and nectar sources within foraging range are insufficient, bees consume their stores. If the weather is too severe for bees to forage and if they do not have sufficient stores of pollen and nectar in their colonies, then bees will starve without beekeeper intervention. Hence, many beekeepers actively plant species that provide forage resources for their bees to improve nutrition and overwintering success. In addition, beekeepers may provide supplemental nutrition such as sugar and pollen supplement, which is needed for the brood and provides protein, lipids, vitamins, and minerals. A variety of protein supplements are commercially available.

Nearly all beekeepers (92.1%) with more than 250 colonies used supplemental sugar during the 2021/22 season (Figure 32). In contrast, only 60.9% of beekeepers with 250 or fewer colonies provided supplemental sugar. Sugar solution was most commonly used across all operation sizes.

Beekeepers with more than 250 colonies were also significantly more likely to provide supplemental protein than beekeepers with 250 or fewer colonies (63.8% vs. 22.9%, Figure 33). MegaBee was the most common type of protein supplement used in 2021/22.

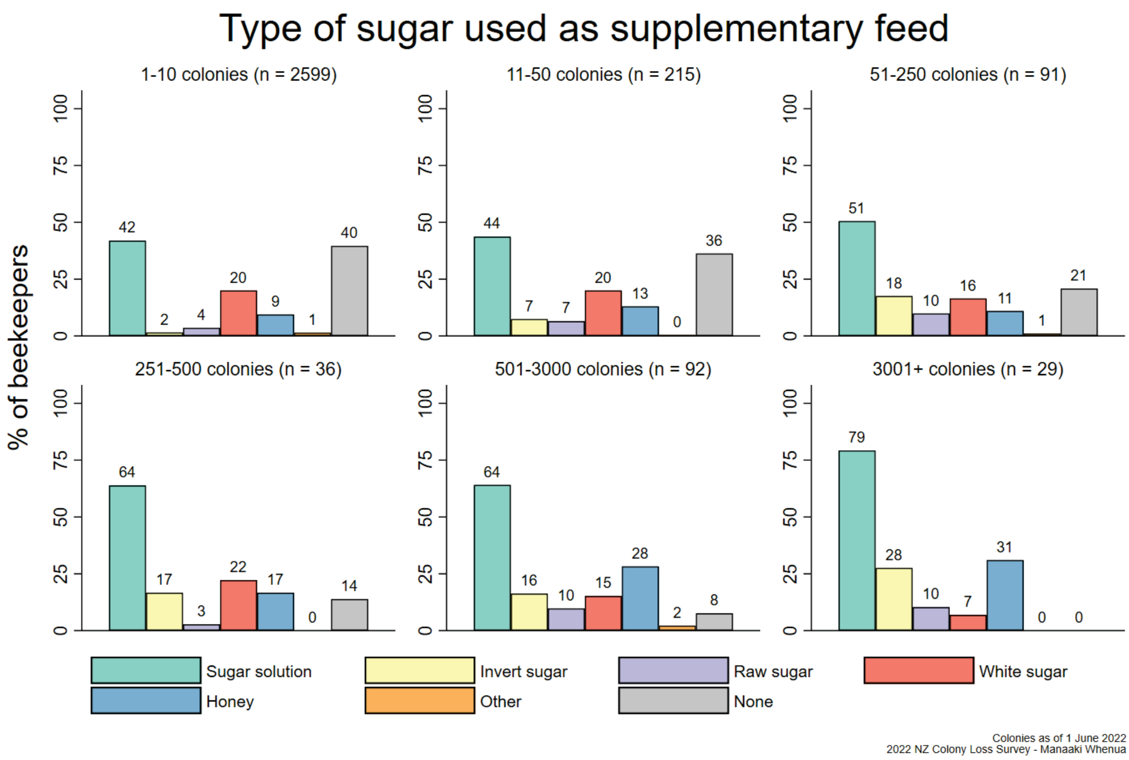

Figure 32: Types of supplemental sugar feeding, by operation size.

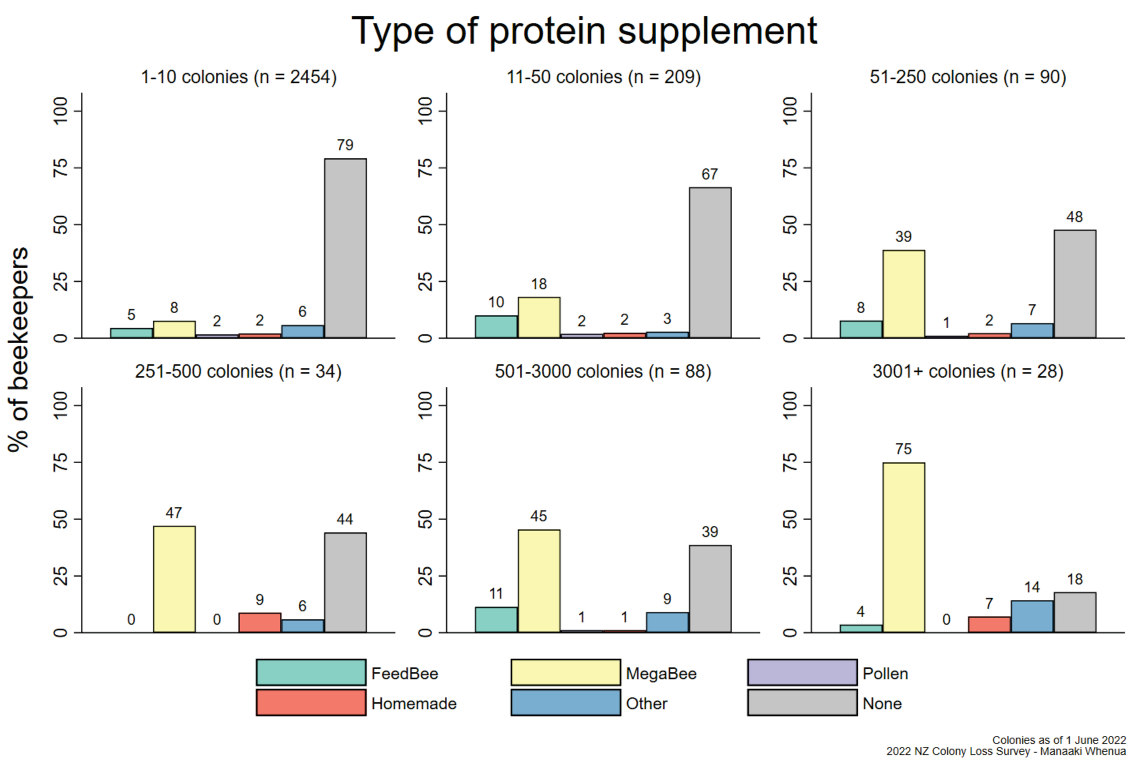

Figure 33: Types of protein supplements, by operation size.

4.7 Beekeeper profile and beekeeping environment

4.7.1 Beekeeping experience and record keeping

Beekeepers who responded to the survey had 7.8 years of experience, on average. However, the median[14] was 5 years of experience, indicating positive skewness. Experience varied substantially across size classes. For example, 17.5% of beekeepers with 1–10 colonies had 1 year of experience or less and 8.0% had had at least 20 years of experience (Figure 34). For beekeepers with more than 500 colonies, none had 1 or fewer years of experience and 20.5% had at least 20 years of experience.

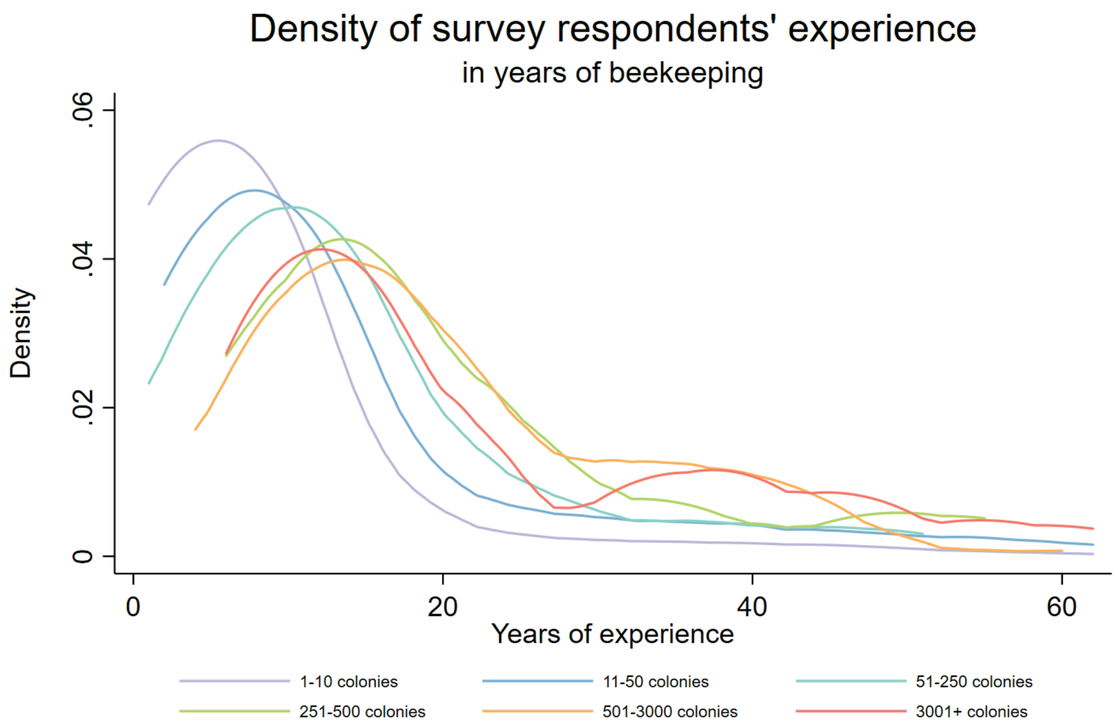

Figure 34: Beekeeper experience, by operation size.

