Biosecurity New Zealand

Tiakitanga Pūtaiao Aotearoa

Report on the 2019 New Zealand Colony Loss Survey

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Contents

Page

Executive summary

The 2019 NZ Colony Loss Survey recorded colony losses incurred over winter 2019. It builds on four previous NZ Colony Loss Surveys (2015–2019), thus providing an opportunity for monitoring 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 more than 35 countries. It also included questions that are specific to New Zealand, reflecting our unique context. The questionnaire itself was similar to that used in the 2018 NZ Colony Loss Survey, but new questions on queen stock and tutin were added in 2019. Because the survey is administered online, it was also optimised for mobile devices in 2019.

Invitations to participate in the survey were sent to all New Zealand beekeepers who had registered valid email addresses with AsureQuality, which administers the New Zealand Apiary Register. Participation was encouraged by industry groups as well as prominent beekeepers. In addition, the directors of the largest beekeeping operations were contacted before the start of the survey, and all beekeepers with more than 250 colonies registered with AsureQuality received personal phone calls to encourage completion.

In total, 3,456 beekeepers completed the 2019 NZ Colony Loss Survey, indicating a response rate of 40.9 percent of all registered beekeepers with valid email addresses. Among the beekeepers who completed the survey were 187 of the 540 beekeepers with more than 250 registered colonies and valid email addresses, indicating a response rate of 34.6 percent. We estimate the total share of registered hives included in the survey to be 36.2 percent. These response rates are 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 were alive on 1 June 2019) is estimated to be 10.46 percent, with a 95 percent confidence interval of [10.10%, 10.82%]. These loss rates imply that New Zealand lost approximately 81,965 colonies over winter 2019.

The overall loss rate for winter 2019 is statistically indistinguishable from the overall loss rate for winter 2018. However, overall loss rates for winter 2019 are 7.8 percent, 9.3 percent, and 25 percent higher than overall loss rates for winter 2017, 2016, and 2015, respectively. The difference between a 7.8 and a 10.46 percent loss rate for 2019 amounts to approximately 16,377 colonies.

As in previous years, overall loss rates show considerable regional variation. Estimates of the overall loss rates range from 7.99 percent [7.43%, 8.58%] for the Lower North Island to 12.08 percent [11.42%, 12.77%] for the Middle North Island.

Overall loss rates within regions also exhibited variation over time: for example, overall loss rates in the Lower North Island have shown a uniformly downward trend over the last four years while those in the Lower South Island have shown a uniformly upward trend over the same period. Loss rates in the Upper North Island were significantly lower than in winter 2018 while those in the Middle North Island were significantly higher than in winter 2018.

As with previous waves 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.

Colony losses were most frequently attributed to queen problems (30.3 percent) and suspected varroa and related complications (28.1 percent), followed by suspected starvation (10.3 percent), and wasps (9.6 percent). Losses were also frequently attributed to robbing by other bees (4.5 percent) and suspected nosema and other diseases (4 percent). Natural disasters, American foulbrood disease, suspected exposure to toxins, thefts/vandalism, accidents, and Argentine ants were significantly less common than the causes listed above. These attributions are similar to previous years, although attributions to queen problems are down by over 8 percentage points and attributions to suspected varroa are up by 5 percentage points vis-à-vis the 2018 NZ Colony Loss Survey.

Questions pertaining to queen problems, queen replacement strategies, varroa monitoring and treatment, brood comb replacement, pollination services, nectar flow, nutrition, tutin, and lost and compromised apiary sites were also included in the survey to facilitate further analyses of factors contributing to colony loss. This information also provides useful information on beekeeping management practices.

1 Introduction

Managed bees provide essential pollination services in crop production worldwide, including an, at least, $5 billion worth of pollination services in New Zealand. However, high colony mortality rates of domesticated honey bees (*Apis mellifera*) has been worrying since large-scale disappearances of adult bees from hives were first noted in the USA in 2005[1]. That said, the key challenge facing honey bee populations today is not the decline in the total number of bee colonies but rather the elevated rates of colony losses, especially after overwintering[2].

Despite losses that greatly exceed historical averages, many countries have seen rapid increases in the number of managed bee colonies[3], mainly through splitting existing hives[4]. The year-on-year increases in New Zealand – managed largely by splitting existing hives – are among the highest in the world[5]. Regardless, several features distinguish the New Zealand apiculture industry from its European and North American counterparts:

1. Mānuka honey continues to command significant price premiums[6]. These price premiums have not only contributed significantly to market entry and an increase in colony numbers in the past decade, but they have also led to the uncommon situation whereby many beekeepers' livelihoods depend on honey production rather than providing pollination services.
2. Non-commercial beekeeping operations (fewer than 251 colonies) comprise 93.6 percent of the beekeeping operations and manage 14.6 percent of the colonies, while commercial beekeeping operations (over 250 colonies) comprise 6.4 percent of the beekeeping operations and manage 85.3 percent of the colonies. In contrast, fewer than one-tenth of one percent of beekeepers in Germany have more than 150 colonies[7]. In the United Kingdom, just 50 out of 37,888 beekeepers have more than 150 colonies[8]. Across the entire European Union, 6 percent of beekeepers have more than 150 hives and 2 percent have more than 300 hives[9]. In Canada, 20 percent of beekeepers maintain 80 percent of colonies[10].
3. American foulbrood disease (AFB) is one of only two animal diseases to have its own pest management agency, the American Foulbrood Pest Management Agency, the other being bovine tuberculosis. New Zealand beekeepers are obliged to register their apiaries in ApiWeb[11] and to destroy colonies that are found to have AFB.
4. *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[12] gives New Zealand the advantage of being able to learn from overseas experiences.

Losses associated with varroa and other pests and diseases have prompted many countries to implement annual surveys of colony losses. This approach was first initiated in Canada in 2002 in response to problems with emerging resistance to varroa treatments, and the surveys have continued

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[1] Aizen & Harder 2009; Potts et al. 2010; Goulson et al. 2015.

[2] Neumann & Carreck 2010, Kuhanek et al 2017.

[3] van der Zee et al. 2012.

[4] vanEngelsdorp & Meixner 2010.

[5] MPI 2018.

[6] van Eaton 2014; Ministry for Primary Industries 2018.

[7] European Parliamentary Research Service 2017.

[8] European Parliamentary Research Service 2017.

[9] Chauzat et al. 2013.

[10] Canadian Honey Council 2019.

[11] ApiWeb is the national apiary register held by the American Foulbrood Pest Managment Agency. See https://apiweb.asurequality.com/.

[12] Zhang 2000; Goodwin & Taylor 2007.

annually since 2007[13]. The sudden and dramatic winter colony losses in excess of 35 percent in 2005 and 2006 prompted the USA to initiate annual surveys of winter colony losses, and these have also continued annually[14].

High levels of overwintering colony losses in Europe, as well as in the Middle East, Africa, and Asia, led to the initiation of similar annual surveys[15].

By 2008, COLOSS (Prevention of honey bee COlony LOSSes) had developed a standardised survey format to harmonise data collection on colony losses[16], and this approach to monitoring colony losses has been adopted across Europe, North America, and elsewhere culminating in an international analysis of colony loss data[17].

Until 2015, New Zealand did not systematically record annual wintering losses. MPI has commissioned Manaaki Whenua – Landcare Research to conduct the NZ Colony Loss Survey annually since 2015.

Using methods detailed below, overall loss rates for winter 2015 were estimated to be 8.37 percent, with a 95 percent confidence interval of [7.66%, 9.15%][18].[19]

In winter 2016, overall loss rates were estimated to be 9.57 percent [9.10%, 10.05%][20].[21]

In winter 2017, overall loss rates were estimated to be 9.70 percent [9.37%, 10.05%][22].[23]

In winter 2018, overall loss rates were estimated to be 10.21 percent [9.85%, 10.58%][24].[25]

This report highlights results from the fourth NZ Colony Loss Survey, which covered winter 2019.

2 Methods

2.1 Survey design

As with previous waves of the NZ Colony Loss Survey, the 2019 NZ Colony Loss Survey was administered to beekeepers online. Electronic survey enumeration provides several advantages over alternative data collection methods. In particular, it enables the use of survey logic to deliver a smart, tailored questionnaire to each participant. For example, only beekeepers who indicated that they had new queens in autumn 2019 were asked about the source of those queens. Similarly, only beekeepers who gave their bees supplemental protein were asked which types of protein they gave. Electronic enumeration also reduces data entry error, thereby increasing the accuracy of the results.

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[13] Currie et al. 2010; Canadian Association of Professional Apiculturalists 2016.

[14] Lee et al. 2015; Seitz et al. 2015.

[15] e.g. van der Zee et al. 2012, 2014, 2015; Brodschneider et al. 2016; Meixner & Le Conte 2016.

[16] van der Zee et al. 2014.

[17] Gray et al 2019.

[18] Brown & Newstrom-Lloyd 2016.

[19] See https://www.mpi.govt.nz/dmsdocument/11512-report-on-the-2015-new-zealand-colony-loss-and-survival-survey.

[20] Brown & Newstrom-Lloyd 2017.

[21] See https://www.mpi.govt.nz/dmsdocument/16711-new-zealand-colony-loss-survey-report-2016.

[22] Brown & Robertson 2018.

[23] See https://www.mpi.govt.nz/dmsdocument/27825-report-on-the-2017-new-zealand-colony-loss-survey.

[24] Brown & Robertson 2019.

[25] See https://www.mpi.govt.nz/dmsdocument/33663-2018-bee-colony-loss-survey-report

One criticism levied against online surveying is lack of accessibility, particularly for rural populations. However, 90 percent of rural New Zealanders had home access to broadband at the conclusion of phase one of the Rural Broadband Initiative in 2016[26], and 99.8 percent of New Zealand's population is slated to have broadband Internet access by 2022[27]. The survey was also optimised for mobile devices to increase accessibly for those without high-speed home Internet access. To reach beekeepers without Internet access, the survey was also made available via telephone interview and mail.

The 2015 survey questionnaire[28] was based on an annual survey of beekeepers 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 the varroa mite, supplemental feeding, and colony management. The challenges facing New Zealand beekeepers differ from those facing beekeepers in the northern hemisphere, so the New Zealand questionnaire has been adapted to the local context. For example, the 2015 NZ Colony Loss Survey added questions on competition for apiary sites and on losses from American foulbrood disease (AFB), theft and vandalism, natural disasters, and wasps. It also adapted the question on nectar flow to reflect New Zealand floral sources.

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. In particular, it incorporated three specific suggestions arising from feedback on the 2015 survey report:

- new questions on the acquisition and disposal of hives to improve accounting of winter losses
- replacing AsureQuality's Apiary Registry Location with well-understood geographic regions
- availability to beekeepers as a download before they began the survey.

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 also 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 kept very similar to the 2016 questionnaire to facilitate trend analysis. However, the 2017 questionnaire 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 toxic exposure and suspected starvation, and implicitly includes both varroa and related complications and nosema and other diseases[29]. 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 regarding the nature of queen problems, the leading cause of winter colony losses reported in the 2017 report. Specifically, the survey asked whether queens disappeared, whether queens were drone layers, or whether queens 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

[26] MBIE 2016.

[27] Crown Infrastructure Partners 2018.

[28] Brown 2015; Brown & Newstrom-Lloyd 2016.

[29] Steinhauer et al. 2018.

hopper feeding on the sap of the native tutu plant (*Coriara genus*). In addition, the survey was also optimised for phones and tablets because approximately half of all respondents complete the survey on a mobile device.

2.2 Categories of colony loss used in the 2019 survey

Colony losses, in general, may be attributed to queen problems (including drone-laying queens or no queen), AFB, wasps, robbing by other bees, Argentine ants, suspected starvation, suspected toxic exposure, suspected varroa and related issues, suspected nosema and other diseases, natural disasters, theft and vandalism, and accidents.

Losses due to varroa mite, insecticides or plant toxins, and other pathogens and pests are 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. Questions on the nature of queen problems were added in 2018.

2.3 Sampling strategy

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

Under the Biosecurity Act 1993, all New Zealand beekeepers are obliged to register their apiaries with AsureQuality's ApiWeb System and to complete an Annual Disease Return by 1 June. More than 90 percent of registered New Zealand beekeepers provided email addresses to AsureQuality. AsureQuality provided these email addresses to Manaaki Whenua – Landcare Research for conducting the 2019 NZ Colony Loss Survey.

Manaaki Whenua – Landcare Research sent personalised email invitations to participate in the survey to 8,533 registered New Zealand beekeepers on 4 September 2019.[30] In total, 84 emails bounced (probably due to invalid email addresses and/or spam filters). Non-respondents received up to four email reminders between 18 September 2019 and 31 October 2019.

Participation was encouraged by industry groups and prominent individual beekeepers. Presentations of results at Apiculture New Zealand conferences, interviews on television and radio news, articles in newspapers and *The New Zealand BeeKeeper Journal*, and the opportunity to win vouchers for morning tea provided by Manaaki Whenua – Landcare Research also raised participation levels. In addition, the directors of the largest beekeeping operations were contacted before the start of the survey, and all beekeepers with more than 250 colonies registered with AsureQuality received personal phone calls to encourage completion; phone calls began in late September for northern New Zealand and continued through mid-October for southern New Zealand, targeting beekeepers who had not completed the survey at the time of the call.

In total, 3,456 beekeepers completed the 2019 NZ Colony Loss Survey (including nine who completed the survey offline), indicating a response rate of 36.7 percent of all registered beekeepers and 40.9 percent of all registered beekeepers with valid email addresses. Among the beekeepers who completed the survey were 187 of the 540 beekeepers with more than 250 registered colonies and valid email addresses, indicating a response rate of 34.6 percent among this group of beekeepers. These response rates significantly higher those obtained for any European country[31].

The number of registered colonies in New Zealand increased by approximately 500 percent between 1945 and 2015. Between June 2015 and June 2016, registered colonies increased by a further 20.0 percent. Between June 2016 and June 2017, registered colonies increased by 17.7 percent. Between June 2017 and June 2018, registered colonies increased by 9.1 percent. And between June 2018 and June 2019, registered hives increased by 4.9 percent. Thus, there were 43,000 more colonies registered in June 2019 than in June 2018 for 879,178 registered colonies in total.

[30] Interestingly, while the number of beekeepers in New Zealand grew by just 3.2 percent between 1945 and 2016, the year-on-year increase in beekeeper numbers was 16.3 percent in 2017, 10.5 percent in 2018, and 9 percent in 2019.

[31] Brodschneider et al. 2017.

While beekeepers face penalties if they fail to accurately register their apiaries, there is less incentive to accurately report the number of colonies in each apiary. To assess the extent of over-reporting or under-reporting of colonies, we matched 3409 beekeepers who responded to the 2019 NZ Colony Loss Survey with their ApiWeb entries.[32] Using weighted averages to account for different operation sizes and assuming that hive numbers reported on the NZ Colony Loss Survey are correct, we estimate that actual registered hive numbers are 10.87 percent lower than the figures reported in ApiWeb.[33]

Beekeepers reported on 297,377 colonies in 2019 NZ Colony Loss Survey. Thus, we estimate the total share of registered hives included in the survey to be 36.2 percent. In comparison, the share of colonies included in US calculations is approximately 11.9 percent[34].

Table 1: Number of beekeepers responding to the NZ Colony Loss Survey, by region and operation size

Region	0-10 colonies	11-50 colonies	51-250 colonies	251-500 colonies	501-3000 colonies	3001+ colonies
Upper North Island	701	64	31	12	19	24
Middle North Island	538	98	55	18	37	
Lower North Island	517	73	38	13	14	
Upper South Island	179	33	15	8	14	
Middle South Island	386	41	18	7	11	
Lower South Island	238	28	14	8	14	
Total	**2,780**	**329**	**160**	**61**	**102**	**24**

Notes: To preserve anonymity, beekeepers with 3001+ colonies are not reported by region, and 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. Five respondent beekeepers who operate in the Chatham Islands are not included.

Consistent with international practice, all responses were confidential. Data access was limited to the survey director[35], and data were stored exclusively on password-protected computers.

2.4 Estimating colony losses and confidence intervals

Van der Zee et al. (2013) noted two alternative means of calculating loss rates. The ‘overall loss rate’ is calculated as the total winter losses by survey respondents divided by the total number of colonies that were alive on 1 June 2019. 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 that he or she had on 1 June 2019. Although the loss rates experienced by beekeepers with different-sized operations are not equally variable, the latter approach weights losses equally.

[32] The NZ Colony Loss Survey asked beekeepers how many colonies that they had on 1 June 2019; the Apiweb data was generated on 28 August 2019. As such, we don’t expect a perfect match in the number of colonies reported. However, we ignore the difference in dates for the purpose of estimating over- or under-reporting of colonies.

[33] There is a great deal of variation in both over- and under-reporting, with a weighted sample standard deviation of 0.331. We thus winsorized the data by removing 1 percent of the sample from each tail of the distribution in generating our estimates.

[34] Bee Informed Partnership 2019.

[35] Pike Stahlmann-Brown, Manaaki Whenua – Landcare Research.

In addition, the average loss rate is strongly influenced by operation size. For these reasons, van der Zee et al. (2013) advocated reporting overall loss rates rather than average loss rates. This approach has been adopted by COLOSS for reporting wintering losses in Europe[36] and by the Bee Informed Partnership for reporting wintering losses in the US[37].

Confidence intervals (interpreted as the true value falling within this range 95 percent 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[38]. However, the performance of one colony in an apiary often depends on the performance of other colonies in the same apiary. 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[39], which can affect standard errors and confidence intervals[40]. 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[41]. This approach is consistent with that undertaken in Europe[42] and the US[43].

3 Survey questionnaire

The main questions from the standardised international COLOSS survey were included to enable international comparison. Additional questions were added to reflect both the New Zealand context and feedback on the 2015, 2016, 2017, and 2018 NZ Colony Loss Surveys provided by scientists, beekeepers, and other end users. The survey was available online between 4 September and 10 November 2019.

The 2019 NZ Colony Loss Survey comprised four distinct parts. The first part of the survey obtained each respondent’s consent and ensured that he or she was well positioned to complete the survey.

The second, and main, part recorded the number of living colonies on 1 June 2019, the number of living colonies during the first spring round of 2019 (regardless of future viability), and the attributions of any losses in between those periods.

The third part of the survey focused on topics such as queen performance, varroa monitoring and treatment, floral resources, supplemental feeding, and overcrowding during the 2018/19 season.

The fourth part of the questionnaire included open-ended questions about challenges and opportunities in New Zealand beekeeping.

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.

[36] Brodschneider et al. 2016, 2018.

[37] Lee et al. 2015, Seitz et al. 2015.

[38] van der Zee et al. 2013.

[39] McCullagh & Nelder 1989.

[40] Brodschneider et al. 2016.

[41] McCullagh & Nelder 1989; VanEngelsdorp et al. 2012; van der Zee et al. 2013.

[42] Brodschneider et al. 2016, 2018.

[43] Lee et al. 2015; Seitz et al. 2015.

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 corresponding to their AsureQuality apiary registry locations; these political regions were then aggregated and categorised into six regions: Upper North Island, Middle North Island, Lower North Island, Upper South Island, Middle South Island, and Lower South Island (Fig. 1).

Most information is also reported by the total number of colonies comprising each beekeeping operation as of 1 June 2019. In all figures, operation size is categorised into six size categories: 0-10 colonies; 11-50 colonies; 51-250 colonies; 251-500 colonies; 501-3000 colonies; and operators with more than 3000 colonies. This approach represents a departure from that taken in previous years to be more consistent with AsureQuality's categorisation. Beekeepers whose colony numbers changed between the 2018/19 season and 1 June 2019 are classified by the latter date.[44]

Because 6.4 percent of New Zealand beekeepers operated 85.5 percent of production colonies as of 1 June 2019, figures reported by aggregated region restrict the sample to beekeepers with more than 250 colonies (unless noted).[45] Figures reported by operation size include all respondents.

In previous years, we reported losses due to specific problems (e.g. queen problems, wasps, etc.) as a share of losses among those who reported any losses. While this approach made our figures easier to read (effectively, by lengthening the Y-axis), it also required the reader to perform some calculations to estimate total losses attributable to each problem. Hence, from this year, we report total estimated losses attributable to each problem in table form.

4.1 National-level estimates of colony losses during winter 2019

As in the 2018 NZ Colony Loss Report, 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 2019 was 10.46 percent, with a 95 percent confidence interval of [10.10%, 10.82%].

Table 2 reports the overall loss rates and 95 percent confidence intervals for winter 2015–2019. 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 dataset. 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 95 percent level).

The overall loss rate for winter 2019 is statistically indistinguishable from the overall loss rate for winter 2018. However, overall loss rates for winter 2019 are 7.8 percent, 9.3 percent, and 25 percent higher than overall loss rates for winter 2017, 2016, and 2015 respectively, statistically significant at the 0.05 level or higher.[46]

[44] 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.

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

[46] 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.