[14] The median value is the mid-point frequency. In this case, half of responding beekeepers had 5 or more years of experience and half had 5 or fewer years of beekeeping experience.

Brodschneider et al. (2016) and Jacques et al. (2017) found that beekeeper experience is positively correlated with honey bee health and survival, arguing that experience influences the beekeeper's ability to assess the health status of colonies, including sanitary conditions. Experienced beekeepers may also influence the quantity and quality of products used to promote bee health (Sperandino et al. 2019). Indeed, Figure 35 shows a negative correlation between beekeeper experience and the share of colonies lost among beekeepers with more than 50 colonies: colony losses generally decline as experience increases in New Zealand, as elsewhere.

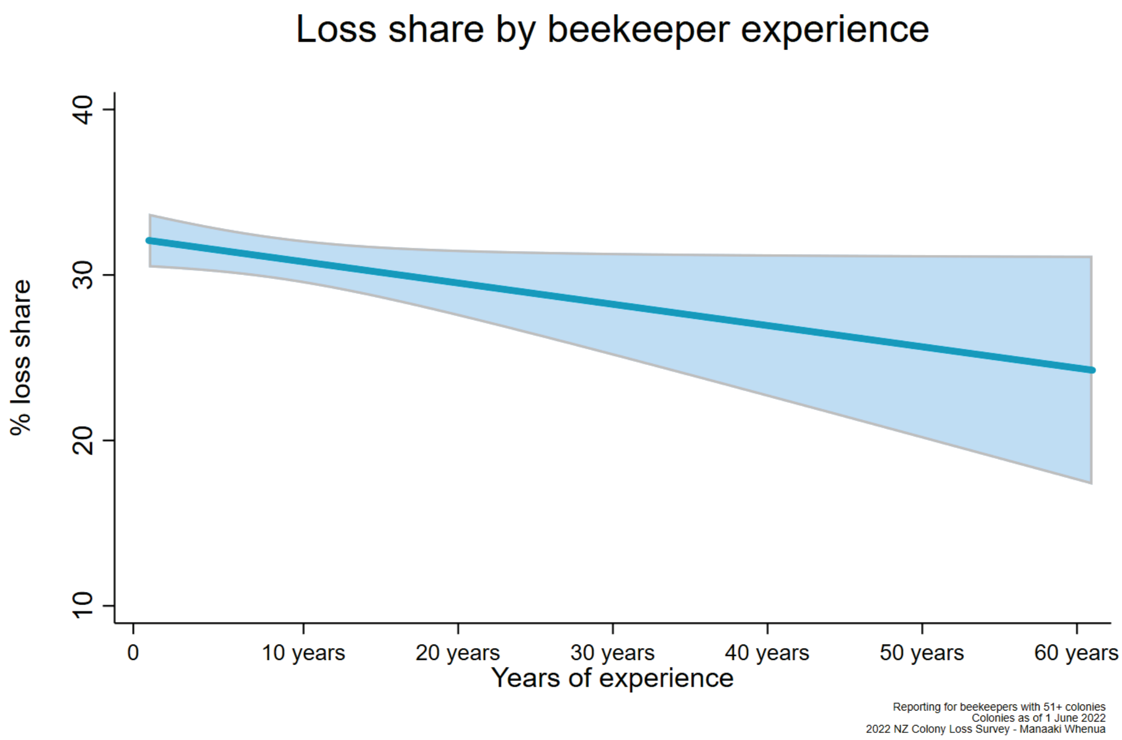

Figure 35: Loss share by years of experience among beekeepers with more than 50 colonies. Linear prediction with 95% confidence intervals.

Regardless of experience, beekeepers employed a diverse range of tools for record keeping (Figure 36). Most beekeepers kept track of colonies formally in ledgers or notebooks, although more sophisticated tools such as spreadsheets and specialty software and apps were commonly used by larger operators. Indeed, among beekeepers with more than 3,000 colonies, specialty software and apps were more commonly used than any other method. Even so, a significant portion of beekeepers kept no formal records.

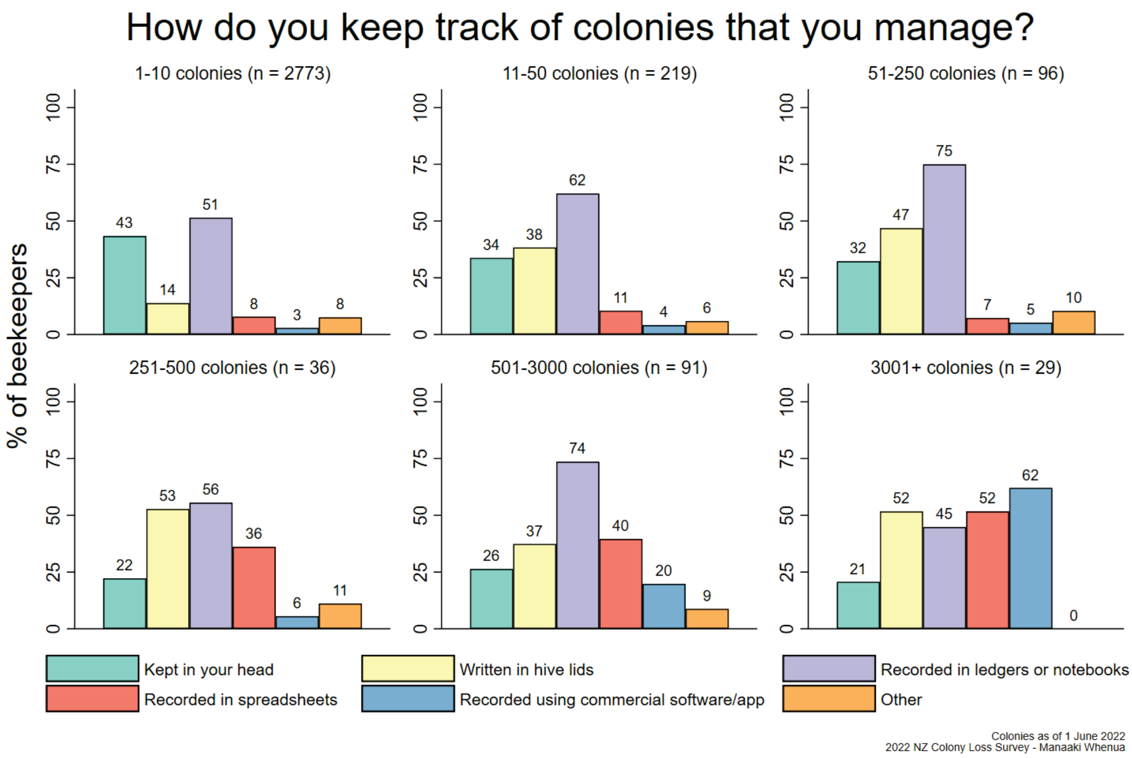

Figure 36: Record keeping, by operation size.

4.7.2 Acceptable Loss

Beginning in 2017, respondents were asked to specify the level of over-winter losses – commonly referred to as 'economic injury level' – they considered to be economically sustainable. As with past waves of the survey, responses ranged from 0% to 100%. The median acceptable loss was 10%, identical to the median acceptable loss rates in 2018, 2019, 2020, and 2021.[15]

Figure 37 shows the winter loss rates considered to be economically sustainable by beekeeping operations with 1–50 colonies, 51–250 colonies, and more than 250 colonies. Across all three groups, current loss rates exceed the economically sustainable loss rate for a majority of beekeepers.

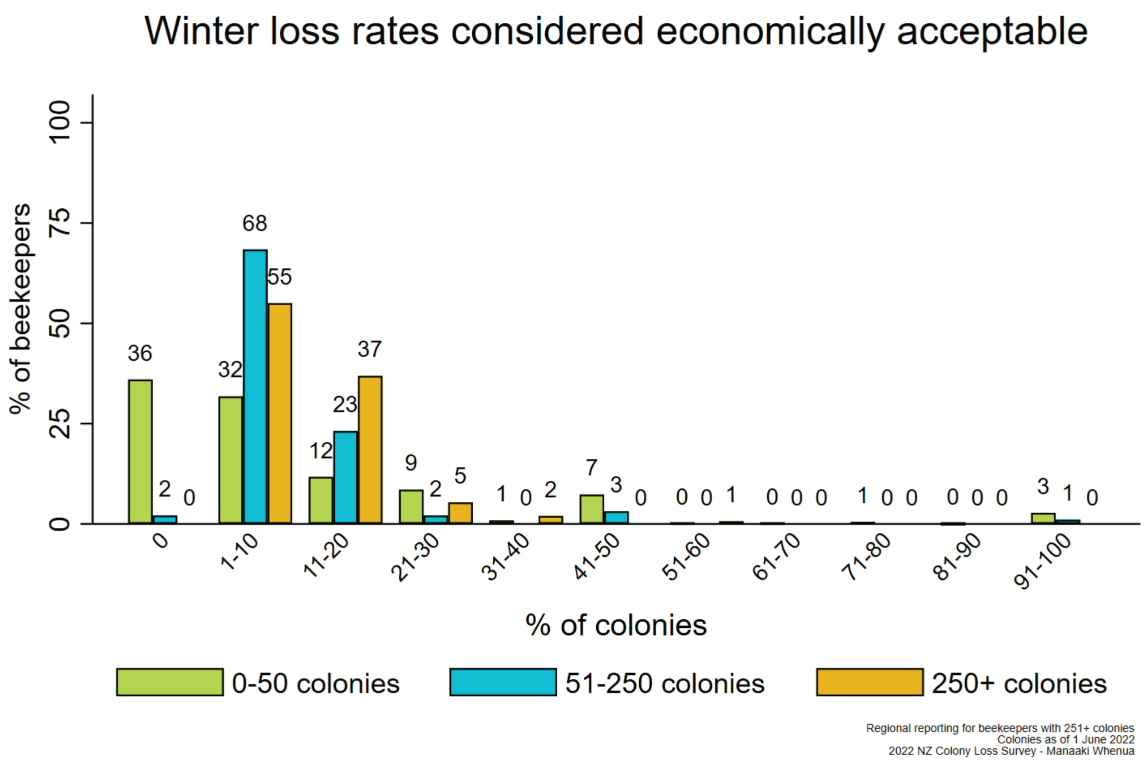

Figure 37: Winter loss rates considered economically acceptable, by operation size.

[15] Bunching at round numbers is not uncommon in survey research. See, for example, Mazza & Hartog 2011.

4.7.3 Beekeeping environment and optimism

In addition, beekeepers with more than 50 colonies were asked to describe the 2021/22 season in terms of the economics of beekeeping (honey prices, pollination prices, etc.), environmental factors (weather, floral resources, etc.), biosecurity (spread of pests and diseases), and beekeeper lifestyle (stress, time pressure, etc.). Respondents answered on the following five-point scale: 1 = very poor, 2 = poor, 3 = moderate, 4 = good, 5 = excellent.

The responses are shown in Figure 38. Beekeepers scored the economics of beekeeping during the 2020/21 season a 2.2, on average, similar to 2021/22 (compared to 2.7 in 2019/20). They scored environmental factors a 3.2, on average (cf. 3.5 in 2019/20 and 3.0 in 2020/21). They scored biosecurity a 3.3, on average, the same as 2019/20 and 2021/22. Finally, they scored beekeeper lifestyle a 3.1, on average (cf. 3.5 in 2019/20 and 3.3 in 2020/21).

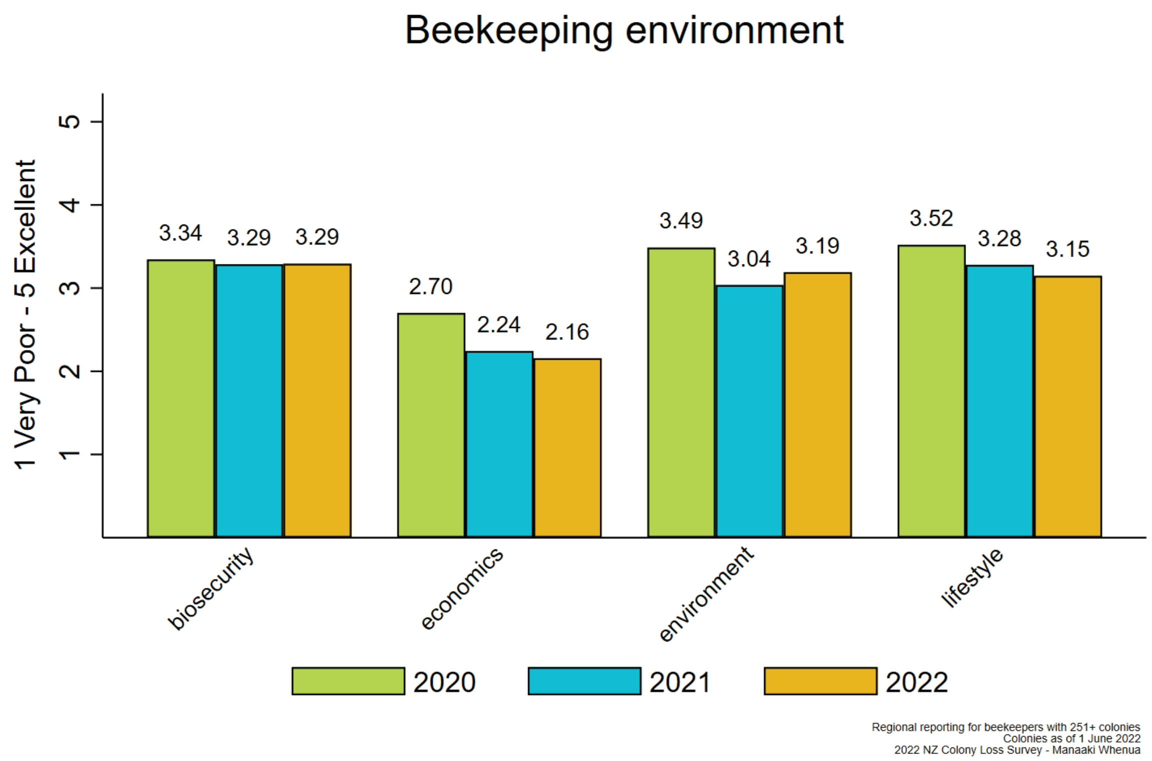

Figure 38: Beekeeping environment, 2021–2022, nationally.

Despite a pessimistic economic outlook, beekeepers with more than 50 colonies maintained some degree of optimism. Indeed, when asked to evaluate their optimism about the future of beekeeping in New Zealand on a score of 0 ('very pessimistic') to 10 ('very optimistic'), the mean score was 5.0 (Figure 39).

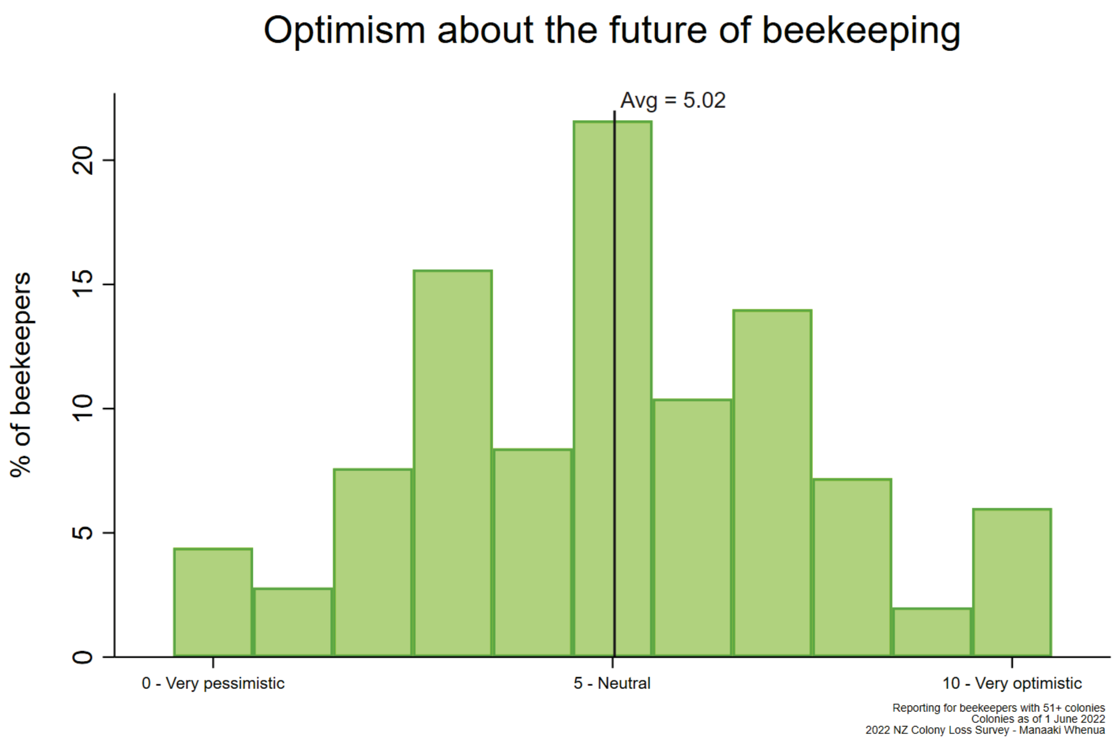

Figure 39: Optimism about the future of beekeeping among beekeepers with more than 50 colonies, nationally.

4.7.4 Risk taking

Beekeeping is an inherently risky activity: the work is physically demanding, it is undertaken in remote environments, and payoffs are uncertain in the face of fluctuating honey prices and unpredictable weather. In addition, colony health depends critically on the management of a range of pathogens and pests, which is costly. Some beekeepers take measures to minimise these risks (e.g. by testing for and treating varroa) while others are willing to gamble on outcomes. But because bees from a colony managed by one beekeeper can spread mites and disease to colonies managed by another beekeeper, risky behaviours may affect others.

In the 2022 NZ Colony Loss Survey beekeepers were also asked to evaluate their willingness to take risks 'in general', a measure that has been shown to correlate highly with actual risky behaviours such as smoking, investing in stocks, participating in certain sports, wearing seat belts, and occupational choice (e.g. Dohmen et al. 2005; Dohmen et al. 2011). In this part of the report we briefly analyse the correlation between risk preferences and colony loss rates among beekeepers with 1–10 colonies. We focus on this group in particular because these beekeepers generally own the colonies they manage and because they don't depend on beekeeping for their livelihoods.