Table 2: Overall loss rates by year (winter)

Winter	Overall loss rate	95% confidence interval	Colonies reporting[47]
2019	10.46%	[10.10%, 10.82%]	297,377
2018	10.21%	[9.85%, 10.58%]	365,988
2017	9.70%	[9.37%, 10.05%]	238,263
2016	9.57%	[9.10%, 10.05%]	275,209
2015	8.37%	[7.66%, 9.15%]	225,660

Overall loss rates over winter 2019 were also calculated by region (as described in Figure 1, which shows the number of colonies recorded in each region by reporting beekeepers as of 1 June 2019). Estimates for loss rates over winter 2019 demonstrates considerable variation by region (Fig. 2). Overall loss rates were estimated to be:

- 10.68 percent (with a 95 percent confidence interval of [9.85%, 11.56%]) for the Upper North Island
- 12.08 percent [11.42%, 12.77%] for the Middle North Island
- 7.99 percent [7.43%, 8.58%] for the Lower North Island
- 8.01 percent [6.93%, 9.24%] for the Upper South Island
- 10.64 percent [9.40%, 12.02%] for the Middle South Island
- 11.87 percent [10.82%, 13.00%] for the Lower South Island.

[47] The number showing in the 'colonies reporting' column for 2019 differs slightly from the overall number of colonies reported above. Here, we account for any colonies that were either acquired or sold/given away over winter, and we remove any colonies for which loss information was not provided.

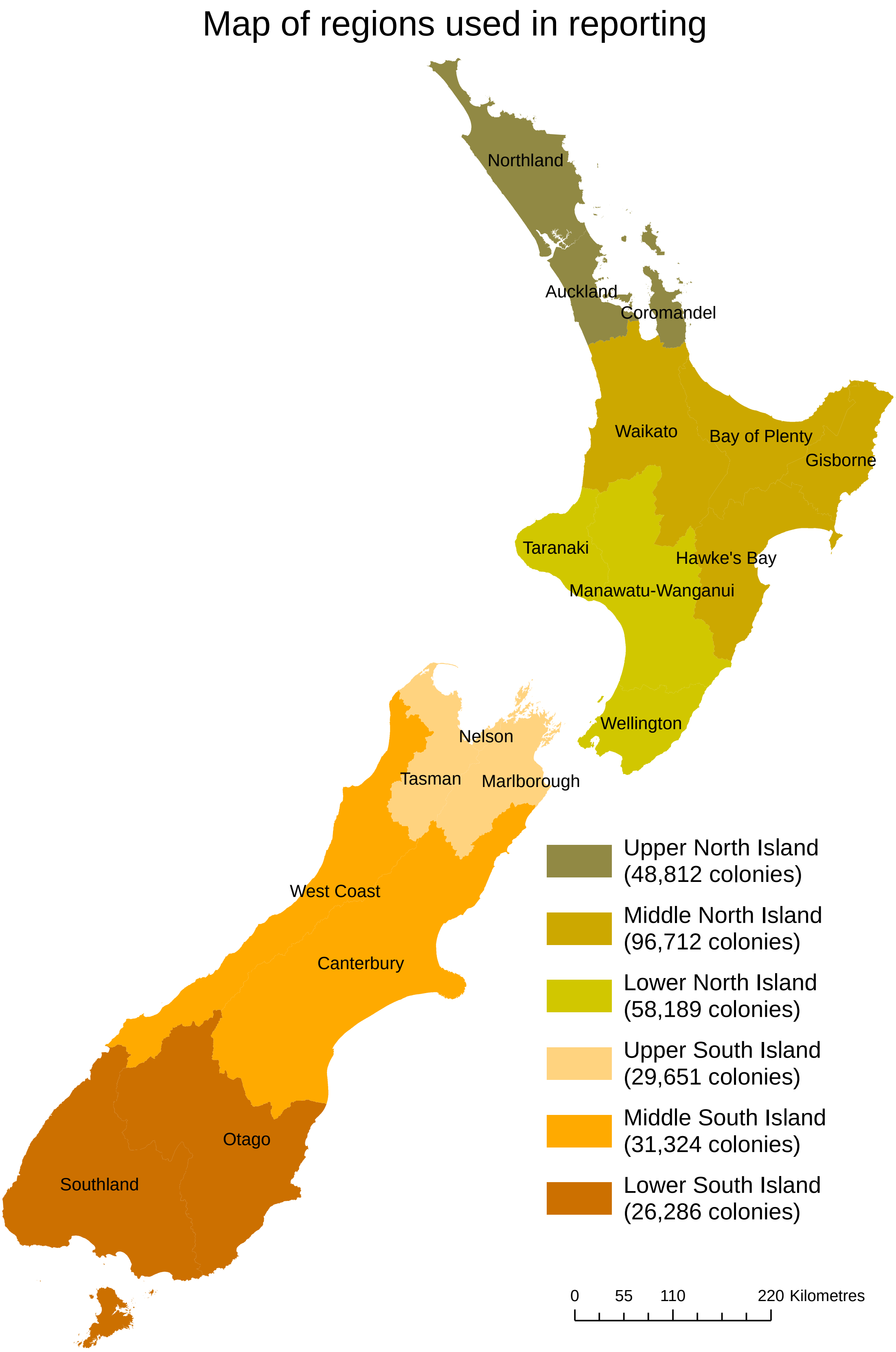

Figure 1: Reference map for reporting by region. Legend shows the number of colonies in each region. Includes all respondents in all operation size categories.

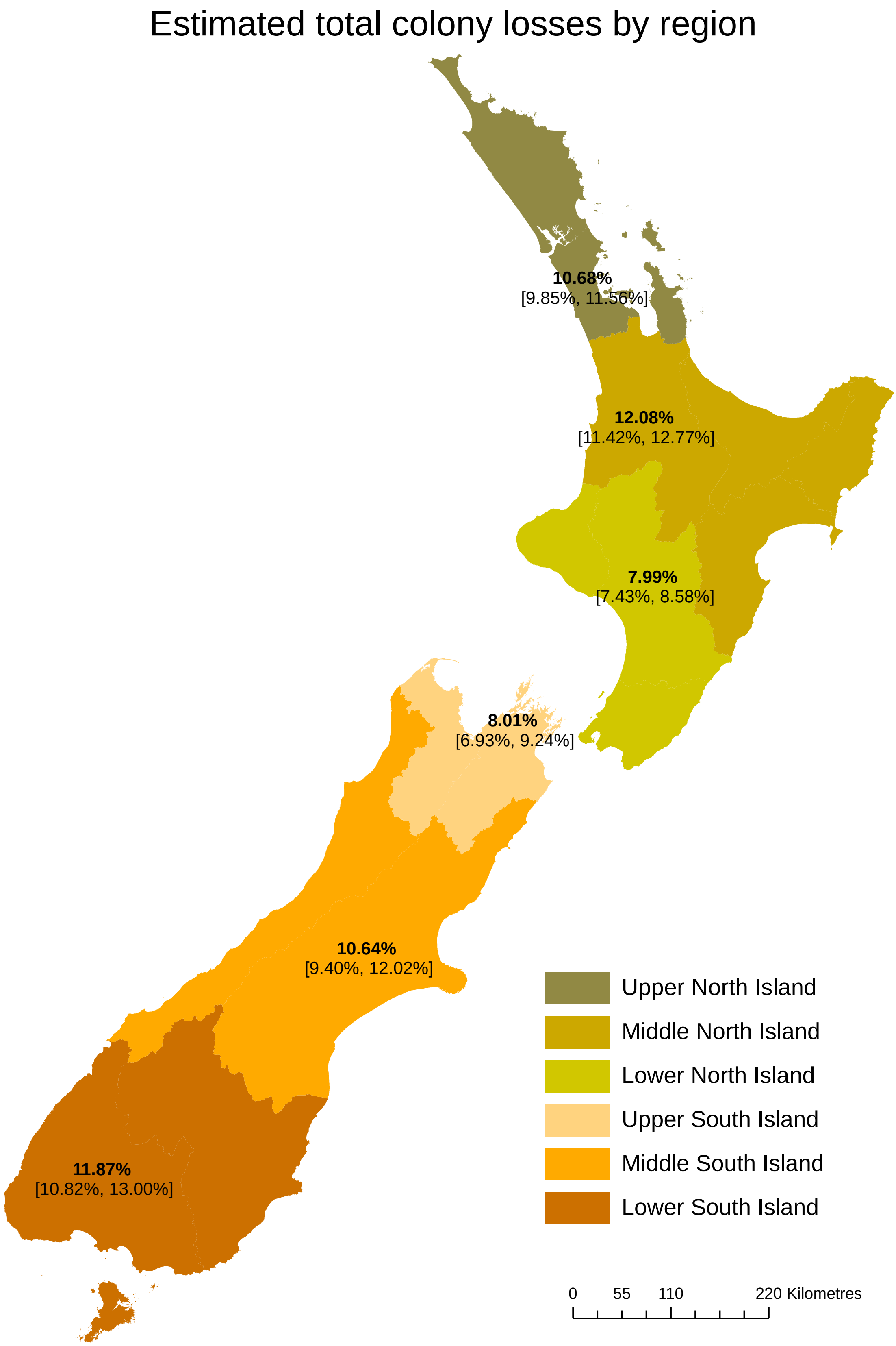

Figure 2: Estimated total colony losses by region. Includes all respondents in all operation size categories.

The share of overall loss rates for winter 2019 attributed to specific causes of colony loss is shown in Figure 3.

Some 30.3 percent of total losses over winter 2019 were attributed to queen problems (compared with 38.5 percent in winter 2018), 28.1 percent to suspected varroa and related complications (23.1 percent), 10.3 percent to suspected starvation (9.3 percent), and 9.6 percent to wasps (9.2 percent). Robbing by other bees accounted for 4.5 percent (3.5 percent) while suspected disease accounted for 4.0 percent (4.9 percent) of overall losses. AFB was cited as the cause of 1.1 percent (1.3 percent) of total colony losses and 1.1 percent (1.6 percent) of total colony losses were attributed to suspected exposure to toxins. Natural disasters accounted for an additional 0.8 percent (1.4 percent) of overall losses, followed by accidents at 0.5 percent (0.7 percent). Losses to theft or vandalism accounted for 0.5 percent (0.5 percent) of total colony losses and Argentine ants were responsible for 0.2 percent (0.2 percent). Beekeepers report being unsure about the cause of 3.9 percent (3.9 percent) of losses.

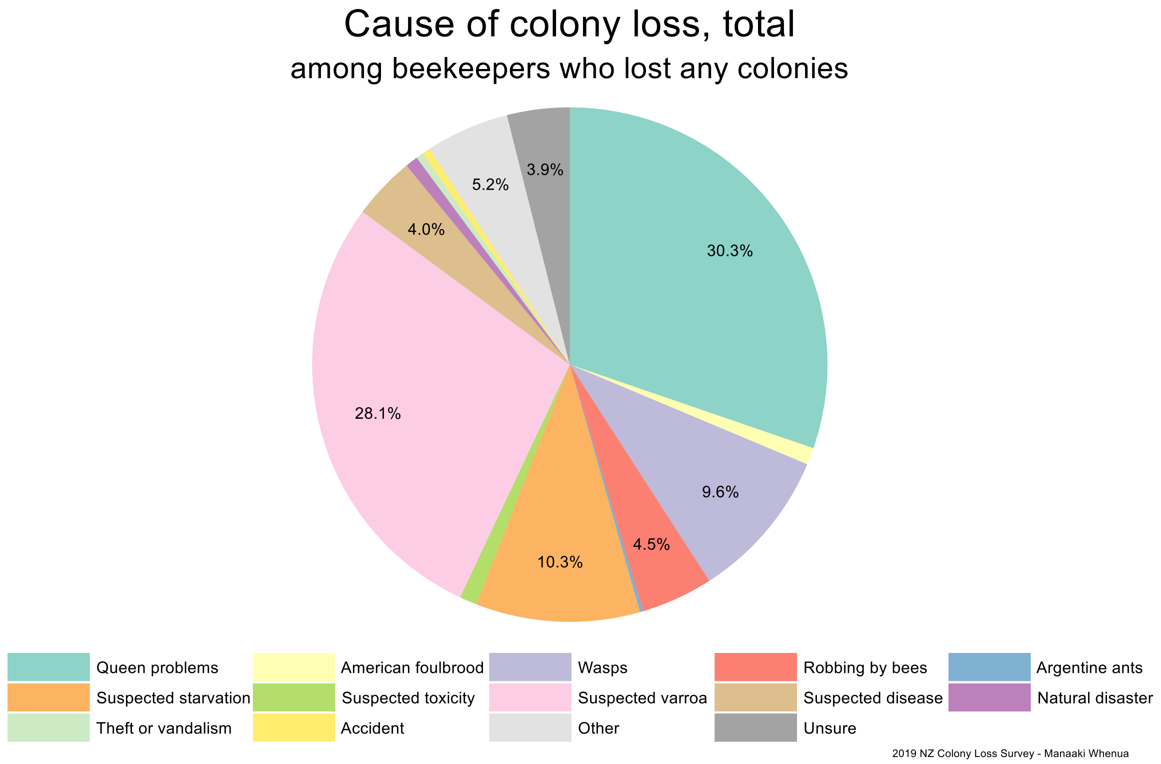

Figure 3: Share of total colony losses over winter 2019 attributed to various causes, based on reports from respondents who lost any colonies, by region.

Overall loss rates by region for winter 2016, 2017, 2018, and 2019 are reported in Table 3 (regions were defined slightly differently in our 2015 reporting and hence are not available for comparison; see Section 2.1 above).[48]

The overall loss rate in winter 2019 in the Upper North Island was estimated to be 32.3 percent higher and 16.7 percent lower than winter loss rates in 2016 and 2018 respectively. The difference in loss rates between winter 2019 and winter 2017 were statistically indistinguishable.

In the Middle North Island, the winter 2019 loss rate was 13.4 percent, 16.5 percent, and 21.8 percent higher than winters 2016, 2017, and 2018 respectively.

[48] 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 2, which reflects colonies as at 1 June 2019.

In the Lower North Island, the loss rate for winter 2019 was 32.4 percent lower than winter 2016 and 12.3 percent lower than 2017, with no statistical difference from winter losses in 2018.

In the Upper South Island, the winter 2019 loss rate was 45.9 percent and 52.0 percent higher than loss rates in winters 2016 and 2017 respectively, while being 19.8 percent lower than winter loss rates in 2018.

In the Middle South Island, the overall loss rate for winter 2019 was 38.7 percent higher than the loss rate in winter 2016 and had no statistical difference from loss rates in winters 2017 and 2018.

In the Lower South Island, the winter 2019 loss rate was 61.3 percent and 21.2 percent higher than winter loss rates in 2016 and 2017 respectively, with no statistical difference from winter 2018.

Hence, regional loss rates tell a different story from national loss rates: we see no statistical difference between winter 2018 and winter 2019 at the national level, but we observe statistically lower loss rates for the Upper North Island and Upper South Island and statistically higher loss rate for the Middle North Island over the same period.

Table 3: Overall loss rates by year by region (winter)

Region	Winter	Overall loss rate	95% confidence interval	Reported colonies
Upper North Island	2019	10.68%	[9.85%, 11.56%]	49.593
	2018	12.82%	[12.00%, 13.68%]	61,401
	2017	9.71%	[9.05%, 10.42%]	54,297
	2016	8.07%	[7.20%, 9.03%]	45,435
Middle North Island	2019	12.08%	[11.42%, 12.77%]	101,202
	2018	9.92%	[9.17%, 10.73%]	110,561
	2017	10.37%	[9.70%, 11.08%]	83,922
	2016	10.65%	[9.77%, 11.59%]	96,472
Lower North Island	2019	7.99%	[7.43%, 8.58%]	58,509
	2018	8.06%	[7.45%, 8.71%]	84,239
	2017	9.11%	[8.30%, 9.98%]	50,584
	2016	11.82%	[10.45%, 13.34%]	62,218
Upper South Island	2019	8.01%	[6.93%, 9.24%]	29,982
	2018	9.99%	[9.05%, 11.02%]	39,782
	2017	5.27%	[4.48%, 6.18%]	12,741
	2016	5.49%	[4.55%, 6.62%]	15,382
Middle South Island	2019	10.64%	[9.40%, 12.02%]	31,573
	2018	11.36%	[10.40%, 12.40%]	43,526
	2017	11.28%	[10.20%, 12.46%]	18,636
	2016	7.67%	[6.81%, 8.63%]	30,820
Lower South Island	2019	11.87%	[10.82%, 13.00%]	26,411
	2018	10.58%	[9.14%, 12.23%]	26,390
	2017	9.79%	[8.80%, 10.88%]	18,083
	2016	7.36%	[6.49%, 8.32%]	24,882

Because regions show such variation, much of the analysis below focuses on performance across regions. The other primary unit of analysis is operation size.

4.2 Respondents by region and operation size

Figure 4 shows the region(s) in which the beekeepers who completed the survey overwintered their colonies in 2019.[49] Because beekeeping operations may span multiple regions, some beekeepers were included in more than one region. The distribution of beekeepers in our sample closely resembled the distribution of apiary register locations recorded by AsureQuality as of November 2019, presented in Figure 4.

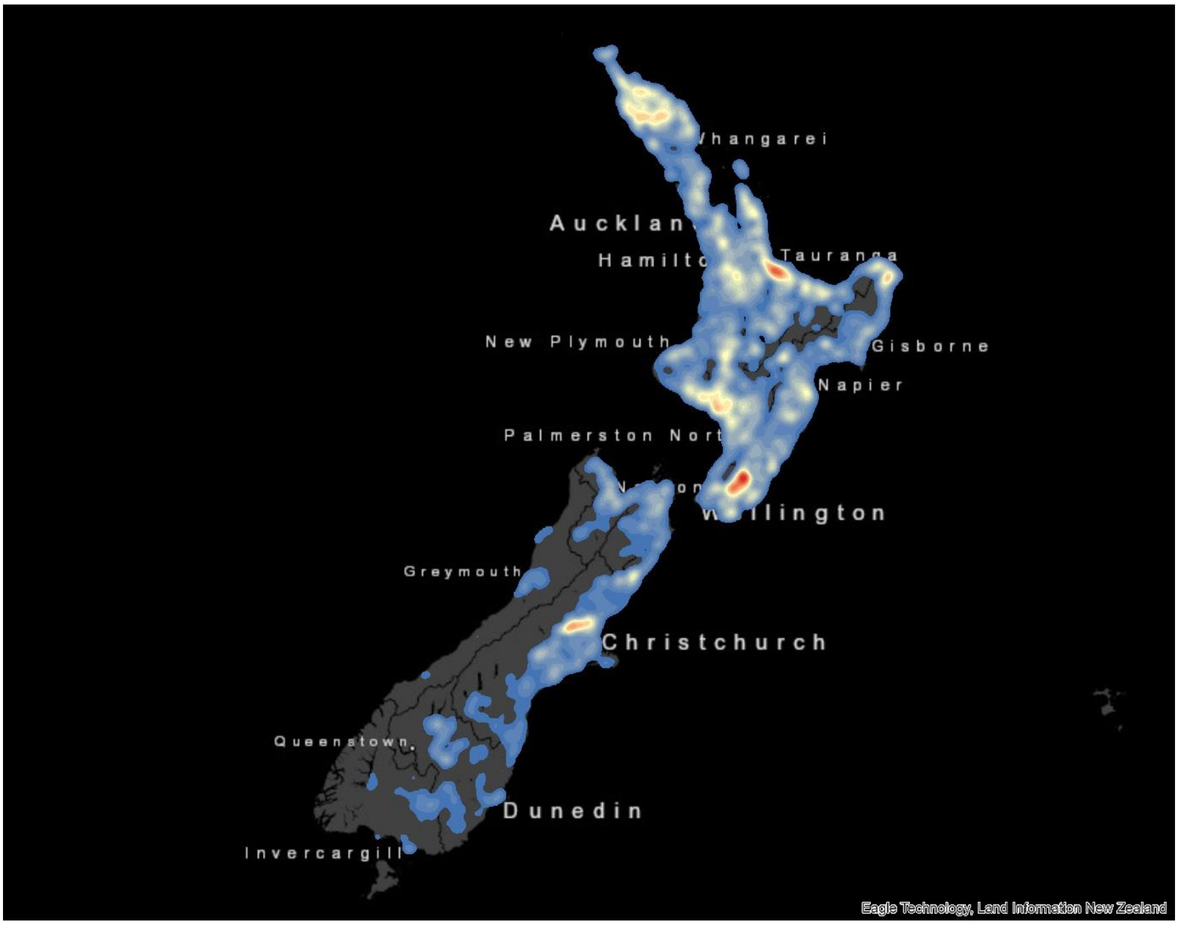

Figure 4: Heat map of apiary register locations reported by AsureQuality as of November 2019.

In line with previous years, more beekeepers report operating in the Upper North Island than any other region (Fig. 5). The Middle South Island has the largest number of respondents in the South Island. Figure 6 shows the operation size reported by each respondent, as at 1 June 2019.