On a scale from 0 ('unwilling to take risks') to 10 ('fully prepared to take risks') beekeepers with 1–10 colonies scored themselves an average of 4.1; the median risk tolerance is 5. Figure 40 shows that loss rates correlate positively with risk tolerance. Indeed, the blue line shows that losses among the most risk-tolerant beekeepers are predicted to be 41.7% higher than those for the least risk-tolerant beekeepers (38.0% vs. 26.8%).

Treating for varroa in autumn is one means of reducing over-winter losses, and risk-avoidant beekeepers may be more likely to undertake such treatments. Hence, the green line shows predicted losses for beekeepers with 1–10 colonies who treated for varroa in autumn. Risk tolerance continues to correlate with over-winter loss rates, even after controlling for autumn treatment.[16] That is, beekeepers with 1–10 colonies who are willing to take risks 'in general' experienced higher loss rates over winter 2022 than risk-averse beekeepers, even when they treated for varroa in autumn.

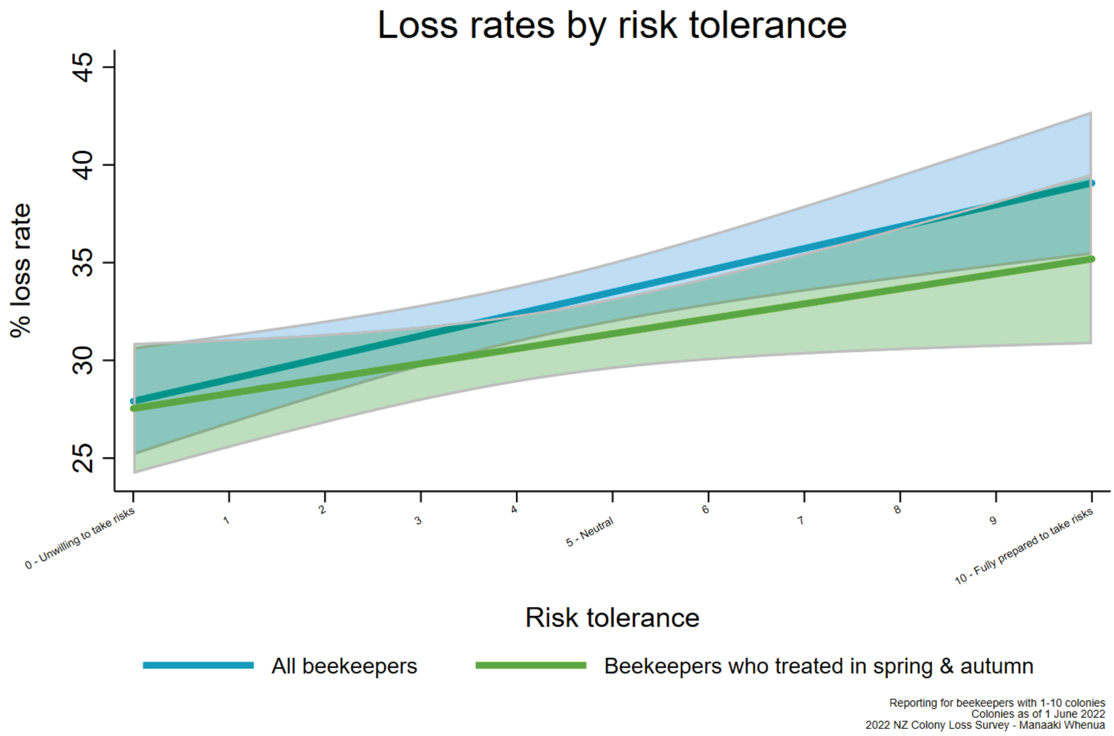

Figure 40: Colony loss rates among beekeepers with 1–10 colonies, by risk profile. Linear prediction with 95% confidence intervals.

5 Discussion

According to Annual Disease Return filings, there were 725,210 honeybee colonies in New Zealand at the start of winter 2022. We estimate the overall winter loss rate to be 13.46%, meaning that New Zealand lost approximately 97,613 colonies over the winter of 2022. This loss rate is statistically unchanged from the winter of 2021 but is higher than that of 2015, 2016, 2017, 2018, 2019, and 2020. These losses represent a substantial impact on the profit margin of beekeepers (Stahlmann-Brown et al. 2022a).

While it is relatively straightforward to quantify losses, it is more difficult to extract the underlying causes of colony losses from surveys rather than lab testing (Stahlmann-Brown et al. 2022b). Nevertheless, between 2017 and 2021, beekeepers most frequently attributed losses to suspected varroa and related complications, queen problems, wasps, and suspected starvation. Table 8 reports the total share of over-wintering colonies attributed to the four largest causes every year since 2017.

[16] Predicted losses among the least risk-tolerant beekeepers is virtually unchanged because almost all of these beekeepers treated for varroa in autumn.

Table 8. Estimated share of all colonies lost to specific causes, 2017–2022.

	2022	2021	2020	2019	2018	2017
Suspected varroa	6.37% [6.09%, 6.66%]	5.31% [5.06%, 5.57%]	3.50% [3.29%, 3.73%]	2.95% [2.73%, 3.20%]	2.28% [2.10%, 2.47%]	1.64% [1.49%, 1.81%]
Queen problems	3.09% [2.93%, 3.26%]	3.28% [3.14%, 3.44%]	3.74% [3.57%, 3.93%]	3.14% [3.01%, 3.28%]	3.88% [3.74%, 4.03%]	3.33% [3.16%, 3.50%]
Wasps	0.91% [0.79%, 1.05%]	1.66% [1.52%, 1.81%]	0.75% [0.64%, 0.87%]	0.95% [0.84%, 1.07%]	0.90% [0.79%, 1.03%]	0.94% [0.84%, 1.06%]
Suspected starvation	0.86% [0.78%, 0.94%]	0.98% [0.90%, 1.07%]	0.86% [0.78%, 0.94%]	1.04% [0.94%, 1.14%]	0.83% [0.74%, 0.92%]	1.35% [1.24%, 1.46%]

Suspected varroa first eclipsed queen problems as the leading attribution of colony losses over winter 2021, and the share of losses attributed to varroa continued to grow over winter 2022. Indeed, while overall losses were statistically unchanged from 2021, losses attributed to varroa increased by 20.0% (6.4% vs. 5.3%) while losses attributed to queen problems fell by 5.8%. Losses attributed to wasps returned to the long-run average.

Self-reported risk tolerance is positively correlated with colony losses, even after accounting for varroa treatment. That is, beekeepers who take more risks in life also take more risks with their bees, and they have higher losses as a consequence. Beekeeper experience is negatively correlated with loss rates for winter 2022: beekeepers with more experience fared better than beekeepers with less experience. One possible explanation is that beekeeper experience also positively correlates with noting signs of DWV and PMS in their colonies, allowing more experienced beekeepers to treat colonies that they recognise as being infested.

Many colonies were lost to what beekeepers identified as varroa despite having been treated in the autumn. Beekeepers with 1–50 colonies most commonly chalked these losses up to not treating at the right time. Beekeepers with more than 50 colonies most often identified re-invasion as the root of their losses to varroa. Most beekeepers treat with amitraz and/or flumethrin, both of which are described as being ‘mostly successful’ or ‘completely successful’ by most beekeepers.

Finally, despite the weakening economics of beekeeping and many beekeepers now losing more colonies than they consider to be economically sustainable, there remains optimism for the future of beekeeping in New Zealand.

6 Acknowledgements

The 2022 report draws extensively from earlier reports, to which Linda Newstrom-Lloyd and Oksana Borowik contributed extensively.

Michelle Taylor provided extremely helpful guidance on best-practice varroa monitoring.

Hayley Pragert and Richard Hall shared their expertise throughout.

We gratefully acknowledge the beekeepers who shared their time and knowledge in responding to the survey every year.

Zoe Smeele, who is undertaking a PhD on the effectiveness of using double-stranded RNA to control DWV in bees and mites through RNA interference, was instrumental in ensuring a high response rate.

Finally, we are indebted to Sam Bartos for programming a complex survey to make it look effortless.

7 References

Ahmad S, Khan KA, Khan SA, Ghramh HA, Gul A 2021. Comparative assessment of various supplementary diets on commercial honey bee (*Apis mellifera*) health and colony performance. PLoS ONE 16(10): e0258430. https://doi.org/10.1371/journal.pone.0258430

Aliano NP, Ellis MD, Siegfried BD 2006. Acute contact toxicity of oxalic acid to Varroa destructor (Acari: Varroidae) and their Apis mellifera (Hymenoptera: Apidae) hosts in laboratory bioassays. Journal of Economic Entomology 99(5): 1579–1582.

Ausseil AE, Dymond JR, Newstrom L 2018. Mapping floral resources for honey bees in New Zealand at the catchment scale. Ecological Applications 28, 1182–1196.

Azizi HR, Sadeghi E, Taghdiri M and Vardanjani ARK 2008. The comparative evaluation of the laboratory methods of separation mite *varroa* from the mature honeybee. Research Journal of Parasitology 3(4): 123–129.

Bee Informed Partnership 2021. 2019-2021 Honey bee colony losses in the United States: preliminary results. https://beeinformed.org/wp-content/uploads/2021/06/BIP_2019_2021_Losses_Abstract.pdf

Blenau W, Rademacher E, Baumann A 2012. Plant essential oils and formamidines as insecticides/acaricides: what are the molecular targets? Apidologie 43(3): 334–347.

Borowik O 2019. The NZ colony loss survey and management decisions: is brood pattern a good indicator of queen quality? New Zealand BeeKeeper July 2019: 11–13.

Brodschneider R, Gray A, Adjlane N, Ballis A, Brusbardis V, Charrière JD, Chlebo R, Coffey MF, Dahle B, de Graaf DC, Maja Dražić M 2018. Multi-country loss rates of honey bee colonies during winter 2016/2017 from the COLOSS survey. Journal of Apicultural Research 57(3): 452–7.

Brodschneider R, Gray A, van der Zee R, Adjlane N, Brusbardis V, Charrière JD, Chlebo R, Coffey MF, Crailsheim K, Dahle B, Danihlík J 2016. Preliminary analysis of loss rates of honey bee colonies during winter 2015/16 from the COLOSS survey. Journal of Apicultural Research 55(5): 375−378.

Brown P 2015. New Zealand Colony Loss and Survival Survey. Landcare Research NZ Ltd. http://www.landcareresearch.co.nz/science/portfolios/enhancing-policy-effectiveness/bee-health. doi: 10.7931/J2GT5K3.

Brown P, Robertson T 2018. Report on the 2017 New Zealand Colony Loss Survey. Ministry of Primary Industries Technical Paper 2018/10. https://www.mpi.govt.nz/dmsdocument/27825-Report-on-the-2017-New-Zealand-Colony-Loss-Survey.

Brown P, Robertson T 2019. Report on the 2018 New Zealand Colony Loss Survey. Ministry of Primary Industries Technical Paper 2019/02. https://www.mpi.govt.nz/dmsdocument/33663-2018-Bee-Colony-Loss-Survey-report.

Brown P, Newstrom-Lloyd LE 2016. Report on the 2015 New Zealand Colony Loss and Survival Survey. Ministry of Primary Industries Technical Paper 2016/07. https://www.mpi.govt.nz/document-vault/11512.

Brown P, Newstrom-Lloyd LE 2017. Report on the 2016 New Zealand Colony Loss Survey. Ministry of Primary Industries Technical Paper 2017/16. https://www.mpi.govt.nz/dmsdocument/16711-new-zealand-colony-loss-survey-report-2016.

Canadian Honey Council. Industry Overview—Canadian Apiculture Industry. Available online: https://honeycouncil.ca/industry-overview/ (accessed on 5 January 2023).

Charrière JD, Imdorf A, Bachofen B, Tschan A 2003. The removal of capped drone brood: an effective means of reducing the infestation of varroa in honey bee colonies. Bee World 84(3): 117–124.

Chauzat MP, Cauquil L, Roy L, Franco S, Hendrikx P, Ribiere-Chabert M 2013. Demographics of the European apicultural industry. PLoS One 2013, 8, e79018, doi:10.1371/journal.pone.0079018

Chen YP, Siede R 2007. Honey bee viruses. Advances in Virus Research 70: 33–80. https://doi.org/10.1016/S0065-3527(07)70002-7

Crown Infrastructure Partners 2018. Broadband extends to 99.8% of the population. Media release accessed on 8 December 2019 at: https://www.crowninfrastructure.govt.nz/wp-content/uploads/2018/12/Media-release-RBI2-MBSF-expansion-announcement-18-Dec-2018-FINAL.pdf

Currie RW, Pernal SF, Guzmán-Novoa E 2010. Honey bee colony losses in Canada. Journal of Apicultural Research 49(1): 104−106. doi: 10.3896/IBRA.1.49.1.18.

Dainat B, Evans JD, Chen YP, Gauthier L, Neumann P 2012. Dead or alive: deformed wing virus and Varroa destructor reduce the life span of winter honeybees. Applied and Environmental Microbiology 78(4): 981–987.

Dainat B, Neumann P 2013. Clinical signs of deformed wing virus infection are predictive markers for honey bee colony losses. Journal of Invertebrate Pathology 112(3): 278–280.

de Feraudy L, Marsky U, Danihlik J 2019. Efficiency of varroa monitoring methods: the benefits of standardized monitoring devices. Apimondia conference. Montreal.

De Jong D, De Andrea Roma D, Goncalves L 1982. A comparative analysis of shaking solutions for the detection of Varroa jacobsoni on adult honey bees. Apidologie 13(3): 297–306.

Dohmen TJ, Falk A, Huffman D, Sunde U, Schupp J, Wagner GG 2005. Individual risk attitudes: New evidence from a large, representative, experimentally-validated survey. Representative, Experimentally-Validated Survey (September 2005).

Dohmen TJ, Falk A, Huffman D, Sunde U, Schupp J, Wagner GG 2011. Individual risk attitudes: Measurement, determinants, and behavioral consequences. Journal of the European Economic Association 9(3): 522-550.

Edwards E, Toft R, Joice N, Westbrooke I 2017. The efficacy of Vespex® wasp bait to control Vespula species (Hymenoptera: Vespidae) in New Zealand. International Journal of Pest Management 63(3): 266–272. doi:10.1080/09670874.2017.1308581

European Parliamentary Research Service. The EU's Beekeeping Sector. Available online: https://epthinktank.eu/2017/10/24/the-eus-beekeeping-sector/ (accessed on 5 January 2023).

Fakhimzadeh K 2000. Potential of super-fine ground, plain white sugar dusting as an ecological tool for the control of Varroasis in the honey bee (Apis mellifera). American Bee Journal 140: 487–491.

Fuchs S 1990. Preference for drone brood cells by Varroa jacobsoni Oud in colonies of Apis mellifera carnica. Apidologie 21(3): 193–199.

Giacobino A, Bulacio N, Cagnolo, Merke J, Orellano E, Bertozzi E, Masciangelo G, Pietronave H, Salto C, Signorini M 2014. Risk factors associated with the presence of Varroa destructor in honey bee colonies from east-central Argentina. Preventive Veterinary Medicine 115(3–4): 280–287. https://doi.org/10.1016/j.prevetmed.2014.04.002.

Goodwin RM, Taylor MA, Mcbrydie HM, Cox HM 2006. Drift of Varroa destructor-infested worker honey bees to neighbouring colonies. Journal of Apicultural Research and Bee World 45(3): 155.

Goodwin M, Taylor M 2007. Control of varroa: a guide for New Zealand beekeepers. Revised edn. Wanganui, Ministry of Agriculture and Forestry. 182 p.

Gray A, Brodschneider R, Adjlane N, Ballis A, Brusbardis V, Charrière JD, Chlebo R, F. Coffey M, Cornelissen B, Amaro da Costa C, Csáki T 2019 Loss rates of honey bee colonies during winter 2017/18 in 36 countries participating in the COLOSS survey, including effects of forage sources. Journal of Apicultural Research 58(4): 479–85.

Gray A, Adjlane N, Arab A, Ballis A, Brusbardis V, Douglas AB, Cadahía L, Charrière J-D, Chlebo R, Coffey MF, Cornelissen B, da Costa CA, Danneels D, Danihlík J, Dobrescu C, Evans G, Fedoriak M, Forsythe I, Gregorc A, Arakelyan II, Johannesen J, Kauko L, Kristiansen P, Martikkala M, Martín-Hernández R, Mazur E, Medina-Flores CA, Mutinelli F, Omar EM, Patalano S, Raudmets A, San Martin G, Soroker VA, Stahlmann-Brown P, Stevanovic J, Uzunov A, Vejsnaes F, Williams A, Brodschneider R 2022. Honey bee colony loss rates in 37 countries using the COLOSS survey for winter 2019-2020: The combined effects of operation size, migration and queen replacement. Journal of Apicultural Research https://doi.org/10.1080/00218839.2022.2113329

Grozinger CM, Flenniken ML 2019. Bee viruses: ecology, pathogenicity, and impacts. Annual Review Entomology 64: 205–226.

Hall RJ, Pragert H, Phiri BJ, Fan QH, Li X, Parnell A, Stanislawek WL, McDonald CM, Ha HJ, McDonald W, et al. 2021. Apicultural practice and disease prevalence in Apis mellifera, New Zealand: a longitudinal study. Journal of Apicultural Research 60(5): 644–658.

Higes M, Martín R, Meana A 2006. Nosema ceranae, a new microsporidian parasite in honeybees in European Journal of Invertebrate Pathology 92: 93–5.

Honey Bee Health Coalition 2015. Tools for varroa management: a guide for effective varroa sampling and control. https://honeybeehealthcoalition.org/wp-content/uploads/2015/08/HBHC-Guide_Varroa-Interactive-PDF.pdf

Imdorf A, Charriere JD, Maqueln C, Kilchenmann V, Bachofen B 1996. Alternative varroa control. American Bee Journal 136(3): 189–194.

Jacques A, Laurent M, Ribière-Chabert M, Saussac, M, Bougeard S, Budge GE, Hendrikx P, Chauzat MP 2017. A pan-European epidemiological study reveals honey bee colony survival depends on beekeeper education and disease control. PLoS One 12, e0172591. https://doi.org/10.1371/journal.pone.0172591

Kielmanowicz MG, Inberg A, Lerner IM, Golani Y, Brown N, Turner CL, Hayes JR, Ballam JM 2015. Prospective large-scale field study generates predictive model identifying major contributors to colony losses. PLoS Pathogens 11(4): e1004816.

Komissar AD 1985. Heat-treatment of varroa-infected honeybee colonies. Apiacta 4, 113–117.

Le Conte Y, Ellis M, Ritter W 2010. Varroa mites and honey bee health: can Varroa explain part of the colony losses? Apidologie 41(3): 353–363.

Lee KV, Goblirsch M, McDermott E, Tarpy DR, Spivak M 2019. Is the brood pattern within a honey bee colony a reliable indicator of queen quality? Insects 10(1): 12.