Operations with 0-10 colonies comprised 79.0 percent of the sample; operations with 11-50 colonies comprised 10.2 percent; operations with 51-250 colonies comprised 5 percent; operations with 251-500 colonies comprised 1.9 percent; operations with 501-3000 colonies comprised 3.2 percent; and operations with more than 3000 colonies comprised 0.7 percent.

[49] Beekeepers who exited the industry during the 2018/19 season (and thus neither had any registered colonies on 1 June 2019 nor acquired any new colonies during winter 2018) were naturally omitted from all over-winter colony loss calculations.

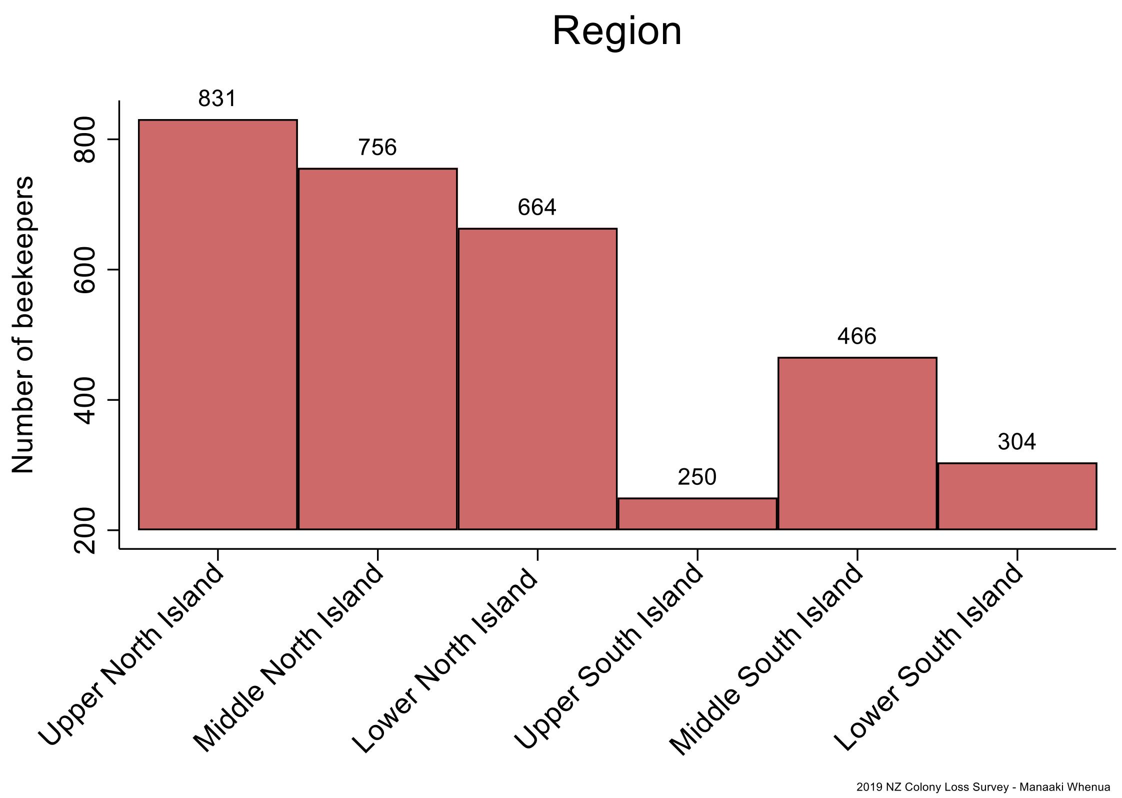

Figure 5: Number of respondents who operate in each region. Includes all respondents in all size categories.

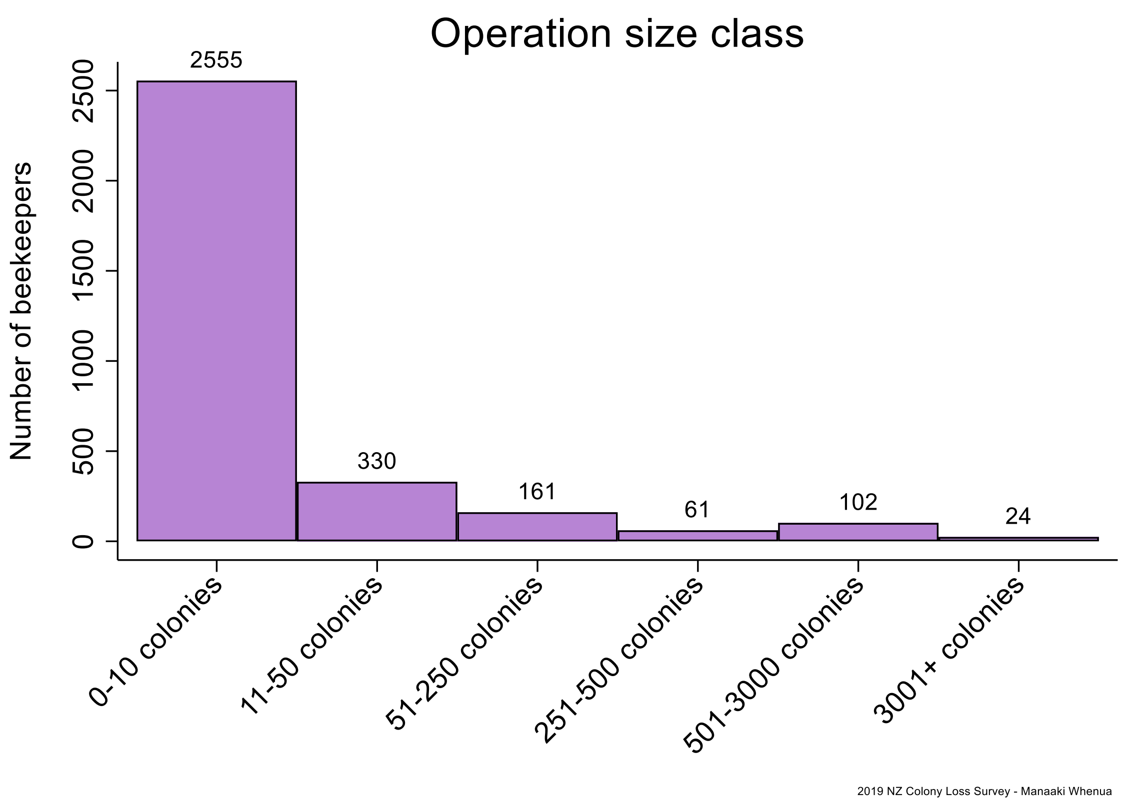

Figure 6: Operation size of respondents grouped into five size categories.

4.3 Average loss rates over winter 2019

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) within each region, Figure 7 reports the average loss rates for beekeepers within each region.

For 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 percent of his or her colonies and that the larger beekeeper lost 12 percent of his or her colonies. The overall loss rate for the region would be 11.64 percent, but the average loss rate would be 10 percent.

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 colonies. 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 as, for example, wasps are especially 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 Middle North Island with those of a small non-commercial beekeeper in the Upper South Island. 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 2019 was 9.3 percent (Fig. 7), compared with 10 percent in 2018. The average shares of colonies lost among beekeepers with more than 250 colonies in the North Island and South Island were 9.3 percent and 9.5 percent, respectively, with the highest average losses in the Upper North Island and Middle North Island at 12.4 percent and 11.4 percent, respectively. These two regions also had the highest average losses in 2018, at 11.4 percent for the Upper North Island and 11.5 percent for the Middle North Island.

Among beekeepers with more than 250 colonies, every region except for the Lower North Island had at least one beekeeper who lost 25 percent or more of his or her colonies in that region over winter 2019.

The highest share of colonies lost in the Lower North Island was 16.1 percent. In 2018, the average shares of colonies lost among beekeepers with more than 250 colonies in the North Island and South Island were 10 percent and 9.7 percent, respectively.[50]

Figure 8 shows the distribution of colony losses by operation size, including those with fewer than 251 colonies.

Operations with 0-10 colonies lost the highest share of colonies, on average, at 25.1 percent (compared with 35.6 percent in 2018), although the distribution was bimodal and 58.5 percent (compared to 48.7 percent in 2018) of operations with 0-10 colonies reported having no losses.

Operations with 11-50 colonies lost 18.8 percent (18.4 percent) of their colonies, on average, with 22.7 percent (25.4 percent) reporting no losses.

Operations with 51-250 colonies lost 14.6 percent (14.5 percent), on average, while operations with 251-500 colonies lost 8.3 percent (11 percent), on average.

Operations with 501-3000 colonies had average losses of 10 percent (9.4 percent) and operations with over 3000 colonies lost 9.5 percent (9.2 percent), on average.

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[50] Among beekeepers with more than 250 colonies, 8.5 percent in the Upper North Island reported not losing any colonies during winter 2019 (compared with 10.9 percent during winter 2018); 1.5 percent in the Middle North Island (compared to 3.2 percent); and 11.1 percent in the Lower North Island (compared to 7.1 percent). No losses were reported in the Upper South Island, Middle South Island and Lower South Island (compared to 4.2 percent, 3.9 percent and 4.5 percent, respectively, during winter 2018).

Some 98 percent of those with between 501 and 3000 colonies, and 100 percent of those with more than 3000 colonies, reported colony losses over winter 2019.

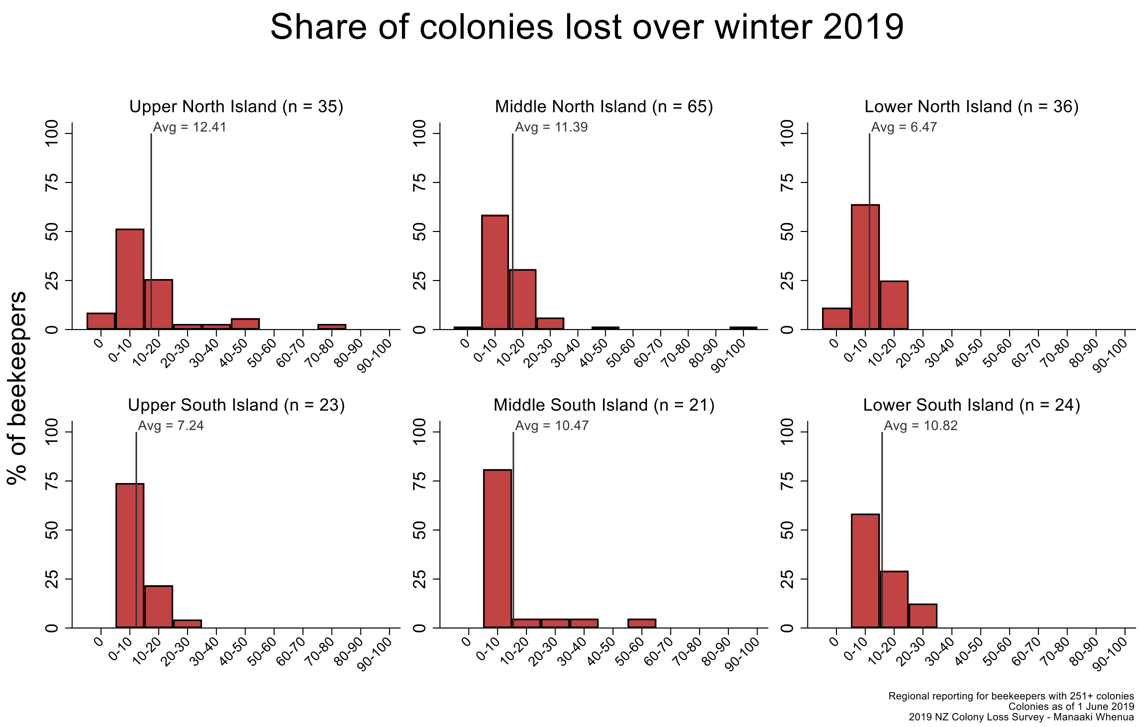

Figure 7: Winter 2019 colony losses as a share of total winter colonies, based on reports from respondents with more than 250 colonies at 1 June 2019, by region.

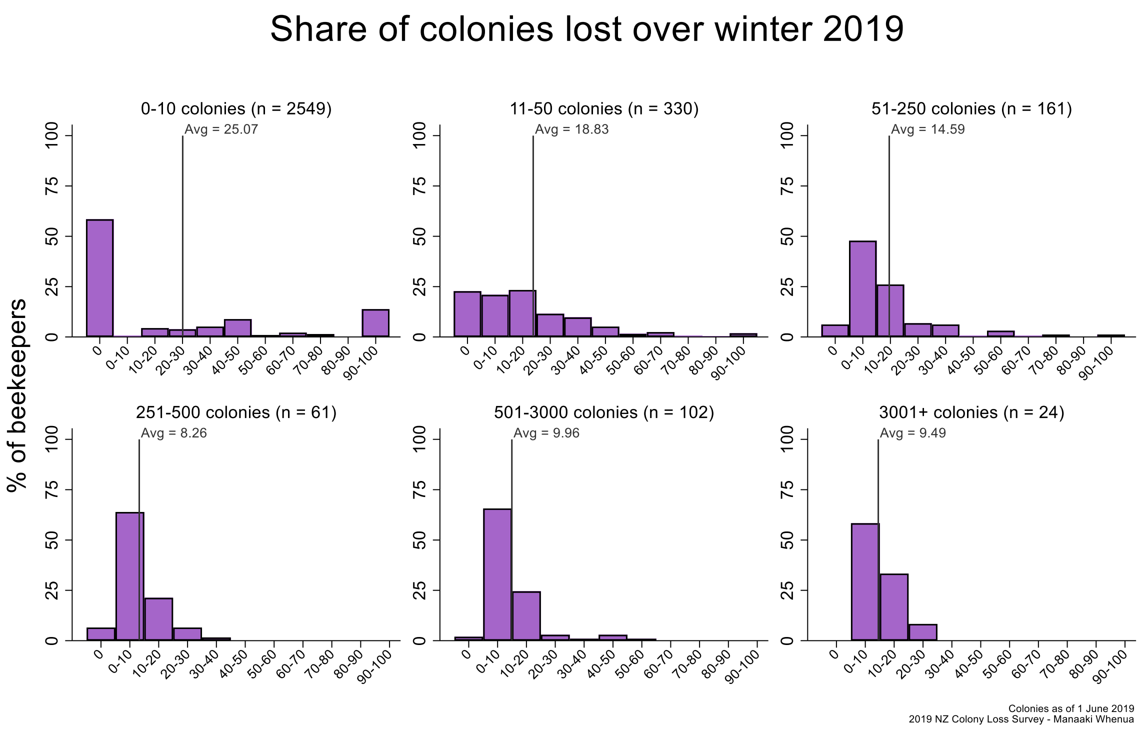

Figure 8: Winter 2019 colony losses as a share of total winter colonies for all respondents, by operation size.

4.4 Colony losses by categories of loss

Among beekeepers with more than 250 colonies, 96.8 percent reported experiencing colony losses over winter 2019.

Figures 9 and 10 report the average share of colonies lost by category, by region for beekeepers with more than 250 colonies and by operation size, *among beekeepers who experienced any losses*. For example, among beekeepers with 0-10 colonies, 21.1 percent of losses were attributed to queen problems, on average, as were 25.9 percent of losses among beekeepers with 11-50 colonies.

On average, queen problems accounted for 40.1 percent of colony losses over winter 2019 among beekeepers with more than 250 colonies[51] (compared with 40.3 percent in 2018); this figure ranged from 36.6 percent in the Lower North Island to 46.5 percent in the Upper South Island.

In addition, 23.2 percent of losses among beekeepers with more than 250 colonies were attributed to suspected varroa and related complications, on average (compared with 22.6 percent in 2018), as were 13.1 percent (10.1 percent) to suspected starvation, and 7.0 percent (8.5 percent) to wasps.

The average share of losses attributed to suspected varroa and related complications among beekeepers with more than 250 colonies was much higher for the Middle South Island than all other regions at 39.7 percent of winter 2019 losses. The next highest average share appeared in the Middle North Island at 23.6 percent. Robbing by bees accounted for 3.6 percent (4.1 percent) of losses among beekeepers with more than 250 colonies, on average, and suspected nosema and other diseases accounted for 3.1 percent (3.6 percent) of losses among beekeepers with more than 250 colonies, on average. On average, losses attributed to suspected toxic exposure among beekeepers with more than 250 colonies decreased from 1.9 percent of losses over winter 2018 to 0.6 percent of losses over winter 2019.

On average, winter 2019 losses attributed to AFB comprised 1.2 percent (1.2 percent) of losses among beekeepers with more than 250 colonies. Average losses attributed to theft and vandalism increased from 0.4 percent of losses over winter 2018 to 0.9 percent of losses over winter 2019.

Losses attributed to accidents (typically livestock knocking over hives) were uncommon (0.4 percent of winter 2019 losses among beekeepers with more than 250 colonies, on average), and those attributed to Argentine ants were rare (0.5 percent of winter 2019 losses among beekeepers with more than 250 colonies, on average).

As operation size increases, the average share of losses attributed to queen problems also increases. Beekeepers with over 3000 colonies are an exception to this; an average of 34 percent of winter 2019 losses were attributed to queen problems for beekeepers with over 3000 colonies, lower than beekeepers with 51-250 colonies who attributed 37.3 percent of winter 2019 losses to queen problems, on average.

Alternatively, as operation size increases, the average share of losses to both wasps and robbing by other bees decreases. Beekeepers with over 3000 colonies are again an exception; losses attributed to wasps and robbing by other bees comprised 8.6 percent and 3.9 percent of winter 2019 losses on average, respectively, higher than the average shares reported for beekeepers with 251-500 colonies at 7.2 percent and 3.8 percent of winter 2019 losses, for wasps and robbing by other bees respectively.

[51] Some beekeepers operated in multiple regions and thus appear in figures that report results by region multiple times. Our calculation for the share of losses attributed to queen problems (40.1 percent) differs from the figure that is directly calculatable from the figure (39.5 percent) because we count each beekeeper just once. In any case, we note any differences in the two calculations that are not negligble.

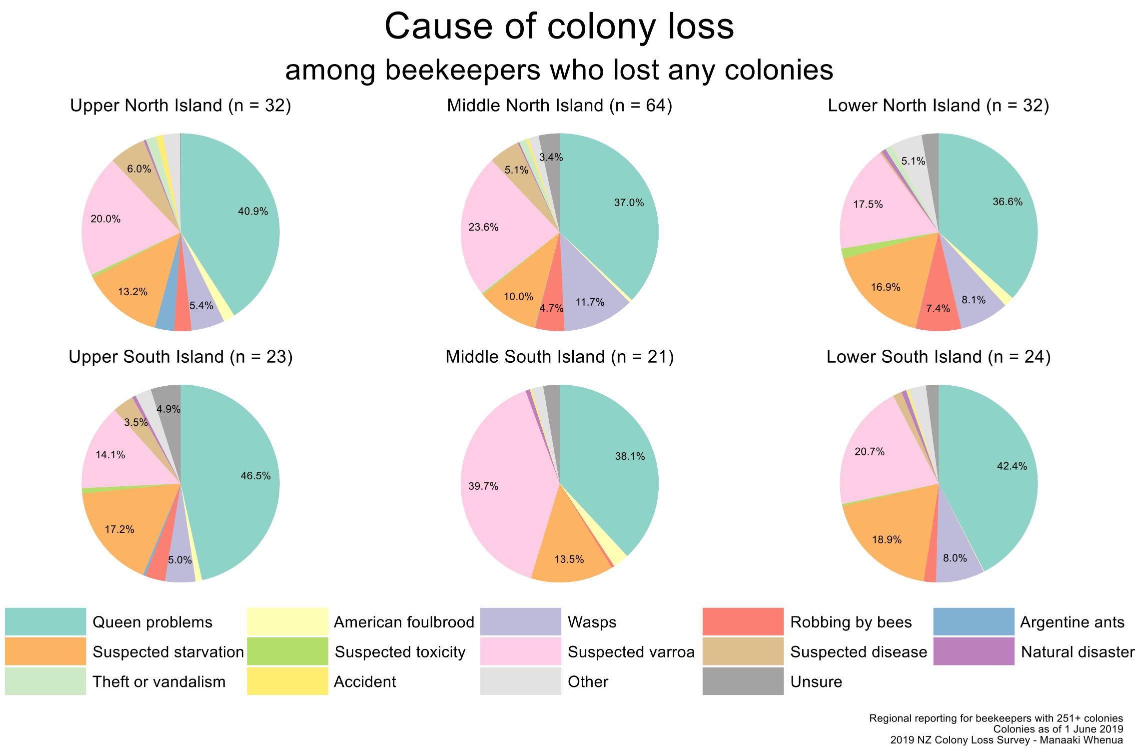

Figure 9: Share of colony losses attributed to various causes based on reports from respondents with more than 250 colonies who lost any colonies, by region.