Lee K, Reuter G, Spivak M 2010. Standardized sampling plan to detect varroa density in colonies and apiaries. American Bee Journal 150(12): 1151–1155.

Lee KV, Steinhauer N, Rennich K, Wilson ME, Tarpy DR, Caron DM, et al. 2015. A national survey of managed honey bee 2013–2014 annual colony losses in the USA. Apidologie 46(3): 292−305.

Macedo P, Wu J, Ellis M 2002. Using inert dusts to detect and assess varroa infestations in honey bee colonies. Journal of Apicultural Research 41: 3–7.

MAF 2011 Apiculture: Key results from MAF's 2011 horticulture and arable monitoring programme. https://www.mpi.govt.nz/dmsdocument/5701-farm-monitoring-report-2011-horticulture-monitoring-apiculture

Mazza J, Hartog J 2011. Do they understand the benefits from education? Evidence on Dutch high school students' earnings expectations. IZA Discussion paper no. 5714. Accessed on 15 February 2021 at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1849469

McCullagh P, Nelder JA 1989. Generalized linear models, Vol. 37. Boca Raton, FL, CRC Press.

Meixner MD, Le Conte Y 2016. A current perspective on honey bee health. Apidologie 47(3): 273−275.

Mortensen AN, Jack CJ, Bustamante TA, Schmehl DR, Ellis JD 2019. Effects of supplemental pollen feeding on honey bee (Hymenoptera: Apidae) colony strength and Nosema spp. infection. Journal of Economic Entomology 112(1): 60–66. https://doi.org/10.1093/jee/toy341

MPI (Ministry for Primary Industries) 2018. Apiculture: 2018 Apiculture monitoring programme. https://www.mpi.govt.nz/dmsdocument/34329/direct

MPI (Ministry for Primary Industries, N.Z.; 2022 Apiculture Monitoring. Available online: https://www.mpi.govt.nz/dmsdocument/54238-2022-MPI-apiculture-monitoring-date (accessed 14 February 2022).

Palmer-Jones T, Line LJS 1962. Poisoning of honey bees by nectar from the karaka tree (Corynocarpus laevigata J. R. et G. Forst.). New Zealand Journal of Agricultural Research 5(5−6): 433−436. doi: 10.1080/00288233.1962.10419940.

Pettis JS, Rice N, Joselow K, vanEngelsdorp D, Chaimanee V 2016. Colony failure linked to low sperm viability in honey bee (Apis mellifera) queens and an exploration of potential causative factors. PLOS One DOI:10.1371/journal.pone.0147220

Popovska Stojanov D, Dimitrov L, Danihlík J, Uzunov A, Golubovski M, Andonov S, Brodschneider R 2021. Direct economic impact assessment of winter honeybee colony losses in three European countries. Agriculture 11(5). DOI: 10.3390/agriculture11050398

Ramsey SD, Ochoa R, Bauchan G, Gulbronson C, Mowery JD, Cohen A, Lim D, Joklik J, Cicero JM, Ellis JD, Hawthorne D 2019. Varroa destructor feeds primarily on honey bee fat body tissue and not haemolymph. Proceedings of the National Academy of Sciences 116(5): 1792–801.

Rangel J, Keller JJ, Tarpy DR 2013. The effects of honey bee (Apis mellifera L.) queen reproductive potential on colony growth. Insectes Sociaux 60(1): 65–73.

Rosenkranz P, Aumeier P, Ziegelmann B 2010. Biology and control of Varroa destructor. Journal of Invertebrate Pathology 103(Suppl 1): S96–S119.

Runckel C, Flenniken ML, Engel JC, Ruby JG, Ganem D, Andino R, DeRisi JL 2011. Temporal analysis of the honey bee microbiome reveals four novel viruses and seasonal prevalence of known viruses, Nosema, and Crithidia. PLoS ONE. https://doi.org/10.1371/journal.pone.0020656

Seitz N, Traynor KS, Steinhauer N, Rennich K, Wilson ME, Ellis JD, et al. 2015. A national survey of managed honey bee 2014–2015 annual colony losses in the USA. Journal of Apicultural Research 54(4): 292−304.

Sperandio G, Simonetto A, Carnesecchi E, Costa C, Hatjina F, Tosi S, Gilioli G 2019. Beekeeping and honey bee colony health: A review and conceptualization of beekeeping management practices implemented in Europe. Science of the Total Environment. 696(13): 133795.

Stahlmann-Brown, P, Hall RJ, Butt R, McCall B, Torres G, Wright T. 2022a. Valuing over-winter colony losses for New Zealand's commercial beekeepers. New Zealand Economic Papers, 1-7.

Stahlmann-Brown, P, Hall RJ, Pragert H, Robertson T 2022b. Varroa appears to drive persistent increases in New Zealand colony losses. Insects 13(7): 589.

Stahlmann-Brown P, Robertson T 2022. Report on the 2021 New Zealand Colony Loss Survey. New Zealand Ministry for Primary Industries Technical Paper. 2022/02. https://www.mpi.govt.nz/dmsdocument/50221-Report-on-the-2021-New-Zealand-Colony-Loss-Survey

Stahlmann-Brown P, Robertson T, Borowik O 2020. New Zealand Colony Loss Survey report – 2019. New Zealand Ministry for Primary Industries Technical Paper. 2021/02. https://www.mpi.govt.nz/dmsdocument/40349-Bee-Colony-Loss-Survey-Report-Report-2019-FINAL

Stahlmann-Brown P, Robertson T, Borowik O 2021. New Zealand Colony Loss Survey report – 2020. New Zealand Ministry for Primary Industries Technical Paper. 2021/04. https://www.mpi.govt.nz/dmsdocument/44590-Report-on-the-2020-New-Zealand-Colony-Loss-Survey

Steinhauer N, Kulhanek K, Antúnez K, Human H, Chantawannakul P, Chauzat MP 2018. Drivers of colony losses. Current Opinion in Insect Science 26: 142–148.

Steinhauer N, vanEngelsdorp D, Saegerman C 2021. Prioritizing changes in management practices associated with reduced winter honey bee colony losses for US beekeepers. Science of the Total Environment 753: 141629. https://doi.org/10.1016/j.scitotenv.2020.141629.

Strachecka A, Borsuk G, Olszewski K, Paleolog J, Gagos M, Chobotow J, Nawrocka A, Gryzin´ska M, Bajda M 2012. The effect of amphotericin B on the lifespan, body-surface protein concentrations, and DNA methylation levels of honey bees (Apis mellifera). Journal of Apicultural Science 56(2): 107–113.

Taylor MA, McBrydie HM, Cox HM, Dominiak BC, Goodwin RM. 2023. Effectiveness of tools to monitor *Varroa Destructor* populations in honey bee colonies. Under review.

van der Steen J, Vejsnæs F 2021. Varroa control: a brief overview of available methods. Bee World 98(2): 50–56.

van der Zee R, Brodschneider R, Brusbardis V, Charriere JD, Chlebo R, Coffey MF, et al. 2014. Results of international standardised beekeeper surveys of colony losses for winter 2012–2013:

analysis of winter loss rates and mixed effects modelling of risk factors for winter loss. Journal of Apicultural Research 53(1): 19−34.

van der Zee R, Gray A, Holzmann C, Pisa L, Brodschneider R, Chlebo R, et al. 2012. Standard survey methods for estimating colony losses and explanatory risk factors in Apis mellifera. In: Dietemann V, Ellis JD, Neumann P eds The COLOSS BEEBOOK, Vol. I: Standard methods for Apis mellifera research. Journal of Apicultural Research 52(4). http://dx.doi.org/10.3896/IBRA.1.52.4.18.

van der Zee R, Gray A, Pisa L, De Rijk T 2015. An observational study of honey bee colony winter losses and their association with Varroa destructor, neonicotinoids and other risk factors. PloS One 10(7): e0131611.

Van Eaton C 2014. Manuka: the biography of an extraordinary honey. Auckland, NZ: Exisle Publishing.

vanEngelsdorp D, Brodschneider R, Brostaux Y, van der Zee R, Pisa L, Underwood R, Lengerich EJ, Spleen A, Neumann P, Wilkins S, Budge GE, Pietravalle S, Allier F, Vallon J, Human H, Muz M, Le Conte Y, Caron D, Baylis K, Haubruge E, Pernal S, Melathopoulos A, Saegerman C, Pettis JS, Nguyen BK 2012. Calculating and reporting managed honey bee colony losses. In: Sammataro, Yoder eds Honey Bee colony health: challenges and sustainable solutions. Boca Raton. FL: CRC Press, Taylor & Francis Group. Pp. 237–244.

Zhang ZQ 2000. Notes on *Varroa destructor* (Acari: Varroidae) parasitic on honeybees in New Zealand. Systematic and Applied Acarology Special Publications.

8 Questionnaire

Welcome to the 2022 NZ Colony Loss Survey!

This survey is for **every beekeeping operation**, large or small. Whether you lost 0% or 100% of your hives, please complete the survey soon after hives have been opened in spring.

Similar surveys are undertaken in more than 30 countries. In New Zealand, it has been **conducted annually since 2015**. The project is funded by Biosecurity New Zealand and is undertaken by Manaaki Whenua - Landcare Research, a Crown Research Institute.

Your participation makes it possible to identify trends in New Zealand beekeeping, to compare loss rates across countries, and to better understand risk factors. Click here to see a summary of last year's results.