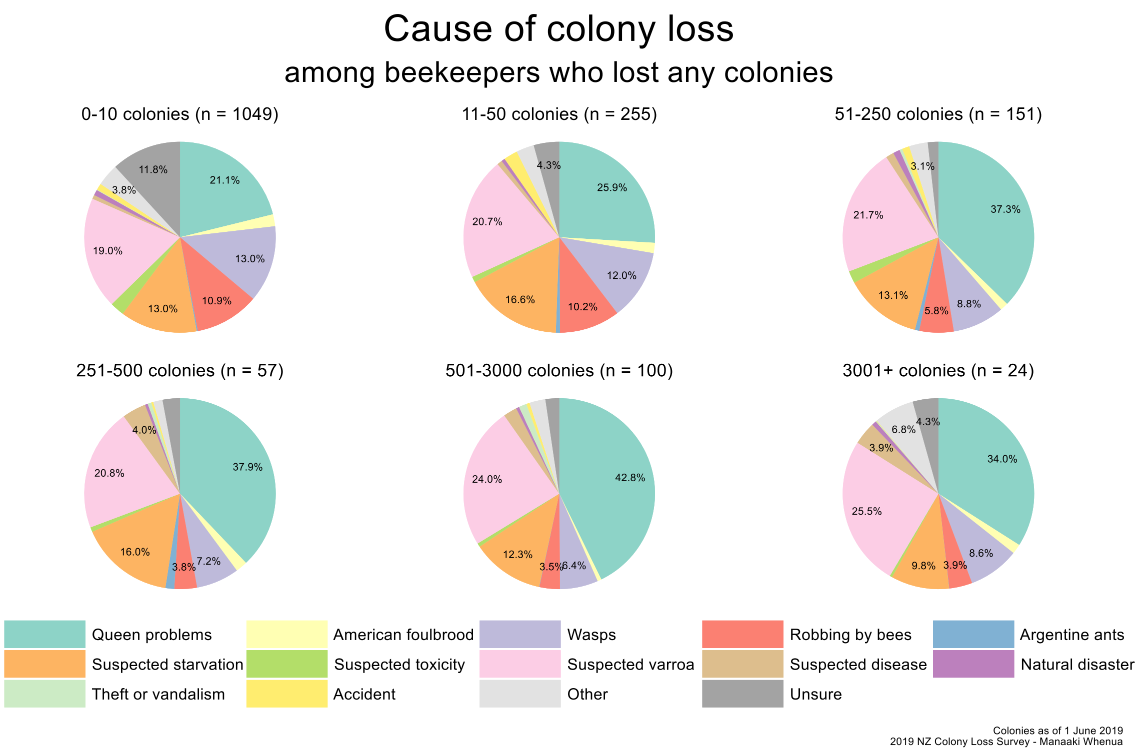

Figure 10: Share of colony losses attributed to various causes, based on reports from respondents who lost any colonies, by operation size.

Tables 4 and 5 present the estimated share of colonies lost due to each given reason by region and operation size, respectively. For example, 0.14 percent of all existing colonies in the Upper North Island were estimated to be lost to AFB over winter 2019, and 0.14 percent of all existing colonies in the Upper North Island were estimated to be lost to wasps over winter 2019. Bracketed values indicate 95 percent confidence intervals. Note that for the regional values in Table 4, calculations included all beekeepers, not just those with more than 250 colonies.

Table 4: Estimated share of all colonies lost to specific causes, based on reports from all respondents, by region

	Upper North Island	Middle North Island	Lower North Island	Upper South Island	Middle South Island	Lower South Island
Queen problems	3.16% [2.87%, 3.47%]	3.16% [2.91%, 3.43%]	2.53% [2.28%, 2.80%]	3.85% [3.34%, 4.44%]	2.48% [2.23%, 2.75%]	4.66% [4.13%, 5.25%]
AFB	0.14% [0.09%, 0.23%]	0.09% [0.05%, 0.18%]	0.08% [0.04%, 0.17%]	0.12% [0.02%, 0.68%]	0.26% [0.12%, 0.56%]	0.01% [0.00%, 0.01%]
Wasps	0.73% [0.51%, 1.05%]	1.59% [1.33%, 1.89%]	1.01% [0.83%, 1.23%]	0.58% [0.27%, 1.24%]	0.10% [0.01%, 0.76%]	0.77% [0.57%, 1.03%]
Robbing	0.51% [0.32%, 0.82%]	0.57% [0.39%, 0.84%]	0.59% [0.44%, 0.81%]	0.30% [0.16%, 0.56%]	0.22% [0.09%, 0.52%]	0.25% [0.13%, 0.45%]
Argentine ants	0.04% [0.02%, 0.09%]	0.02% [0.01%, 0.03%]	0.02% [0.00%, 0.09%]	0.04% [0.01%, 0.31%]	0% [-, -]	0% [-, -]
Suspected starvation	0.86% [0.67%, 1.11%]	1.32% [1.16%, 1.50%]	0.70% [0.54%, 0.91%]	0.82% [0.54%, 1.24%]	0.82% [0.61%, 1.10%]	1.99% [1.56%, 2.52%]
Suspected toxicity	0.14% [0.05%, 0.42%]	0.14% [0.05%, 0.38%]	0.09% [0.04%, 0.20%]	0.16% [0.01%, 1.94%]	0.03% [0.00%, 1.17%]	0.08% [0.01%, 0.56%]
Suspected varroa	3.63% [3.18%, 4.15%]	3.34% [3.02%, 3.69%]	1.15% [0.91%, 1.45%]	1.42% [1.10%, 1.83%]	6.16% [5.01%, 7.55%]	1.97% [1.35%, 2.85%]
Suspected disease	0.40% [0.32%, 0.49%]	0.78% [0.61%, 1.00%]	0.06% [0.02%, 0.14%]	0.29% [0.17%, 0.49%]	0.03% [0.01%, 0.12%]	0.43% [0.33%, 0.57%]
Natural disaster	0.13% [0.09%, 0.17%]	0.05% [0.03%, 0.11%]	0.13% [0.08%, 0.22%]	0.08% [0.02%, 0.29%]	0.05% [0.01%, 0.31%]	0.04% [0.03%, 0.06%]
Theft/vandalism	0.09% [0.06%, 0.13%]	0.08% [0.03%, 0.19%]	0.03% [0.01%, 0.06%]	0% [-, -]	0.01% [0.00%, 4.48%]	0.00% [0.00%, 0.01%]
Accidents	0.07% [0.04%, 0.15%]	0.08% [0.03%, 0.19%]	0.04% [0.01%, 0.13%]	0.01% [0.00%, 0.76%]	0.02% [0.00%, 0.12%]	0.02% [0.00%, 0.13%]

Table 5: Estimated share of all colonies lost to specific causes based on reports from all respondents, by operation size

	0-10 colonies	11-50 colonies	51-250 colonies	251-500 colonies	501-3000 colonies	+3001 colonies
Queen problems	4.22% [3.73%, 4.76%]	3.73% [3.11%, 4.48%]	3.84% [3.02%, 4.87%]	2.43% [1.95%, 3.03%]	3.17% [2.64%, 3.82%]	3.08% [2.12%, 4.45%]
AFB	0.40% [0.25%, 0.63%]	0.32% [0.15%, 0.66%]	0.22% [0.05%, 1.02%]	0.18% [0.10%, 0.33%]	0.06% [0.03%, 0.14%]	0.09% [0.04%, 0.23%]
Wasps	3.28% [2.80%, 3.85%]	3.05% [2.18%, 4.25%]	1.49% [0.96%, 2.29%]	0.60% [0.35%, 1.03%]	0.94% [0.62%, 1.42%]	0.77% [0.40%, 1.49%]
Robbing	2.74% [2.31%, 3.24%]	1.88% [1.35%, 2.63%]	0.70% [0.43%, 1.12%]	0.25% [0.15%, 0.41%]	0.42% [0.15%, 1.16%]	0.29% [0.12%, 0.65%]
Argentine ants	0.03% [0.00%, 0.21%]	0.07% [0.02%, 0.22%]	0.06% [0.01%, 0.28%]	0.07% [0.01%, 0.39%]	0.01% [0.00%, 0.06%]	0.01% [0.00%, 0.04%]
Suspected starvation	2.52% [2.14%, 2.96%]	2.32% [1.77%, 3.03%]	1.36% [0.96%, 1.93%]	1.42% [0.91%, 2.20%]	1.05% [0.69%, 1.60%]	0.82% [0.44%, 1.50%]
Suspected toxicity	0.79% [0.57%, 1.08%]	0.40% [0.17%, 0.95%]	0.82% [0.29%, 2.31%]	0.07% [0.02%, 0.24%]	0.04% [0.02%, 0.10%]	0.02% [0.00%, 0.19%]
Suspected varroa	4.56% [4.01%, 5.19%]	4.24% [3.19%, 5.63%]	3.58% [2.61%, 4.88%]	2.31% [1.28%, 4.12%]	3.22% [1.96%, 5.25%]	2.52% [1.50%, 4.19%]
Suspected disease	0.18% [0.11%, 0.32%]	0.10% [0.04%, 0.27%]	0.26% [0.12%, 0.57%]	0.60% [0.21%, 1.64%]	0.22% [0.12%, 0.42%]	0.61% [0.14%, 2.67%]
Natural disaster	0.23% [0.13%, 0.41%]	0.13% [0.03%, 0.63%]	0.10% [0.03%, 0.31%]	0.06% [0.01%, 0.33%]	0.05% [0.02%, 0.10%]	0.10% [0.04%, 0.29%]
Theft/vandalism	0.03% [0.01%, 0.10%]	0% [-, -]	0.09% [0.01%, 0.55%]	0.10% [0.02%, 0.52%]	0.09% [0.02%, 0.42%]	0.01% [0.00%, 0.03%]
Accidents	0.18% [0.09%, 0.37%]	0.44% [0.24%, 0.80%]	0.08% [0.03%, 0.21%]	0.01% [0.00%, 0.08%]	0.07% [0.03%, 0.22%]	0.00% [0.00%, 0.02%]

4.4.1 Queen problems

We recognise that queen problems are difficult to diagnose and that many other bee health problems may present as queen problems[52]. Nevertheless, many beekeepers attribute losses to perceived queen problems, and we record those attributions here.

Due to colonies functioning as 'superorganisms', any disruption in the replenishment of each cohort, can cause a colony to fail[53]. Thus a well-mated, healthy queen is integral to drive the reproduction and growth of the colony, but she needs nurse bees to feed her, and nurse bees need foragers to bring pollen and nectar to make royal jelly. She, of course, needs healthy drones for mating to produce worker bees. Without a healthy queen, the hive will fail.

Perceived queen problems were a major contributor to colony losses across all regions and all operation sizes.[54] Queen problems accounted for more losses than any other reason in the Lower North Island, Upper South Island, and Lower South Island, with loss rates of 2.5 percent (compared with a loss rate of 4.6 percent over winter 2018), 3.9 percent (3.1 percent), and 4.7 percent (3.6 percent), respectively (Table 4).

For the remaining regions, queen problems were the second highest loss reason, with loss rates of 3.2 percent (4.6 percent), 3.2 percent (2.9 percent), and 2.5 percent (4.4 percent) for the Upper North Island, Middle North Island, and Middle South Island, respectively.

Queen problems accounted for the most losses over winter 2019 for beekeepers with 51-250 colonies, 251-500 colonies, and +3001 colonies with respective loss rates of 3.8 percent (3.4 percent), 2.4 percent (2.9 percent), and 3.1 percent (3.8 percent).

For the remaining operation sizes, queen problems were the second highest loss reason, with loss rates of 4.2 percent (3.9 percent), 3.7 percent (3.5 percent), and 3.2 percent (3.7 percent) for operation sizes of 0–10 colonies, 11–50 colonies, and 501–3000 colonies, respectively.

Internationally, perceived queen problems top the list as a major contributor in colony loss surveys[55]. Given the large proportion of overall losses attributed to queen problems in previous NZ Colony Loss Surveys, the 2019 NZ Colony Loss Survey included questions regarding the nature of those losses. Specifically, beekeepers were asked to specify whether queen problems lay with queens disappearing, drone-laying queens, or queen failure that resulted in poor brood pattern and/or poor hive build up.

Among beekeepers with more than 250 colonies, drone-laying queens and queen failure were dominant problems (Fig. 11), occurring with similar frequency across regions. Surprisingly, old queens were only somewhat more likely to be drone layers than young queens and were typically more likely to disappear than young queens. Old queens had a higher failure rate than young queens; 26.3 percent more beekeepers reported old queen failure than young queen failure among beekeepers with more than 250 colonies.

Across all size categories, old queens disappeared more than young queens (Fig. 12), with queens disappearing being particularly challenging for beekeepers with 0-10 colonies.

For operations exceeding 3000 colonies, young queens were more problematic than old queens in terms of drone laying and failure; for all other operation sizes, this reverse is often case (except drone laying for operators with 50 or fewer colonies). This observation of young queens with higher drone laying rates and higher fail rates as compared to older queens in large operations is counterintuitive and worthy of further examination[56].

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[52] Lee et al. 2019.

[53] Pettis et al. 2016.

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

[55] Brodschneider et al. 2016; Pettis et al. 2016; Gray et al. 2019; Lee et al 2019.

[56] Genersch et al. 2010.

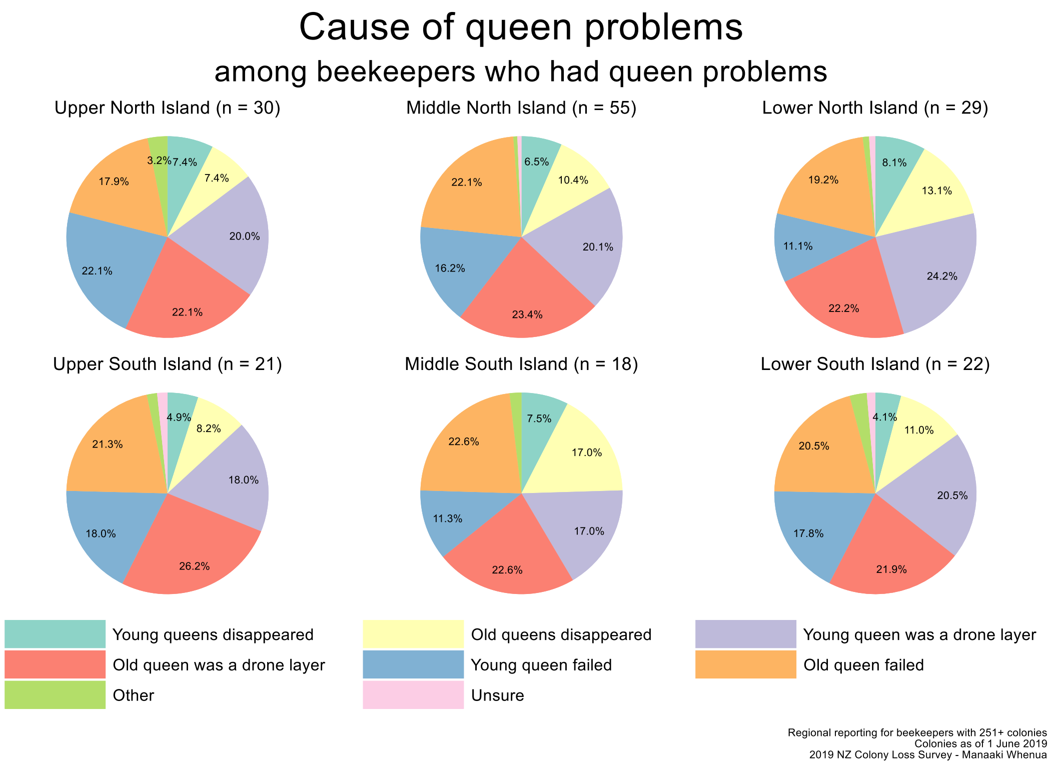

Figure 11: Cause of queen problems during winter 2019, based on reports from respondents with more than 250 colonies who lost any colonies, by region.

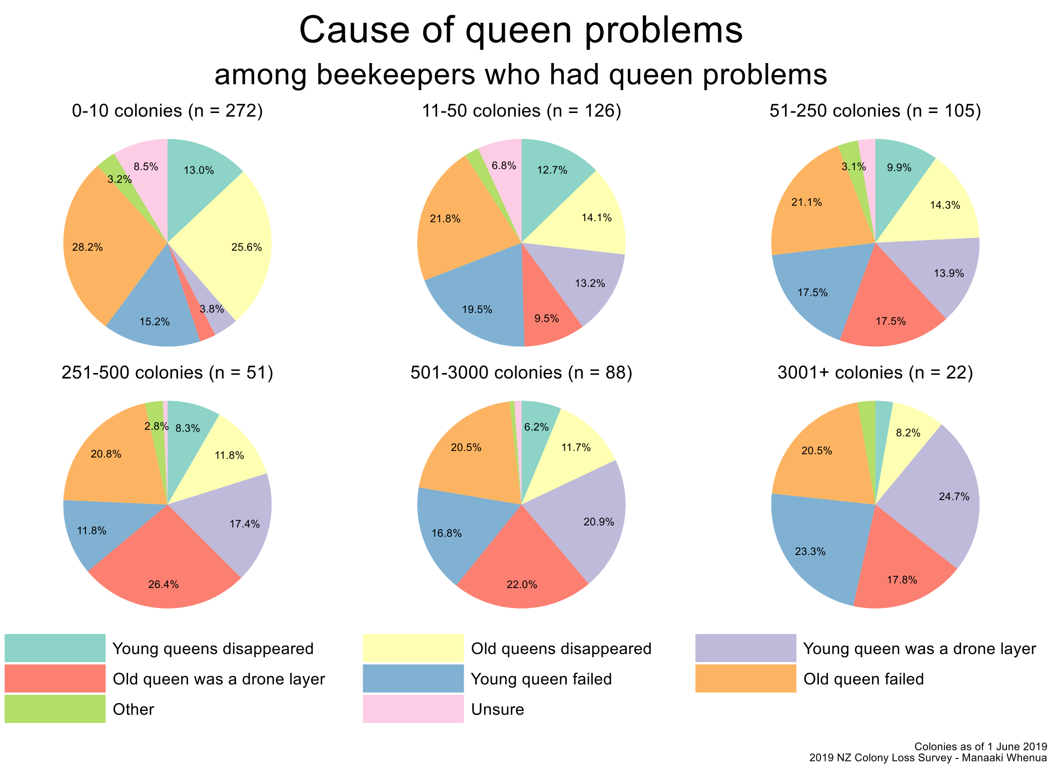

Figure 12: Cause of queen problems during winter 2019, based on reports from all respondents who lost any colonies, by operation size.

The 2019 survey included a new set of questions regarding how well colonies with new queens performed over winter 2019 relative to colonies with old queens.

Among beekeepers with more than 250 colonies, colonies with old queens rarely survived better over winter 2019 than colonies with new queens. In particular, colonies with new queens in the Upper North Island survived better than colonies with old queens, where 75 percent of all responding beekeepers in this region with more than 250 colonies reported that colonies with new queens survived either somewhat better or better than colonies with old queens over winter 2019 (Fig. 13).

Generally, as operation size increased, the share of beekeepers whose colonies with new queens survived better compared to colonies with old queens over winter 2019 increased (Fig. 14). Notably, the share of beekeepers with more than 3000 colonies whose colonies with new queens performed somewhat worse or worse than colonies with old queens was much higher than the next two size classes, at 22.7 percent.

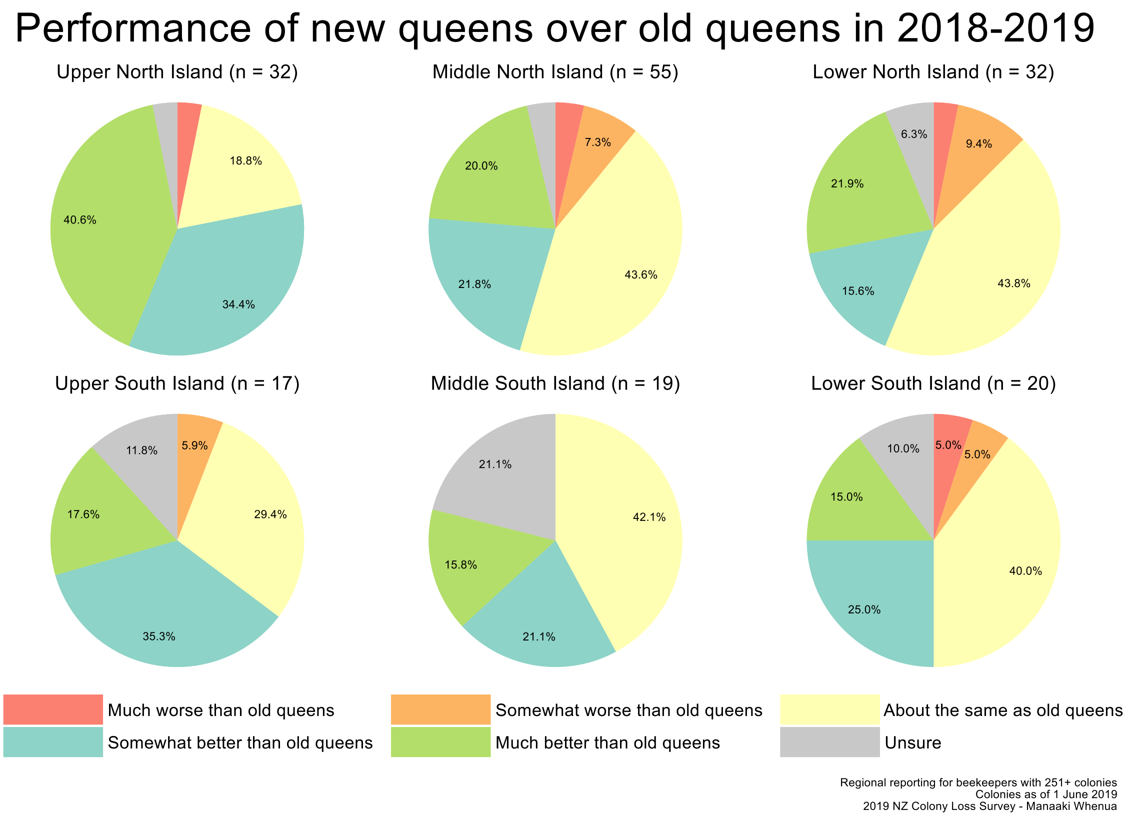

Figure 13: Survival of colonies with new queens relative to colonies with old queens during winter 2019, based on reports from respondents with more than 250 colonies, by region.

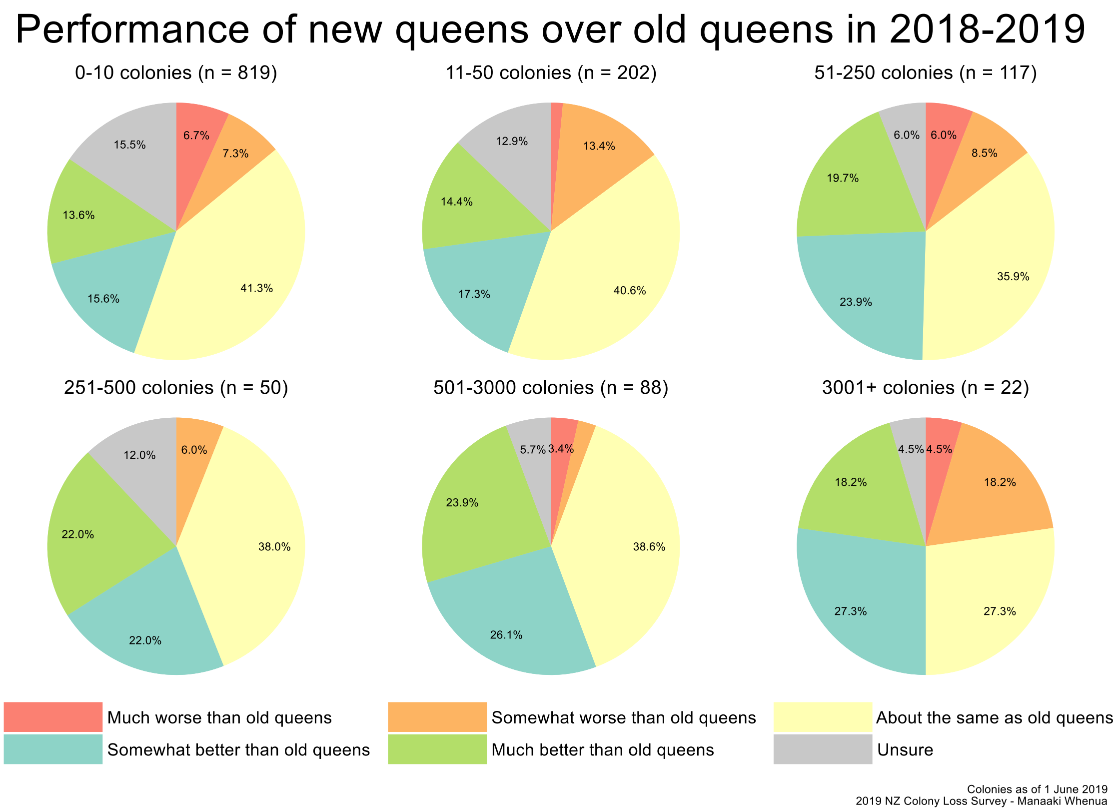

Figure 14: Survival of colonies with new queens relative to colonies with old queens during winter 2019, based on reports from all respondents, by operation size.

4.4.2 Suspected varroa and related complications

The varroa mite is an ectoparasite that feeds off the fat body tissue of honey bees[57] and is generally regarded as the biggest threat to beekeeping worldwide[58]. Varroa has been shown to transmit five deleterious viruses including deformed wing virus (which is also transmitted sexually; see Amiri et al. 2016) and possibly up to 13 other viruses[59]. 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.

Some 2.9 percent of all colonies over winter were lost to suspected varroa and related complications over winter 2019, versus 2.2 percent for winter 2018. This figure ranged from 1.2 percent in the Lower North Island to 6.2 percent in the Middle South Island (Table 4).

Notably, the estimated share of losses attributed to varroa and related complications increased in the Middle South Island from 3.1 percent in winter 2018 to 6.2 percent in winter 2019 and decreased in both the Upper South Island and Lower South Island from 3.3 percent to 1.4 percent and from 4.1 percent to 2.0 percent, respectively.

Beekeepers with more than 250 colonies attributed 23.2 percent of their total losses to varroa and related complications (Fig. 9), and the shares of total winter colonies lost that were attributed to varroa

[57] 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".

[58] Rosenkrantz et al. 2010; Ramsey et al. 2019.

[59] Ramsey et al. 2019.

and related complications ranged from 2.3 percent for beekeepers with 251-500 colonies to 4.6 percent for beekeepers with 0-10 colonies (Table 5).

4.4.3 Suspected starvation

Dead worker bees in cells with no food present in the colony is indicative of starvation. An estimated 1.1 percent of all winter 2019 colonies were lost to suspected starvation, compared with 0.9 percent in winter 2018.

Suspected starvation seemed to be more problematic in the Middle North Island and Lower South Island, with estimated loss rates over winter 2019 of 1.3 percent and 2.0 percent (compared with loss rates of 1.0 percent and 0.7 percent over winter 2018), respectively (Table 4).

Estimated loss shares attributed to starvation decreased as operation size increased (Table 5), decreasing from 2.5 percent of all winter 2019 colonies for beekeepers with 0-10 colonies to 0.8 percent of all winter 2019 colonies for beekeepers with more than 3000 colonies. This follows a similar pattern to winter 2018 with loss rates due to suspected starvation decreasing from 2.7 percent of all winter 2018 colonies for beekeepers with 0-10 colonies to 0.7 percent of all winter 2018 colonies for beekeepers with more than 3000 colonies.

Starvation may be a symptom of excessive competition for nectar and pollen sources, particularly during bad weather, although these problems may be mitigated by supplementary feeding of sugar and protein. See additional discussion in subsection 4.6.6 and section 4.7.

4.4.4 Wasps

Widespread infestations of the giant willow aphid and a mild winter across much of New Zealand have contributed to increasing populations of wasps that feed on the honeydew produced by these aphids. Wasps debilitate honey bee colonies in winter by robbing their honey stores and/or by seeking protein to feed their own young, which can lead to starvation and a reduced workforce of foragers. Beekeepers lost an estimated 1 percent of all winter 2019 colonies to wasps, versus 0.9 percent in winter 2018.

Similar to previous years, a greater share of winter 2019 colonies were lost to wasps in the North Island (1.2 percent) than in the South Island (0.5 percent), with the highest share in the Middle North Island at 1.6 percent (Table 4).

Very few losses due to wasps were recorded in the Middle South Island with an estimated loss rate of 0.1 percent.

Small operators were most affected by wasps; beekeepers with 0-10 colonies lost an estimated 3.3 percent of all winter 2019 colonies to wasps and beekeepers with 11-50 colonies lost an estimated 3.1 percent of all winter 2019 colonies to wasps (Table 5). These loss rates were similar to winter 2018 where beekeepers with 0-10 colonies and 11-50 colonies had estimated loss rates of 3.4 percent and 3 percent, respectively.

4.4.5 Natural disasters

A mild winter across much of New Zealand contributed to low losses due to natural disasters.

Among beekeepers with more than 250 colonies, an estimated 0.1 percent of all winter 2019 colonies were lost to natural disasters, unchanged from winter 2018.

Differing from winter 2018, however, estimated loss rates due to natural disasters were highest in the Upper North Island and Lower North Island, both with an estimated loss rate of 0.13 percent, compared with estimated loss rates of 0.07 percent and 0.04 percent over winter 2018 for the Upper North Island and Lower North Island, respectively (Table 4).

4.4.6 Robbing by other bees

Weak colonies are susceptible to robbing from strong hives, particularly when there is a dearth of nectar sources. An estimated 0.5 percent of all winter 2019 colonies were lost due to robbing by other bees, slightly higher than winter 2018, where an estimated 0.3 percent of all winter colonies were lost.

Robbing was more common in the North Island, where mānuka honey production is prominent (Table 4).

Robbing presented greater challenges for small operators, where beekeepers with 0-10 colonies and 11-50 colonies had estimated loss rates due to robbing of 2.7 percent and 1.9 percent, respectively, similar to winter 2018 loss rates which were 2.5 percent and 1.7 percent (Table 5).

4.4.7 American foulbrood disease (AFB)

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

Among the 297,377 colonies reported on by all beekeepers, of which 297,345 had detailed loss information, 331 cases of AFB were reported for winter 2019 (cf. 435 cases out of 347,007 colonies for winter 2018). An estimated 0.11 percent of all winter 2019 colonies were lost due to AFB, down from winter 2018 where the estimated loss rate was 0.13 percent.

The Middle South Island had a particularly high loss rate due to AFB at 0.26 percent, an increase from winter 2018 where the estimated loss rate due to AFB was 0.16 percent (Table 4).

As operator size increased, estimated loss rates due to AFB over winter 2019 typically decreased, going from 0.4 percent for beekeepers with 0-10 colonies to 0.1 percent for beekeepers with more than 3000 colonies.

Beekeepers reported that AFB affected 0.06 percent of the colonies included in the 2015 NZ Colony Loss Survey, 0.21 percent of the colonies included in the 2016 NZ Colony Loss Survey, and 0.27 percent of the colonies included in the 2017 NZ Colony Loss Survey.

4.4.8 Suspected toxic exposure

Having a large number of dead bees in or in front of the colony may be indicative of exposure to environmental toxins such as plant toxins and chemicals such as insecticides, fungicides, and surfactants. Over winter 2019, 0.11 percent of all colonies were lost to suspected toxic exposure, compared with 0.15 percent over winter 2018.

All regions had low loss rates due to suspected toxicity, with the highest being 0.16 percent in the Upper South Island (Table 4). Comparatively, the highest regional loss rate due to suspected toxicity over winter 2018 was 0.61 percent in the Lower South Island.

Importantly, the survey does not distinguish between insecticides/agrochemicals and naturally occurring karaka poisoning[60]. Regardless, similar to 2018 results, exposure to toxicity was qualitatively lower among larger operations than among smaller operations (Table 5).

4.4.9 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* has 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[61]. Nosemosis is exacerbated when bees cannot leave their colonies to eliminate waste (e.g. during cold and wet winters or when bees are remain indoors).

Symptoms of nosemosis may include dysentery, and hives tend to dwindle rapidly with no dead bees present in or outside the hive. These symptoms are not syndromic, meaning they may be confused with other honey bee diseases (including parasitic mite syndrome) and may be confused with poor queen quality[62].

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[60] Palmer-Jones & Line 1962.

[61] MAF 2011.

[62] Borowik 2019.

An estimated 0.4 percent of all colonies over winter 2019 were lost due to suspected diseases (compared with 0.5 percent for winter 2018), with significantly higher shares in the Middle North Island of 0.8 percent (compared with 0.9 percent for winter 2018) (Table 4).

While suspected nosema and other diseases were recorded as causing a loss of 1.0 percent in the Upper South Island over winter 2018, that figure dropped to 0.3 percent for winter 2019.

Suspected diseases appeared to be more problematic for larger operations than smaller operations (Table 5).

4.4.10 Theft or vandalism

Theft and vandalism were extremely rare overall but more common in mānuka-producing areas than elsewhere.

An estimated 0.05 percent of all winter 2019 colonies were lost due to theft or vandalism, almost exclusively on the North Island (Table 4). Interestingly, theft and vandalism were most common for moderate to large operators and rare for beekeepers with more than 3000 colonies (Table 5).

4.5 State of surviving colonies

Production colonies may survive winter but enter spring in a weakened state. In spring 2019, beekeepers with more than 250 colonies reported that 19.8 percent of their colonies were weak but queenright, on average, up from spring 2018 where the average was 17 percent.

Beekeepers with more than 3000 colonies had the highest average share of weak but queenright colonies in spring 2019 at 30.1 percent.

Adjusting for operation size, approximately 18.9 percent of all surviving colonies were weak for beekeepers with more than 250 colonies, and approximately 20.1 percent of all surviving colonies were weak for beekeepers with more than 3000 colonies.

4.6 2018/19 season

The third part of the 2019 NZ Colony Loss Survey asked respondents to reflect on the previous year. Specifically, it focused on topics such as queen replacement, varroa monitoring and treatment, toxicity, colony use, floral resources, supplemental feeding, tutin contamination, and compromised/lost apiary sites during the 2018/19 season.

All questions were optional, so data were available for a subset of respondents. The number of respondents (n) is shown in each figure.

4.6.1 Queen replacement

Re-queening is a common strategy for reducing potential queen problems, especially among commercial beekeepers. It is accepted practice that younger queens outperform older queens[63].

Indeed, among beekeepers with more than 250 colonies, 46.6 percent of colonies were re-queened during the 2018/19 season (compared with 54.4 percent of colonies during the 2017/18 season).

Among beekeepers with more than 250 colonies, re-queening was most common in the Upper North Island and Upper South Island (Fig. 15).

Differences in re-queening rates across operation size categories were very small, on average (Fig. 16).

[63] Rangel et al. 2013.

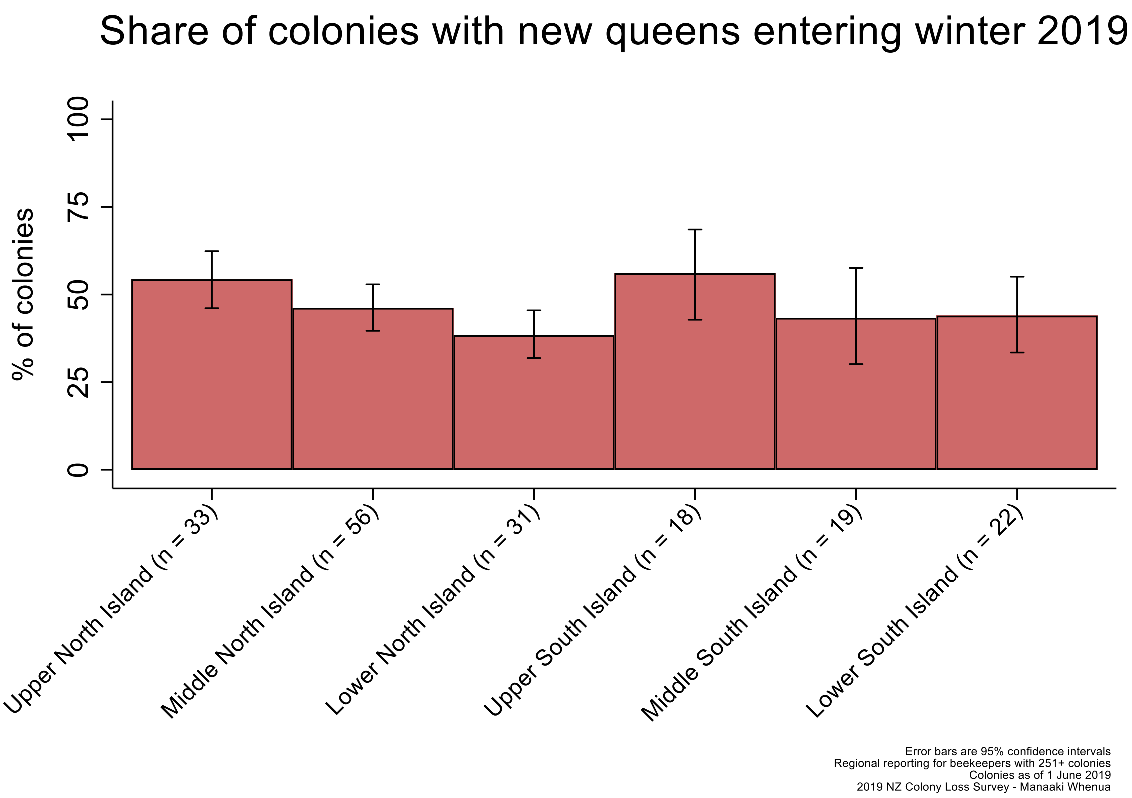

Figure 15: Share of colonies with new queens entering winter 2019, by region.

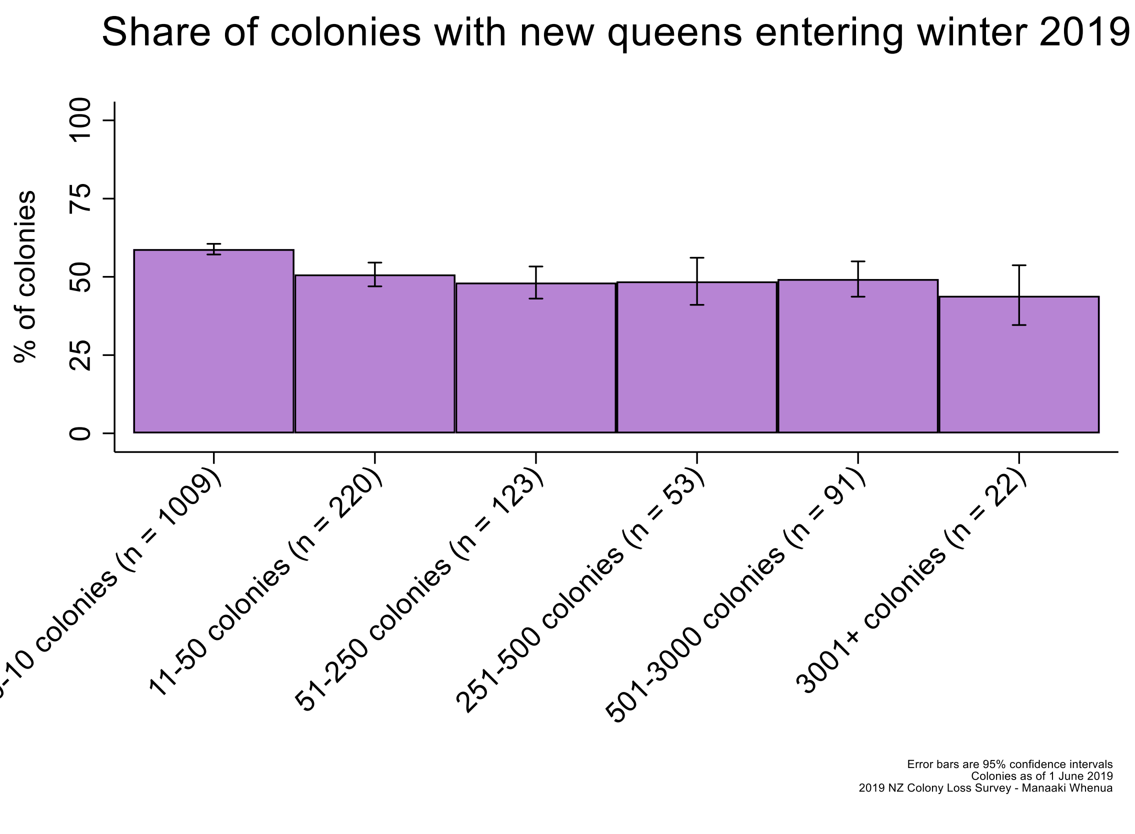

Figure 16: Share of colonies with new queens entering winter 2019, by operation size.

Generally, most beekeepers had a queen replacement strategy; no beekeepers with more than 250 colonies and only 9.9 percent of all beekeepers reporting having no particular strategy for queen replacement.

Strategies for replacing queens among beekeepers with more than 250 colonies varies across regions, with shares of beekeepers using mated queens ranging from 25 percent in the Lower South Island to 90 percent in the Upper South Island (Fig. 17).

Notably, most regions had very few beekeepers using virgin queens with the Lower South Island having the highest share at 17 percent.

Queen replacement strategies decrease in diversity as operation size increases: beekeepers with 0-10 colonies engage in all queen replacement strategies, while beekeepers with more than 3000 colonies only use queen cells and mated queens (Fig. 18).