Before you begin, a few important notes related to your privacy:

- Data are collected for **research purposes only**.
- Your participation in this survey is **voluntary**. You can stop the survey at any time. If you decide that you do not want your data to be used, email Pike at the address below before 15 November 2022 and it will be removed.
- Individual results will remain **confidential** and all data will be stored on password-protected computers.
- We will not share your personal information with MPI, other beekeepers, or anyone else. Read our statement on survey privacy and ethics here.
- **Anonymized results** will be reported in the April issue of *The Beekeeper*, scientific papers, and reports.

And a few notes about how the survey works:

- Some questions include blue text, which can be clicked to show additional information.
- Additional information may include definitions or an explanation of why a question is being asked. Click this text to hide the additional information.
- On average, the survey takes approximately 12 minutes for small hobbyists and 22 minutes for large commercial beekeepers.
- We recommend using a computer, but the survey also works on mobile devices (please turn your phone sideways).
- By completing the survey, you will be eligible for a prize draw for one of five $100 supermarket vouchers.

Please email Pike at brownp@landcareresearch.co.nz if you run into problems.

Q3 Click **YES** to begin the survey, then **NEXT** (scroll down if needed) to continue

- ○ **YES, take me to the survey**
- ○ NO, I don't want to do the survey this year

Section: Responsibility

Q4 Which of the following best describes your beekeeping operation?

- ○ Small-scale or hobby beekeeping
- ○ Commercial or semi-commercial beekeeping

Q5 Which of these best describes your role within the operation?

- Owner/partner
- Apiary manager

Q6 Do you personally manage all apiaries?

- Yes
- No

Q7 Ideally, managers will complete the survey for the apiaries that they manage. Do you wish to complete the survey yourself or to ask managers to complete the survey?
If you will report on some apiaries and managers will report on others, please select 'Apiary managers will complete the survey'.

- I will complete the survey myself
- Apiary managers will complete the survey
- I will complete the survey for some apiaries and apiary managers will complete the survey for other apiaries

Q8 Please enter the email address of each apiary manager in the box below. We will send a request to complete the survey directly to the apiary manager(s).

Enter each address on a new line. ________________________________

Q9 Please enter the email address of each apiary manager in the box below. We will send a request to complete the survey directly to the apiary manager(s).

Enter each address on a new line. ________________________________

Section: Winter 2022 colony losses

The survey has three parts. This first part covers **winter 2022**. It is the main focus of the survey.

Q11 Did you have **at least one colony** at the beginning of winter 2022?
Please only consider colonies that were queenright and strong enough to provide a honey harvest and/or pollination services.

- Yes
- No → Next section

Q12 In which region(s) were your apiary sites located during winter 2021?
Select all that apply. Note that Coromandel is listed separately from Waikato and that Wairarapa is listed separately from Wellington.

- Northland
- Auckland
- Coromandel
- Waikato
- Bay of Plenty
- Gisborne
- Hawke's Bay
- Taranaki
- Manawatu-Wanganui
- Wairarapa
- Wellington
- Tasman / Nelson
- Marlborough
- Canterbury
- West Coast
- Otago
- Southland
- Chatham Islands

Q13 How many production colonies did you have **going into winter 2022**? How many production colonies did you acquire or sell/give away over winter?
Enter whole numbers only. If you do not have an exact figure, please estimate.

Viable production colonies **start of winter 2021**: ________

How many were **added to this number** during winter?: ________

How many were **sold or given away** during winter?: ________

Total: ________

Q14 {For each region}
When you checked colonies during the first spring round, how many were alive but had unsolvable queen problems? How many were lost due to natural disasters or accidents? To theft or vandalism? And how many colonies were dead upon inspection?
Enter whole numbers only. If you do not have an exact figure, please estimate.
Please include any colonies that were lost for economic reasons. *For example, if a colony was lost to starvation because it was too expensive to provide supplemental sugar, please include this loss under 'dead upon inspection'.*

How many of these colonies did you lose because they were **alive but had unsolvable queen problems**?: ________
How many of these colonies did you lose because of **natural disasters or accidents**?: ________
How many of these colonies did you lose as a result of **theft or vandalism**?: ________
How many of these colonies **were dead upon inspection** (due to AFB, varroa, wasps, disease, robbing, starvation, etc)?: ________

Total (out of X winter colonies): ________

Q15 How many of these dead colonies were lost to each of the following causes?
{For hives that were dead upon inspection, for each region}
Enter whole numbers only. If you do not have an exact figure, please estimate. If there is more than one cause for the death of a colony, please choose the most significant cause.
Please include any colonies that were lost for economic reasons in the categories below. *For example, if a colony was lost to starvation because it was too expensive to provide supplemental sugar, please include this loss under 'suspected starvation'.*

Out of ## colonies that were dead upon inspection:

How many of these dead colonies were lost to **AFB**? : ________

How many of these dead colonies were lost to **wasps**? : ________

How many of these dead colonies were lost to **robbing by other bees**? : ________

How many of these dead colonies were lost to **Argentine ants**? : ________

How many of these dead colonies were lost to **suspected starvation**? : ________

How many of these dead colonies were lost to **suspected toxic exposure**? : ________

How many of these dead colonies were lost to **suspected varroa and related issues**? : ________

How many of these dead colonies were lost to **suspected nosema and other diseases**? : ________

How many of these dead colonies were lost to **other reasons**? : ________

How many of these dead colonies were lost to **reasons that you are unsure of**? : ________

Total: ________

Q39 Were any of the colonies that you lost over winter 2022 lost due to economic reasons, e.g. because management of colonies became too expensive? {If any colonies were lost}

- Yes
- No
- Unsure

Q40 Did any of the production colonies that you had at the beginning of winter 2022 have new queens? {For each region}

- Yes
- No

Q41 Approximately what percentage of the production colonies that you had in winter 2022 had new queens? {For each region}

- 0%
- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%
- 45%
- 50%
- 55%
- 60%
- 65%
- 70%
- 75%
- 80%
- 85%
- 90%
- 95%
- 100%

Q42 Out of all of your queenright colonies in spring 2021, approximately what percentage were **weak**? {For each region}

- 0%
- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%
- 45%
- 50%
- 55%
- 60%
- 65%
- 70%
- 75%
- 80%
- 85%
- 90%
- 95%
- 100%

Q43 Please describe **wasp activity** over winter 2022.
{For each region}

- None
- Little
- Some
- A lot
- Extreme

Q44 In your opinion, what was the single largest factor in **losses to varroa** over winter? {If losses to varroa}

- Did not treat for varroa
- Did not treat for varroa at the right time
- Used ineffective dosage of varroa treatment
- Used ineffective products for treating varroa
- Winter weather conditions
- Reinvasion

Section: 2021-2022 season

This is the second of three parts of the survey. It focuses on the **2021-2022 season**. It covers topics such as varroa, nectar and pollen sources, supplemental feeding, and overcrowding.

Q46 Did you have at least one colony during the 2021-2022 season?

- Yes
- No → Next section

Q47 In which region(s) did you keep your production colonies at any time during the 2021-2022 season?
Select all that apply. Note that Coromandel is listed separately from Waikato and that Wairarapa is listed separately from Wellington.

- Northland
- Auckland
- Coromandel
- Waikato
- Bay of Plenty
- Gisborne
- Hawke's Bay
- Taranaki
- Manawatu-Wanganui
- Wairarapa
- Wellington
- Tasman / Nelson
- Marlborough
- Canterbury
- West Coast
- Otago
- Southland
- Chatham Islands

Q48 Did you see signs of deformed wing virus or parasitic mite syndrome in your production colonies during the 2021-2022 season?

Signs of deformed wing virus {shrunken and deformed wings or other developmental abnormalities}

- None
- Limited
- Extensive
- Unsure

Signs of parasitic mite syndrome {spotty brood patterns, increased levels of brood disease, and/or white larvae that are chewed or pecked down by workers}

- None
- Limited
- Extensive
- Unsure

Q49 Did you monitor your production colonies for varroa during the 2021-2022 season?

- Yes
- No
- Unsure

Q50 What methods did you use to monitor your production colonies for varroa during the 2021-2022 season? *Select all that apply.* {If monitored}

- Alcohol / detergent wash
- Sticky board (or other collection tray below the hive)
- Sugar shake / roll
- Visual inspection of adult bees
- Visual inspection of drone brood / De-capping brood
- Sent sample to a lab
- CO_2
- Other (please explain) _________

Q51 Approximately what % of your tested colonies had mite counts of at least **9 mites per 300 bees (1/2 cup)** at any time during the 2021-2022 season? {If alcohol / detergent wash, sugar shake / roll, sent sample to a lab, CO_2}

- 0%
- 1-2%
- 3-5%
- 6-10%
- 11-20%
- More than 20%
- Unsure

Q52 Did you treat varroa during the 2021-2022 season?

- Yes, during **spring build-up 2021**
- Yes, during **honey flow**
- Yes, **between harvest and winter**
- Yes, during **over-wintering**
- No, did not treat

Q53 What **methods** did you use to treat varroa between spring 2021 and winter 2022?

Tick all that apply.

	During spring build-up {If selected}	During honey flow {If selected}	Between harvest and winter {If selected}	During over-wintering {If selected}
ApiLife VAR®	○	○	○	○
ApiStan®	○	○	○	○
Apitraz®	○	○	○	○
Apivar®	○	○	○	○
Bayvarol®	○	○	○	○
FormicPro®	○	○	○	○
Thymovar®	○	○	○	○
Oxalic acid - sublimation / vaporisation	○	○	○	○
Oxalic acid - dribbling / trickling	○	○	○	○
Oxalic acid - glycerine strips / staples	○	○	○	○
Other ___	○	○	○	○

Q54 Some beekeepers have reported treating for varroa multiple times between harvest and winter. **How many times** did you treat your colonies for varroa between harvest 2022 and winter 2022, on average?