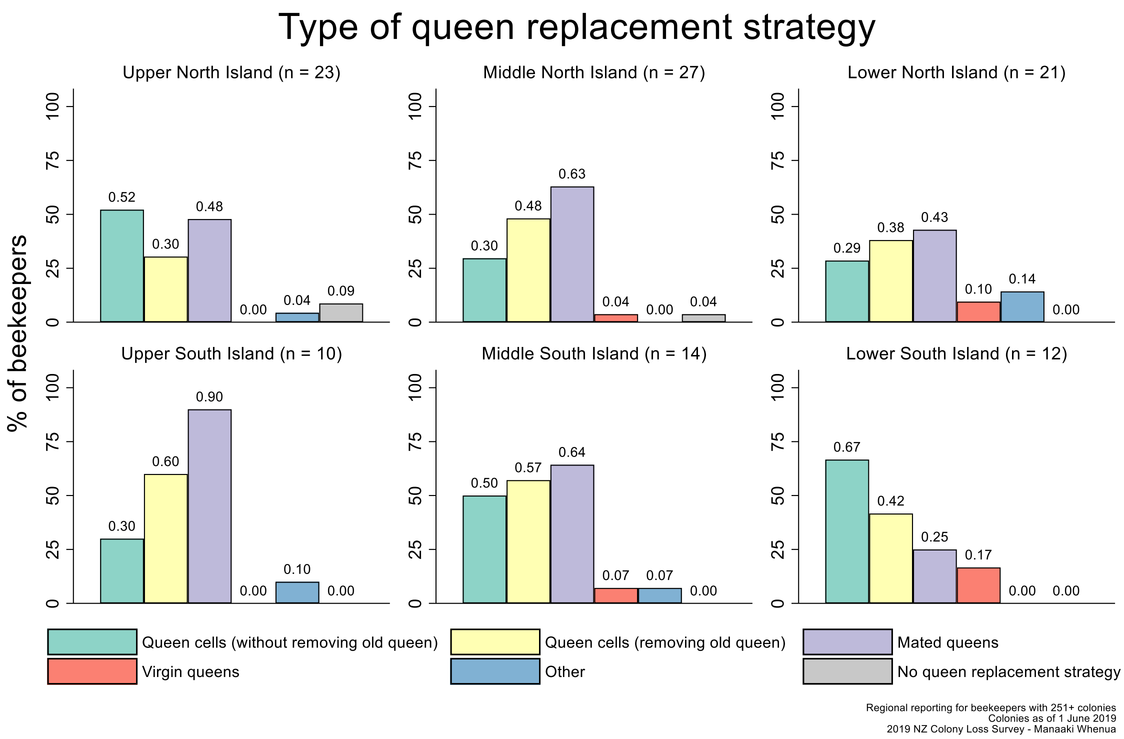

Figure 17: Method of replacing queens during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

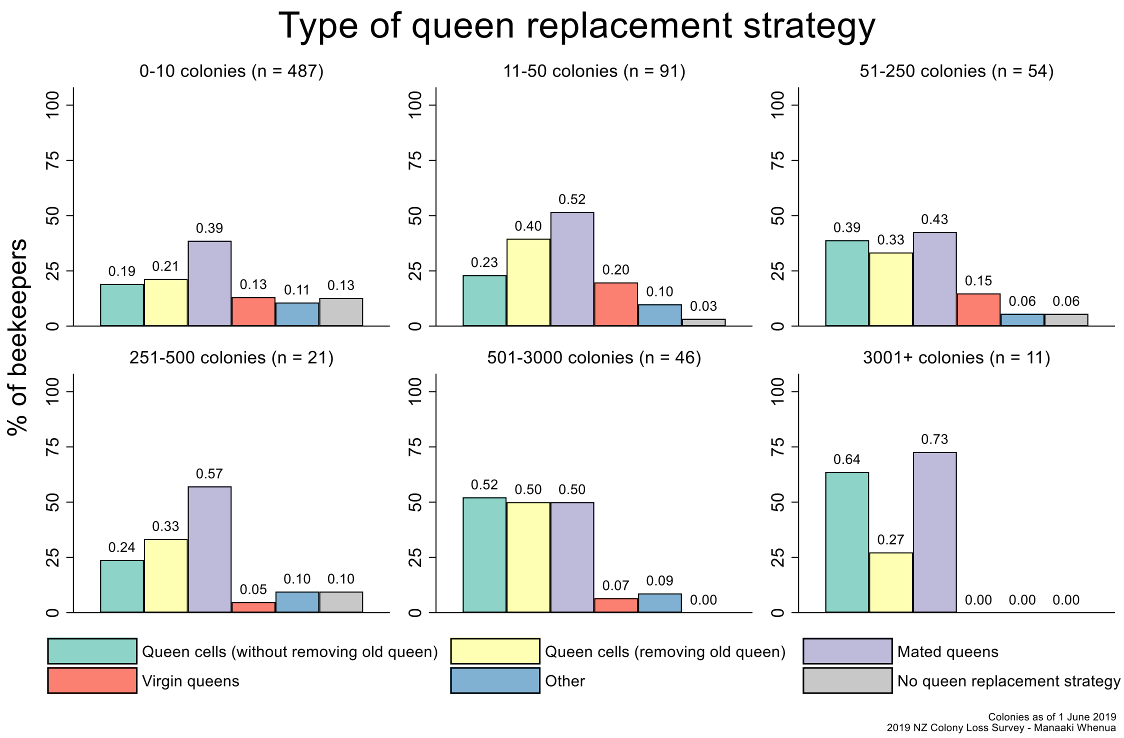

Figure 18: Method of replacing queens during the 2018/19 season, based on reports from all, by operation size.

4.6.2 Varroa

Deformed wing virus (DWV) causes deformities on adult honey bees. Symptoms include stubby wings, deformed abdomens, and discolouration as well as paralysis. Infected bees are typically ejected from the colony. Although DWV exists in bee populations that have not been affected by varroa, the level of infection is highly correlated with varroa. Parasitic mite syndrome (PMS) presents with spotty brood patterns and sunken, dark, and/or perforated cell cappings, although only larvae and prepupae are affected PMS is associated with DWV, and only occurs with infestations of varroa mites.

Overall, 45.1 percent of beekeepers reported having noticed bees with crippled or deformed wings during the 2018/19 season (Fig. 20) compared with 46.4 percent during the 2017/18 season.

As operation size increases, the share of beekeepers who report seeing DWV symptoms increases, going from 40 percent for beekeepers with 0-10 colonies to 84.6 percent for beekeepers with more than 3000 colonies.

Similar to 2017/18 and 2016/17, all responding beekeepers with more than 250 colonies in the Upper South Island report having seen DWV symptoms (Fig. 19).

The share of beekeepers that report seeing PMS symptoms during the 2018/19 season was also high for beekeepers with more than 250 colonies operating in the Upper South Island, at 92.3 percent (every responding beekeeper with more than 250 colonies operating in the Upper South Island reported seeing PMS symptoms during the 2017/18 season) (Fig 21).

Similar to the 2017/18 season, the share of beekeepers that report seeing PMS symptoms during the 2018/19 season increases as operation size increases, at 31.3 percent of beekeepers with 0-10 colonies and 84.6 percent of beekeepers with more than 3000 colonies (Fig. 22).

Similar to the 2017/18 season, smaller operators formally monitor for varroa at higher rates than larger operators (Fig. 24), with the exception of beekeepers with more than 3000 colonies. Among these largest beekeepers, only 8 percent do not formally monitor for varroa, down from 21 percent over the 2017/18 season. Use of visual inspection is much higher for these operators during the 2018/19 season, relative to the 2017/18 season. All operations disproportionately rely on visual inspection for varroa monitoring: only 46.3 percent of beekeepers with 0-10 colonies, 30 percent of beekeepers with 11-50 colonies, 41.5 percent of beekeepers with 51-250 colonies, 35 percent of beekeepers with 251-500 colonies, 36.8 percent of beekeepers with 501-3000 colonies, and 33.3 percent of beekeepers with more than 3000 colonies use alcohol washes, sticky boards, sugar shakes/rolls, or lab sampling to monitor varroa.

During the 2017/18 season, beekeepers were similarly reliant on visual inspection except for beekeepers with more than 3000 colonies: 64.3 percent of these operators used alcohol washes, sticky boards, sugar shakes/rolls, or lab sampling to monitor varroa.

The use of an alcohol wash is much higher for beekeepers with 251-500 colonies and 501-3000 colonies during the 2018/19 season relative to the 2017/18 season, with shares of 46 percent and 41 percent during the 2018/19 season, respectively (up from 19 percent and 24 percent during the 2017/18 season).

The use of sugar shake/roll is also higher for these operations, increasing from 8 percent to 13 percent for beekeepers with 251-500 colonies and from 7 percent to 14 percent for beekeepers with 501-3000 colonies.

Among beekeepers with more than 250 colonies, regional trends for monitoring varroa are evident over the 2018/19 seasons (Fig. 23), although regional trends are less pronounced than they were during the 2017/18 season. In particular, the Lower South Island has much higher formal monitoring rates, where the share of beekeepers not undertaking any monitoring dropped from 47 percent during the 2017/18 season to 29 percent during the 2018/19 season.

Monitoring for varroa was undertaken at qualitatively higher rates in the North Island than in the South Island, with respective monitoring rates of 85 percent and 71 percent.

Beekeepers across all regions and across all operation sizes report using *Flumethrin* and *Amitraz* to treat varroa much more commonly than any other method (Figs 25 and 26).

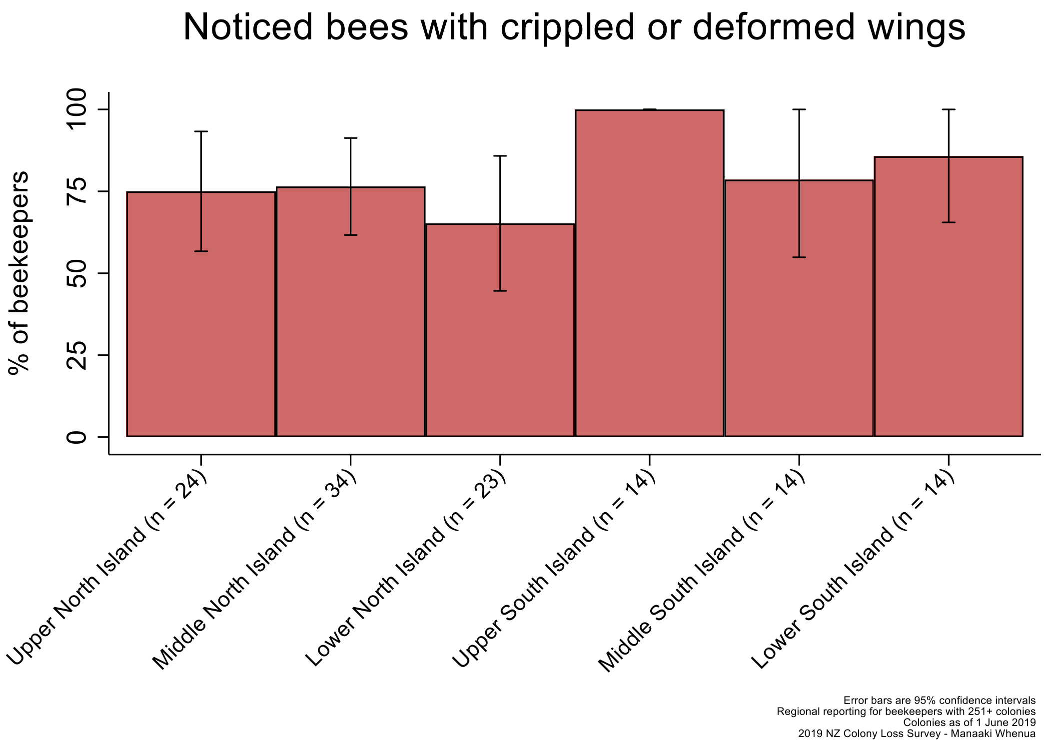

Figure 19: Share of respondents who observed crippled or deformed wings during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

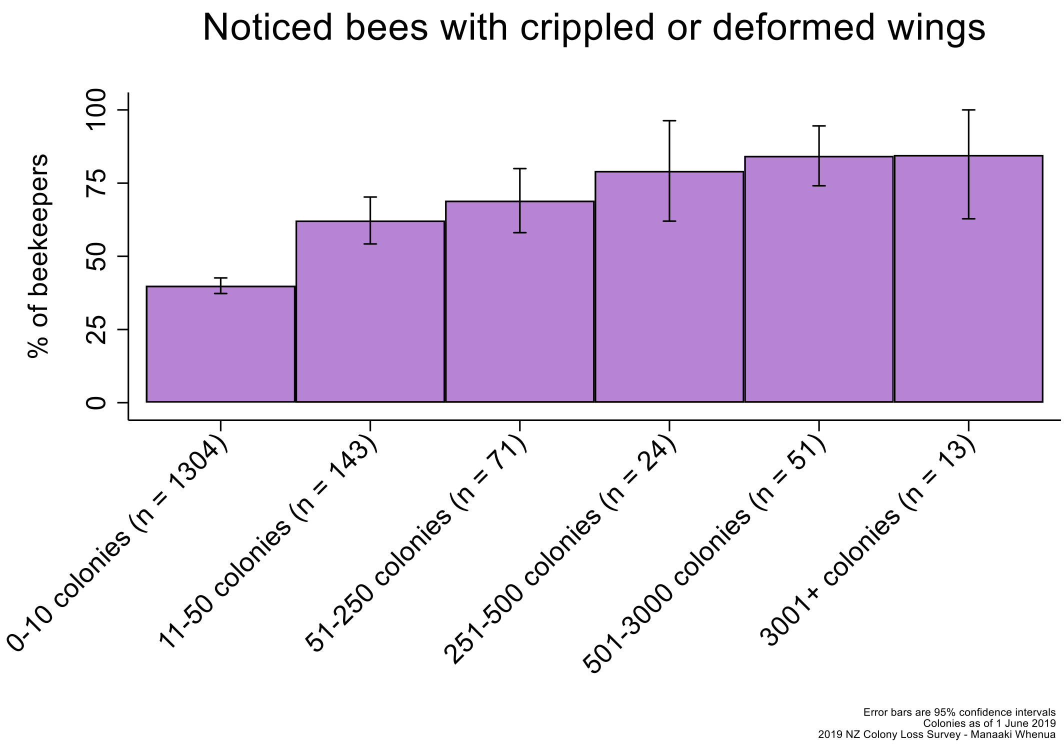

Figure 20: Share of respondents who observed crippled or deformed wings during the 2018/19 season, based on reports from all respondents, by operation size.

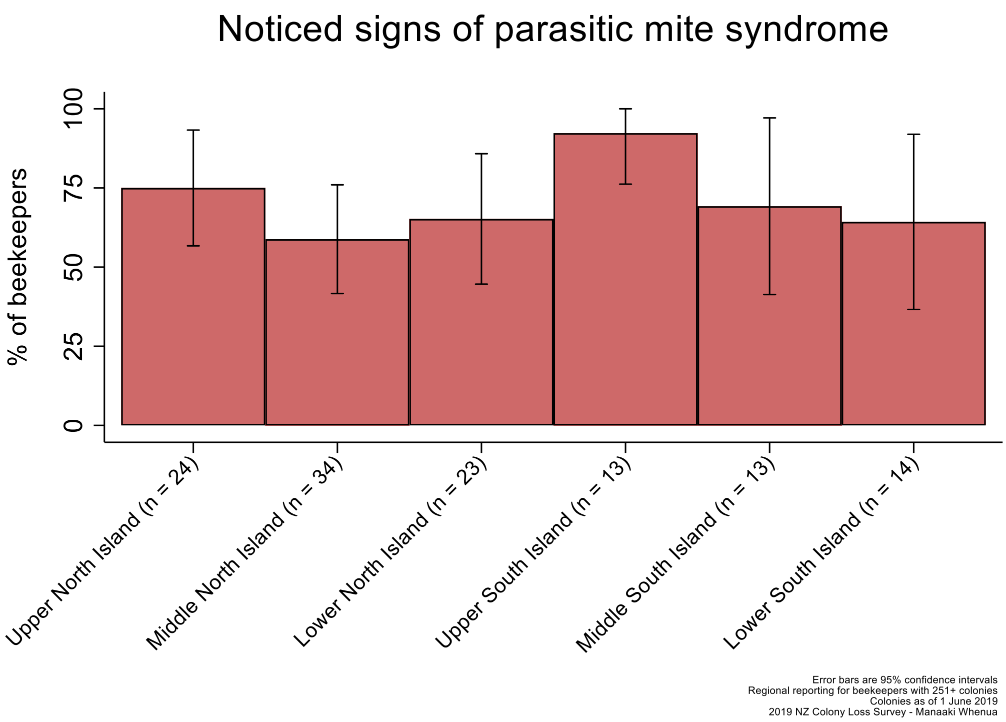

Figure 21: Share of respondents who noticed symptoms of parasitic mite syndrome during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

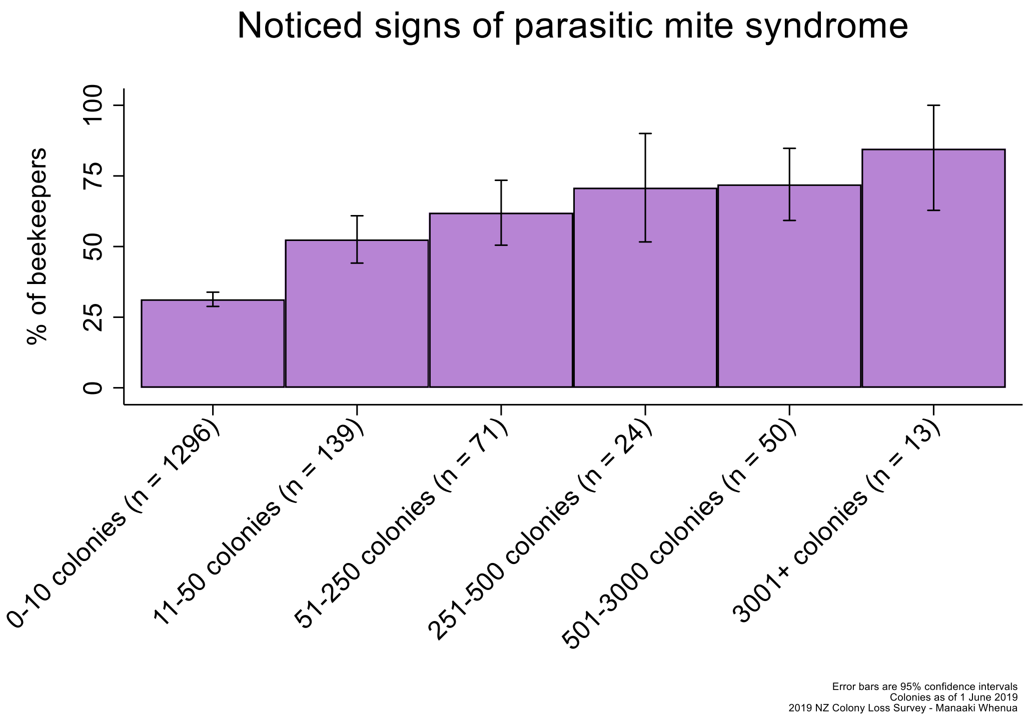

Figure 22: Share of respondents who noticed symptoms of parasitic mite syndrome during the 2018/19 season, based on reports from all respondents, by operation size.

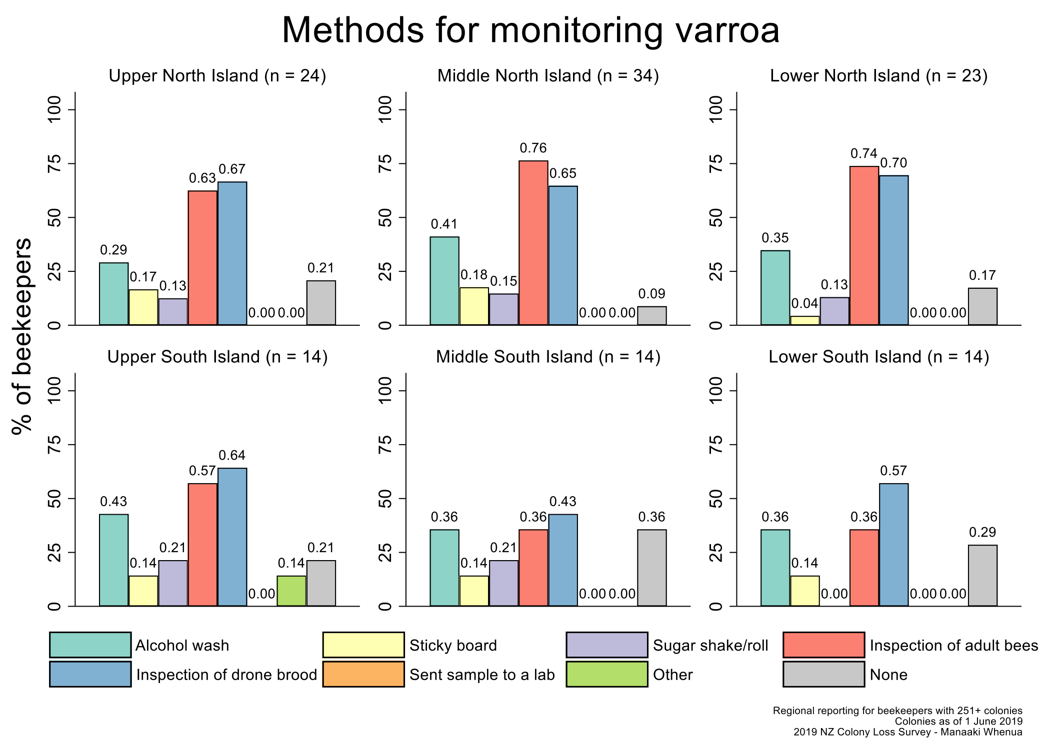

Figure 23: Methods for monitoring varroa during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

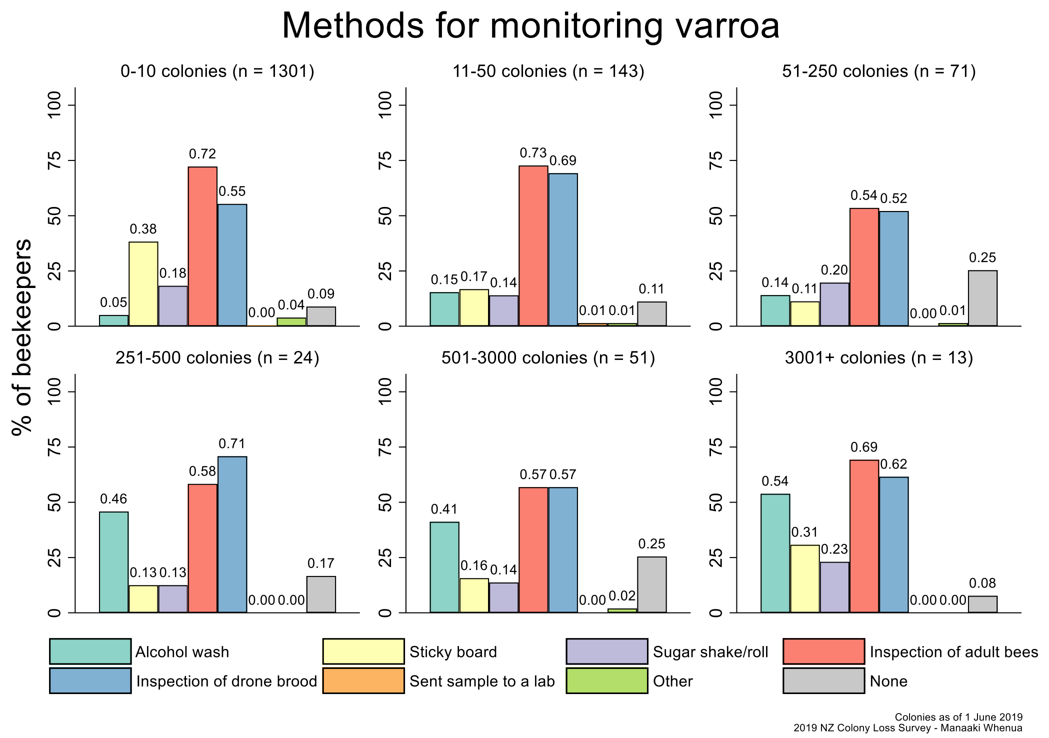

Figure 24: Methods for monitoring varroa during the 2018/19 season, based on reports from all respondents, by operation size.

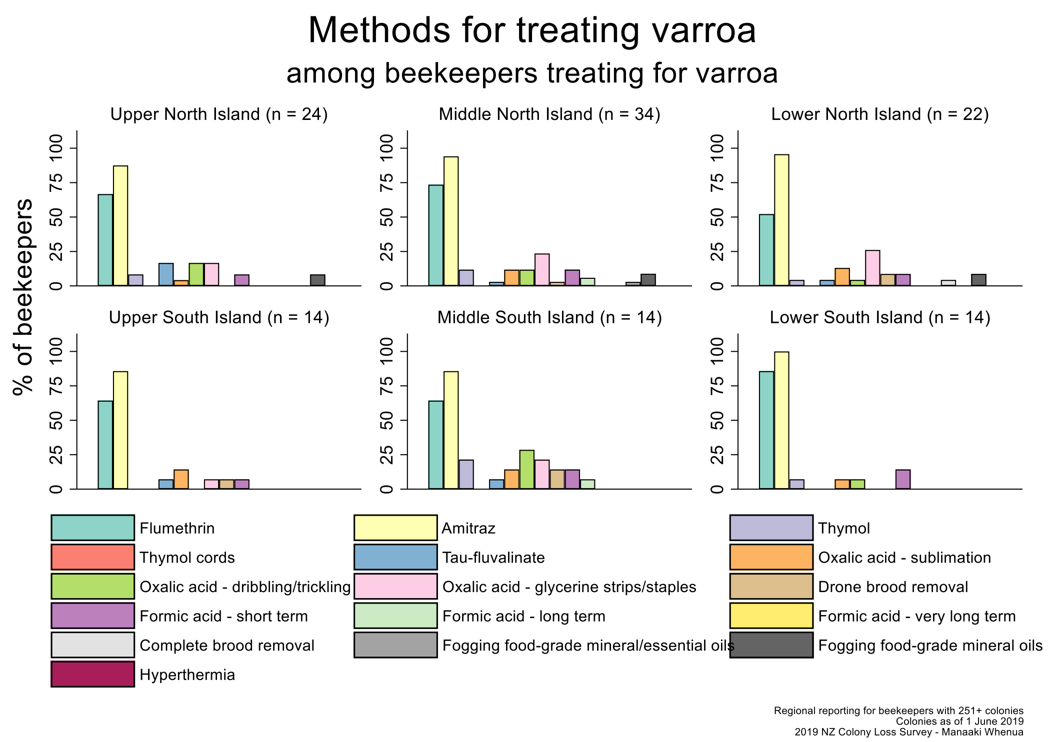

Figure 25: Varroa treatment methods during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

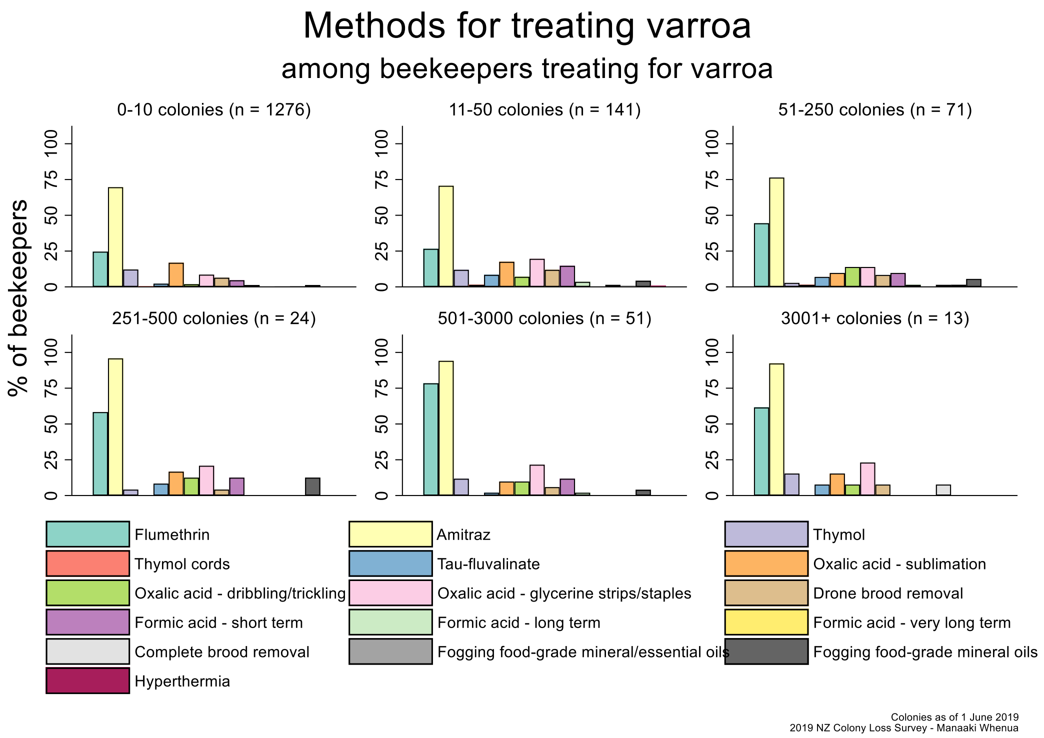

Figure 26: Varroa treatment methods during the 2018/19 season, based on reports from all respondents, by operation size.

4.6.3 Comb replacement

One method to mitigate toxin and pathogen loads embedded inside colonies is replacing old wax brood combs with new foundation.

Beekeepers with more than 250 colonies replaced an estimated 12.2 percent of brood combs during the 2018/19 season.

The South Island had a higher estimated share of colonies with wax brood combs replaced with foundation at 15.8 percent compared to the North Island at 10 percent (Fig. 27).

Rates of replacement were consistent among differing operation sizes except for beekeepers with 0-10 colonies; these operators had a lower estimated rate of replacement at 6.2 percent (Fig. 28). Overall, similar to the 2017/18 season, 69.8 percent of beekeepers with 0-10 colonies reported that they did not replace any brood combs with foundation during the 2018/19 season, compared with 44 percent of beekeepers with 11-50 colonies, 30.9 percent of beekeepers with 51-250 colonies, 13 percent of beekeepers with 251-500 colonies, 26 percent of beekeepers with 501-3000 colonies, and 7.7 percent of beekeepers with more than 3000 colonies.

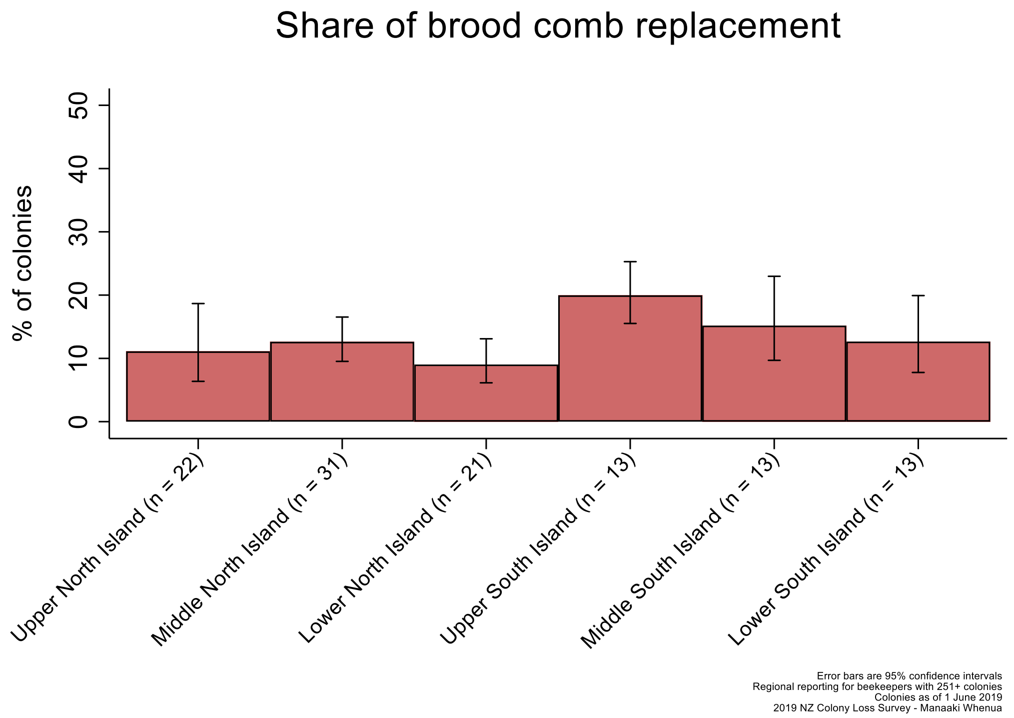

Figure 27: Share of brood combs replaced by comb foundation during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

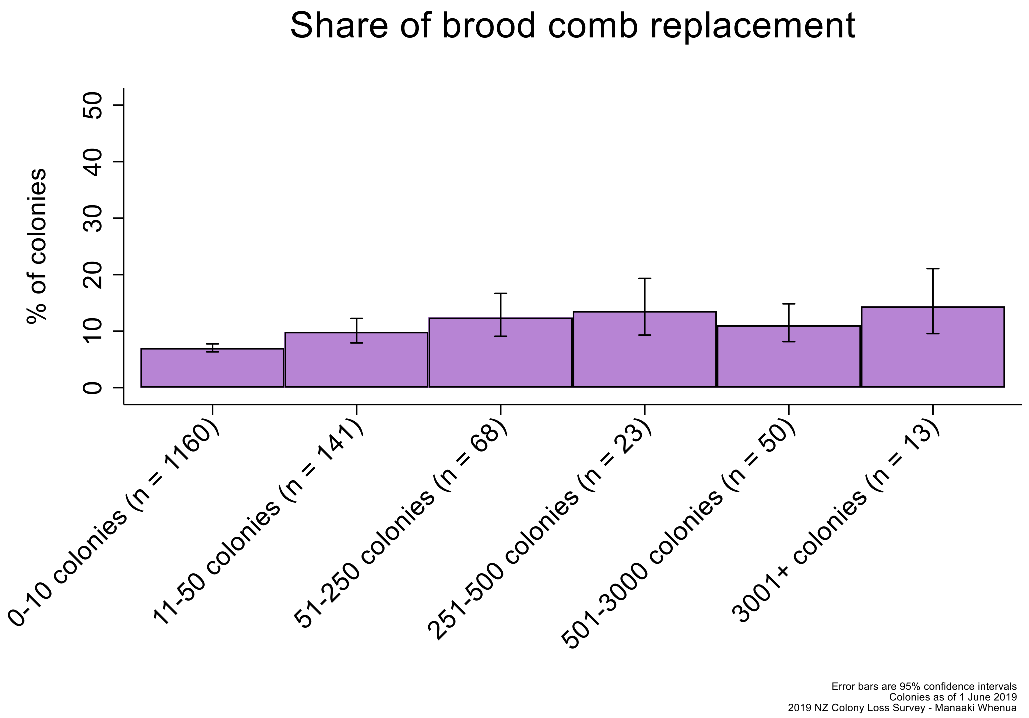

Figure 28: Share of brood combs replaced by comb foundation during the 2018/19 season, based on reports from all respondents, by operation size.

4.6.4 Production colony use

High-value honey from mānuka incentivises many beekeepers to pursue honey rather than providing pollination services, producing queens, producing live bees, and producing other bee products such as propolis.

Honey production was the most common use for colonies for beekeepers with more than 250 colonies, with 81.2 percent of colonies used primarily for this reason (Fig. 29).

Pollination services were the next most common use at 11.7 percent. During the 2018/19 season, only 16.4 percent of beekeepers reported that any of their colonies were used primarily for pollination services.

Queen production and the production of propolis and other bee products account for 3 percent and 3.7 percent of colonies, respectively. While there are some well-known large-scale producers of packaged bees, live bee production was mainly reported among small operations: 5.2 percent of all colonies among beekeepers with 0-10 colonies were used for live bee production as were 6.4 percent of all colonies among beekeepers with 11-50 colonies (Fig. 30).

The production of propolis and other bee products was mainly undertaken by larger operations, with 3.9 percent of all colonies among beekeepers with more than 500 colonies being used primarily for this purpose.

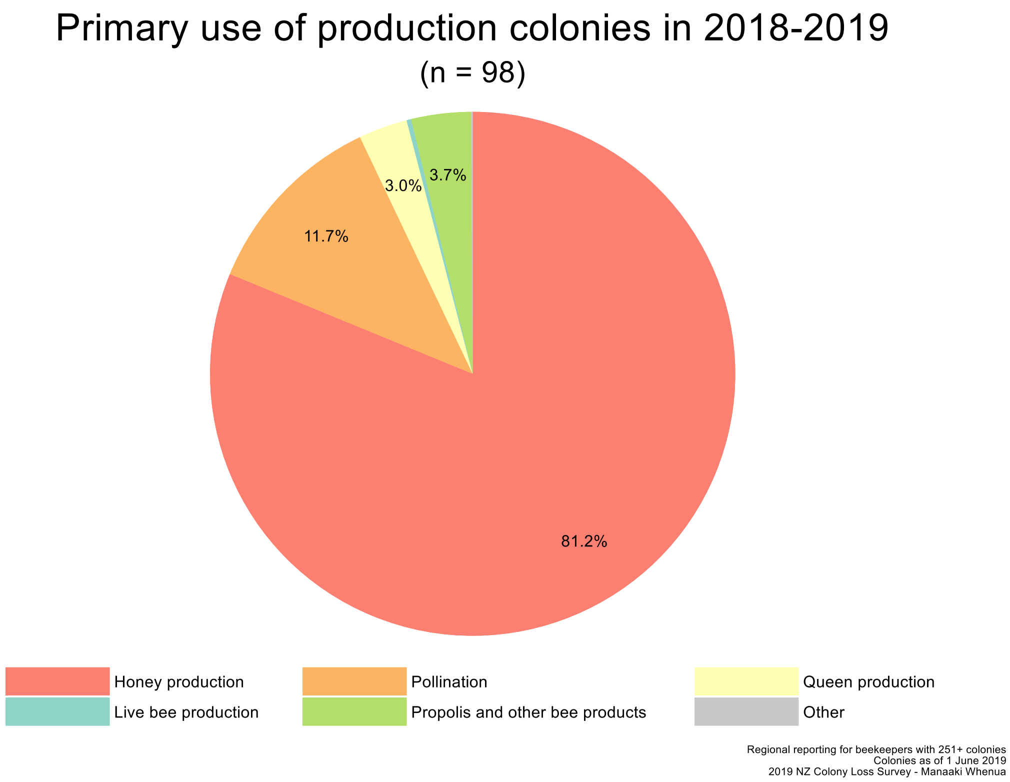

Figure 29: Primary use of production colonies during the 2018/19 season, based on reports from respondents with more than 250 colonies, nationally.

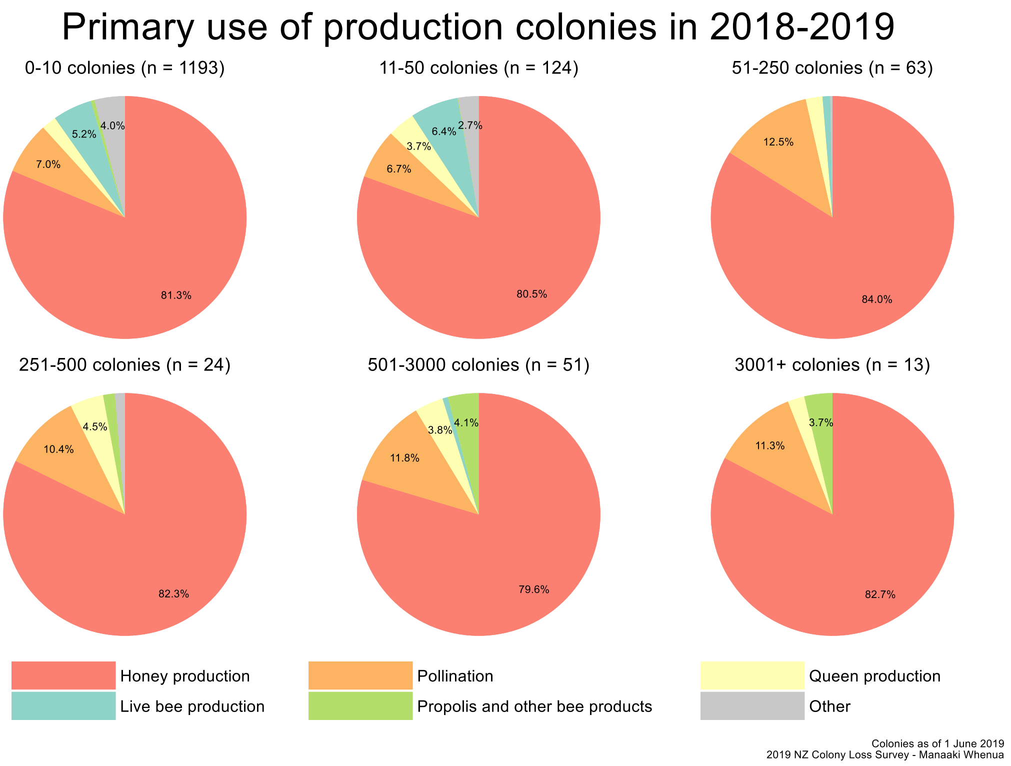

Figure 30: Use of production colonies during the 2018/19 season, based on reports from all respondents, by operation size.

4.6.5 Nectar flows

Nectar flows across regions are reported in Figure 31. Among beekeepers with more than 250 colonies in the Upper North Island, native bush blend was the most prevalent nectar flow, with mānuka, kānuka, clover/pasture, and rewarewa also being very common.