- ○ 1
- ○ 2
- ○ 3+

Q55 In a few words, why did you use these specific varroa treatments in 2021-2022?

Q56 In a few words, why didn't you treat varroa in 2021-2022?

Q57 In general, **how successful** were these products and techniques for managing varroa between spring 2021 and spring 2022?

	Not at all successful	Partly successful	Mostly successful	Complete successful
ApiLife VAR® {if used}	○	○	○	○
ApiStan® {if used}	○	○	○	○
Apitraz® {if used}	○	○	○	○
Apivar® {if used}	○	○	○	○
Bayvarol® {if used}	○	○	○	○
FormicPro® {if used}	○	○	○	○
Thymovar® {if used}	○	○	○	○
Oxalic acid - sublimation / vaporisation {if used}	○	○	○	○
Oxalic acid - dribbling / trickling {if used}	○	○	○	○
Oxalic acid - glycerine strips / staples {if used}	○	○	○	○

Q58
During the 2021-2022 season, approximately what share of production colonies were primarily used for the following purposes?

Primarily honey production :	________
Primarily pollination :	________
Primarily queen breeding :	________
Primarily live bee production :	________
Primarily other bee products (wax, pollen, beebread, propolis, royal jelly, venom, etc.) :	________
Other (please explain) :	________
Total :	________

Q59 Which of the following monofloral honeys did you target during the 2021-2022 season, if any?
Tick all that apply.

- ○ Mānuka
- ○ Kānuka
- ○ Tawari
- ○ Borage / Vipers bugloss
- ○ Kamahi
- ○ Rewarewa
- ○ Rata
- ○ Pōhutukawa
- ○ Nodding thistle
- ○ Clover / pasture
- ○ Ling heather
- ○ Thyme
- ○ Beech honeydew
- ○ Other (please specify) ___
- ○ None of the above

Q60 For which of the following crops did your bees provide pollination under contract during the 2021-2022 season, if any?
Tick all that apply.

- ○ Kiwifruit
- ○ Apples and pears
- ○ Stone fruit, including cherries
- ○ Avocados
- ○ Vegetables (carrots, onions, Asian brassicas, radishes, etc.)
- ○ Oil seed (e.g. rapeseed, sunflower)
- ○ Other (please specify) ___
- ○ None of the above

Q61 Did you do any of the following during the 2021-2022 season?

	Yes	No	Unsure
Replace old brood comb with new foundation	○	○	○
Migrate hives more than 15 km	○	○	○
Test honey for tutin	○	○	○
Provide supplemental sugar	○	○	○
Provide protein supplements	○	○	○

Q62 Approximately what proportion of old brood comb did you replace with new foundation (per colony) during the 2021-2022 season? {If selected}

- ○ 0%
- ○ 5%
- ○ 10%
- ○ 15%
- ○ 20%
- ○ 25%
- ○ 30%
- ○ 35%
- ○ 40%
- ○ 45%
- ○ 50%
- ○ 55%
- ○ 60%
- ○ 65%
- ○ 70%
- ○ 75%
- ○ 80%
- ○ 85%
- ○ 90%
- ○ 95%
- ○ 100%

Q63 Approximately what share of your production colonies were migrated more than 15 km during the 2021-2022 season? {If selected}

- 0%
- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%
- 45%
- 50%
- 55%
- 60%
- 65%
- 70%
- 75%
- 80%
- 85%
- 90%
- 95%
- 100%

Q64 Approximately what percentage of the total honey production was unsaleable due to high tutin levels (that you were unable to blend to acceptable levels)? {If selected}

- 0%
- 5%
- 10%
- 15%
- 20%
- 25%
- 30%
- 35%
- 40%
- 45%
- 50%
- 55%
- 60%
- 65%
- 70%
- 75%
- 80%
- 85%
- 90%
- 95%
- 100%

Q65 What type of sugar did you use as a supplementary feed during the 2021-2022 season? {If selected}
Select all that apply.

- Sugar solution
- Invert sugar solution
- Raw sugar
- White sugar
- Honey
- Other (please specify below) ____________________

Q66 What type of protein supplement did you use during the 2021-2022 season? {If selected}
Select all that apply.

- FeedBee
- MegaBee
- Dry pollen
- Homemade protein supplement
- Other (please describe below) ____________________

Q67 Between the first spring inspection of 2020 and the first spring inspection of 2021, was one or more apiary sites compromised or lost in its entirety? *Possible causes include being overtaken by other beekeepers, overcrowding, lost pollen and nectar sources, and effects of giant willow aphid.*
{For each region}

Compromised

- Yes
- No

Lost in its entirety

- Yes
- No

Q68 What percentage of all your apiary sites were compromised between the first spring inspection of 2021 and the first spring inspection of 2022 due to each of the following reasons? {If selected}

Overcrowding (too many hives close to your apiaries) ________

Pollen and nectar sources were removed and not replaced {Changes made to local plants may affect nectar or pollen availability for honey bees. Examples include clearing of native bush or removal of weed species such as gorse} ________

Effects of giant willow aphid {Giant willow aphid can kill willow trees, which are an important source of pollen for bees in spring. It also produces honeydew from the sap of willow trees, which can attract wasps. If giant willow aphid honeydew is gathered by honey bees, it can become difficult to extract the honey due to the presence of a crystalline sugar called melizitose.} ________

Other (please describe) _____ ________

Q69 What percentage of all your apiary sites were lost in their entirety between the first spring inspection of 2020 and the first spring inspection of 2021 due to each of the following reasons? {If selected}

Overtaken by another beekeeper ________

Overcrowding (too many hives close to your apiaries) ________

Pollen and nectar sources were removed and not replaced {Changes made to local plants may affect nectar or pollen availability for honey bees. Examples include clearing of native bush or removal of weed species such as gorse} ________

Effects of giant willow aphid {Giant willow aphid can kill willow trees, which are an important source of pollen for bees in spring. It also produces honeydew from the sap of willow trees, which can attract wasps. If giant willow aphid honeydew is gathered by honey bees, it can become difficult to extract the honey due to the presence of a crystalline sugar called melizitose.} ________

Other (please describe)_____ ________

Q70 Generally speaking, in which months do the following typically happen (if at all)?
Tick all that apply. {Desktop only}

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	None
You add supers	o	o	o	o	o	o	o	o	o	o	o	o	o
You change queens	o	o	o	o	o	o	o	o	o	o	o	o	o
You split colonies	o	o	o	o	o	o	o	o	o	o	o	o	o
You unite colonies	o	o	o	o	o	o	o	o	o	o	o	o	o
You harvest honey	o	o	o	o	o	o	o	o	o	o	o	o	o
You use colonies for pollination	o	o	o	o	o	o	o	o	o	o	o	o	o
You experience colony losses	o	o	o	o	o	o	o	o	o	o	o	o	o

Section: Experience and Perception

This final part of the survey is quite short. It focuses on your experience as a beekeeper - how long you've been at it, how many people work on the beekeeping operation, and how things are going in general.
The following questions are optional, but they are very helpful for understanding the current situation for beekeeping in New Zealand.

Q72 How many full-time equivalent (FTE) beekeeping staff does this operation have?
For example, if one person works full time and two people two half time, then this equals 2.0 FTE. Please include yourself, if applicable.

_______ FTE beekeeping staff

Q73 Approximately how many years of beekeeping experience do you have?

_______ years of beekeeping experience

Q74 Approximately what share of your household income was derived from beekeeping in the last 12 months?
Why are we asking this question? {We'd like to better understand how much beekeepers rely on beekeeping for their livelihoods.}

- 0%
- 1-10%
- 11-25%
- 26-40%
- 41-60%
- 61-75%
- 76-90%
- 91-99%
- 100%
- Prefer not to answer

Q75 In general, **how do you keep track** of the honey bee colonies you manage?
Tick all that apply.

- Kept in your head
- Written on hive lids
- Recorded in ledgers or notebooks
- Recorded in spreadsheets (e.g. Excel)
- Recorded using commercial software/app
- Other (please describe below) ___

Q76 How would you describe the 2021-2022 season in terms of the economics of beekeeping, environmental factors, biosecurity, and beekeeper lifestyle?

	Very poor	Poor	Moderate	Good	Excellent	Unsure
Economics of beekeeping	o	o	o	o	o	o
Environmental factors	o	o	o	o	o	o
Biosecurity	o	o	o	o	o	o
Beekeeper lifestyle	o	o	o	o	o	o

Q77 What percent of over-winter losses do you consider to be economically sustainable?
_______ % of over-winter losses

Q78 Are you generally a person who is fully prepared to take risks, or do you try to avoid taking risks? *Please enter a number between 0 and 10, where 0 means 'unwilling to take risks' and 20 means 'fully prepared to take risks'.*

- 0 – Unwilling to take risks
- 1
- 2
- 3
- 4
- 5 – Middle
- 6
- 7
- 8
- 9
- 10 – Fully prepared to take risks

Q79 In general, how optimistic do you feel about the future of beekeeping in New Zealand? *Please enter a number between 0 and 10, where 0 means 'Very pessimistic' and 10 means 'Very optimistic'.*

- 0 – Very pessimistic
- 1
- 2
- 3
- 4
- 5 – Middle
- 6
- 7
- 8
- 9
- 10 – Very optimistic

Q80 Please add any additional comments on the 2021-2022 NZ Colony Loss Survey.

____