Clover/pasture and rewarewa were equally dominant and the most common nectar flows for beekeepers with more than 250 colonies operating in the Middle North Island, with native bush blend also being reported as typical.

The Lower North Island had the highest share of beekeepers with more than 250 colonies reporting mānuka as providing significant nectar flow, with clover/pasture, kāmahi, and native bush blend being relatively common.

Beekeepers with more than 250 colonies in the Upper South Island had very high rates of mixed mānuka and kānuka, clover/pasture, kamahi, and beech honeydew, with over 60 percent of respondents reporting significant nectar flows from these flora. Native bush blend was also common in this region.

Beekeepers with more than 250 colonies in the Middle South Island did not have nectar flows coming from diverse flora; most beekeepers reported receiving significant nectar flows from either clover/pasture or beech honeydew.

The Lower South Island had the highest rate of significant nectar flows coming from clover/pasture among beekeepers with more than 250 colonies; over 93 percent of respondents reported receiving significant nectar flow from clover/pasture. Flow from spring willow was also common in the Lower South Island.

The share of beekeepers reporting mānuka and kānuka as providing significant nectar flows increased with operation size, going from 8.5 percent for mānuka and 8.3 percent for kānuka for beekeepers with 0-10 colonies to 76.9 percent for mānuka and 53.8 percent for kānuka for beekeepers with more than 3000 colonies (Fig. 32).

Rates of clover/pasture providing significant nectar flows appeared to be consistent across all operation sizes, while urban floral and garden was only significant for smaller operations.

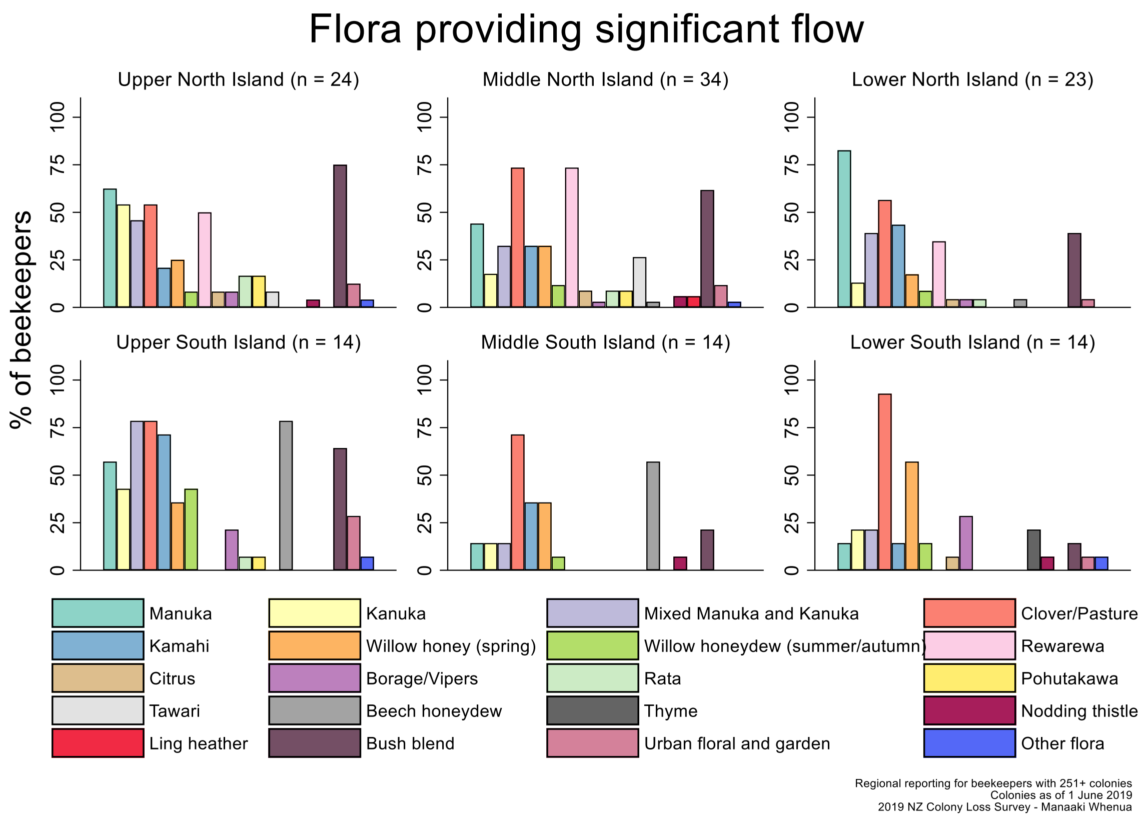

Figure 31: Sources of significant nectar flow during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

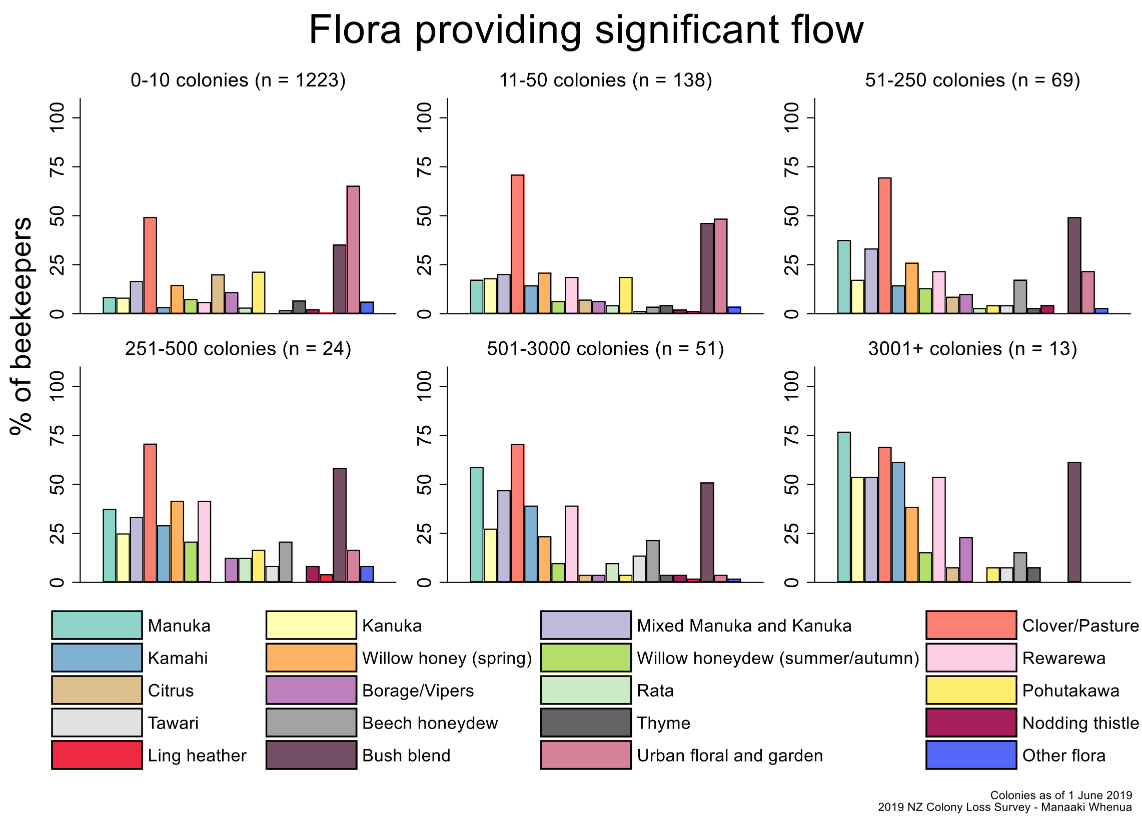

Figure 32: Sources of significant nectar flow during the 2018/19 season, based on reports from all respondents, by operation size.

4.6.6 Supplementary 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[64].

In addition, beekeepers may provide supplemental nutrition such as sugar and pollen supplement, which is needed for the brood, provides protein, lipids, vitamins, and minerals. A variety of protein supplements are commercially available.

Nearly all beekeepers (96.2 percent) with more than 250 colonies used supplemental sugar during the 2018/19 season (Fig. 33), an identical figure to the 2017/18 season.

The highest rates of beekeepers with more than 250 colonies not using any supplemental sugar occurred in the South Island; all responding beekeepers in the North Island used supplemental sugar.

Although supplemental feeding increased among beekeepers with 50 or fewer colonies from the 2016/17 season to the 2017/18 season (from 61 percent to 70 percent), this share dropped to 66 percent for the 2018/19 season (Fig. 34). Sugar solution was most commonly used across all regions and size categories, although, among beekeepers with more than 250 colonies, invert sugar was widely used in the North Island and raw sugar was widely used in the Upper South Island and Middle South Island.

The share of beekeepers with more than 250 colonies providing supplemental protein to their bees dropped from 70.5 percent during the 2017/18 season to 66 percent during the 2018/19 season.

[64] DeGrandi-Hoffman et al. 2016.

Rates of supplemental protein use and type were fairly consistent across regions for beekeepers with more than 250 colonies, with *MegaBee* the most common type of protein supplement (Fig. 35).

Use of supplemental protein increased as operation size increased, going from 19 percent for beekeepers with 0-10 colonies to 92 percent for beekeepers with more than 3000 colonies (Fig. 36). Beekeepers with 50 or fewer colonies used supplemental protein at a higher rate during the 2018/19 season than the 2017/18 season, increasing from 19.6 percent to 21.3 percent.

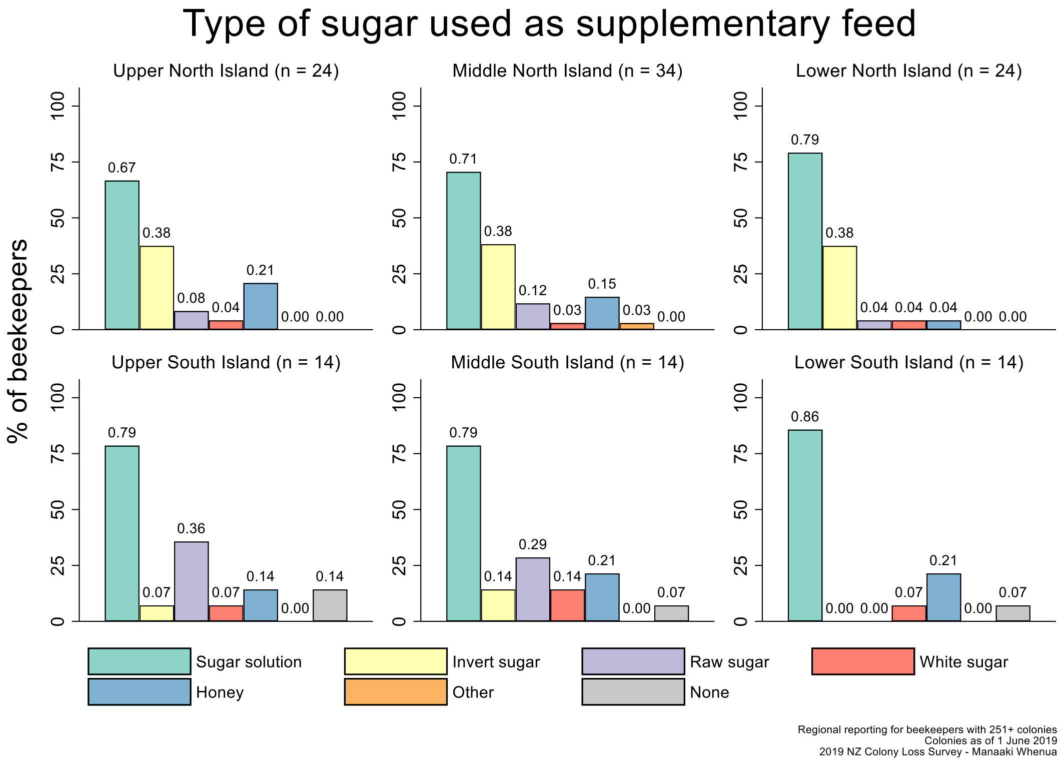

Figure 33: Types of supplemental sugar feed provided to production colonies during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

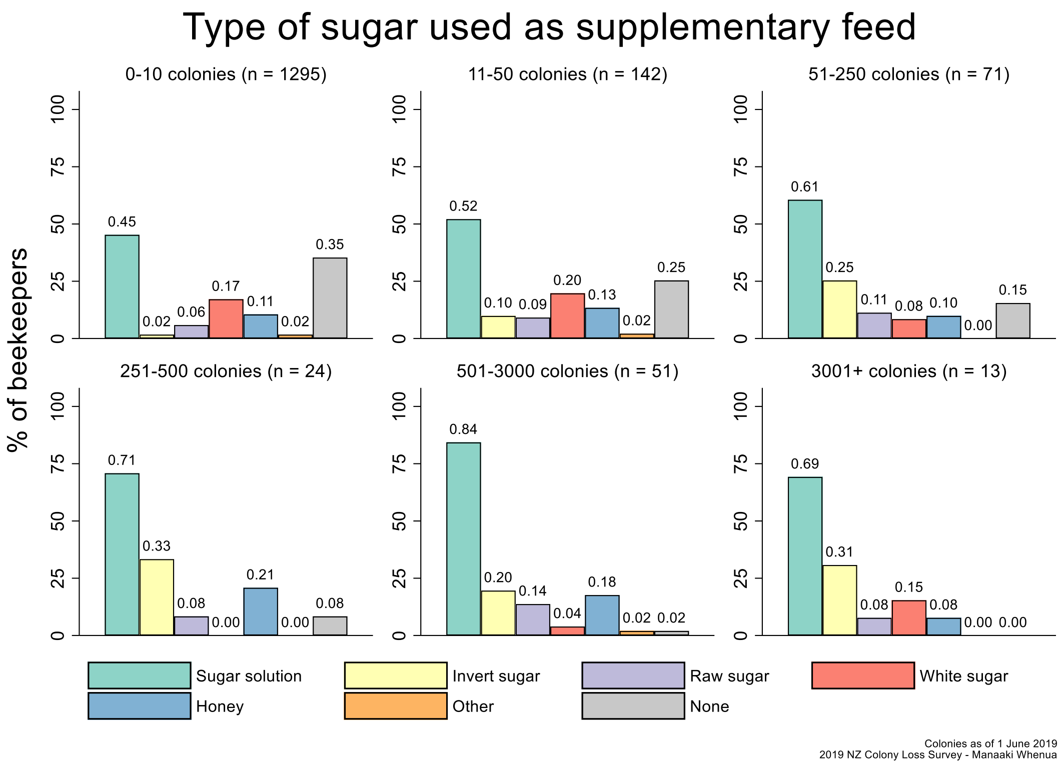

Figure 34: Types of supplemental sugar feed provided to production colonies during the 2018/19 season, based on reports from all respondents, by operation size.

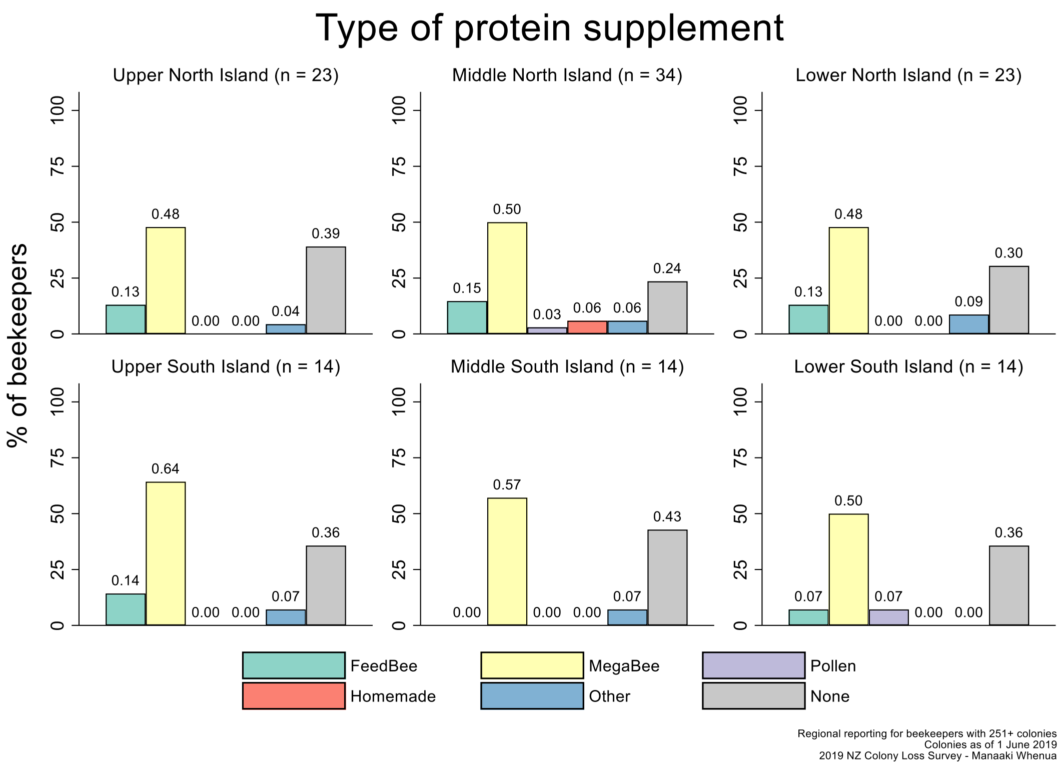

Figure 35: Types of supplemental protein feed provided to production colonies during the 2018/19 season, based on reports from respondents with more than 250 colonies, by region.

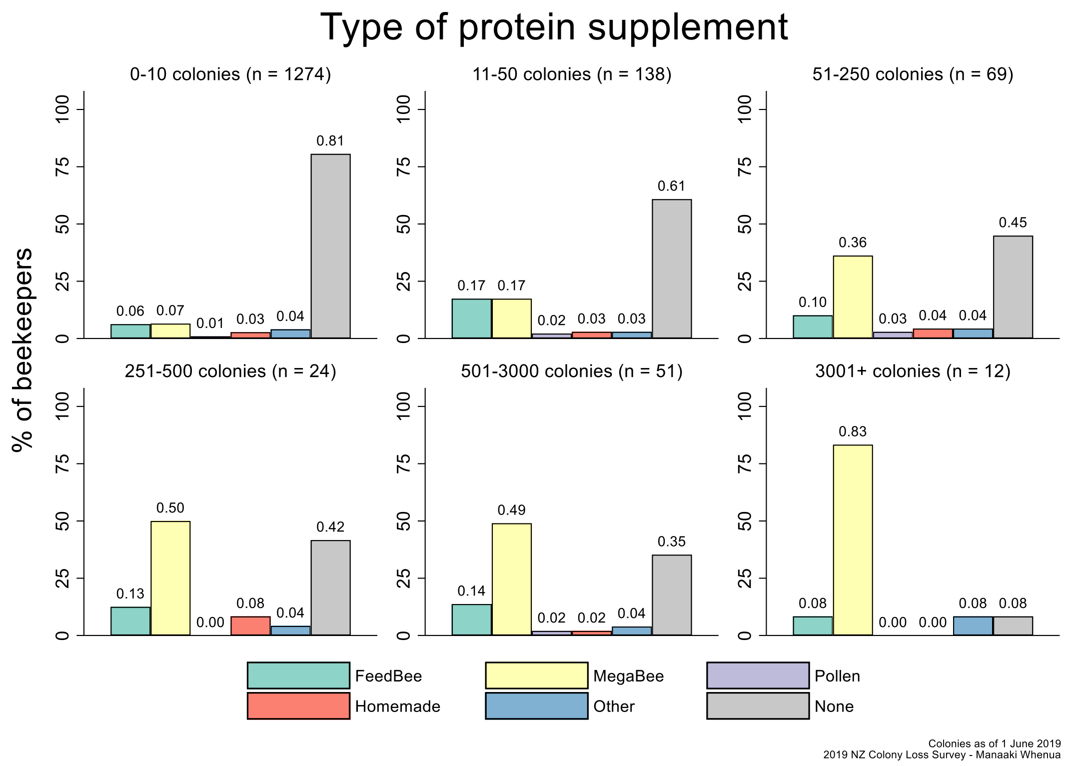

Figure 36: Types of supplemental protein feed provided to production colonies during the 2018/19 season, based on reports from all respondents, by operation size.

4.6.7 Tutin contamination

The 2019 NZ Colony Loss Survey asked respondents what percentage of their honey could not be sold due to high tutin levels. Among beekeepers with more than 250 colonies, high tutin levels appeared to be of little consequence; 94.8 percent of these beekeepers reported having no unsaleable honey due to high tutin levels.

Only the Middle North Island, Lower North Island, and Upper South Island had reports of unsaleable honey due to high tutin levels, each with a low average share (Fig. 37).

Shares of total honey unsaleable due to high tutin levels was fairly consistent across operation size, with an exception for beekeepers with 51-250 colonies (Fig. 38). This was caused by two beekeepers who reported that all of their honey was unsaleable due to high tutin levels.

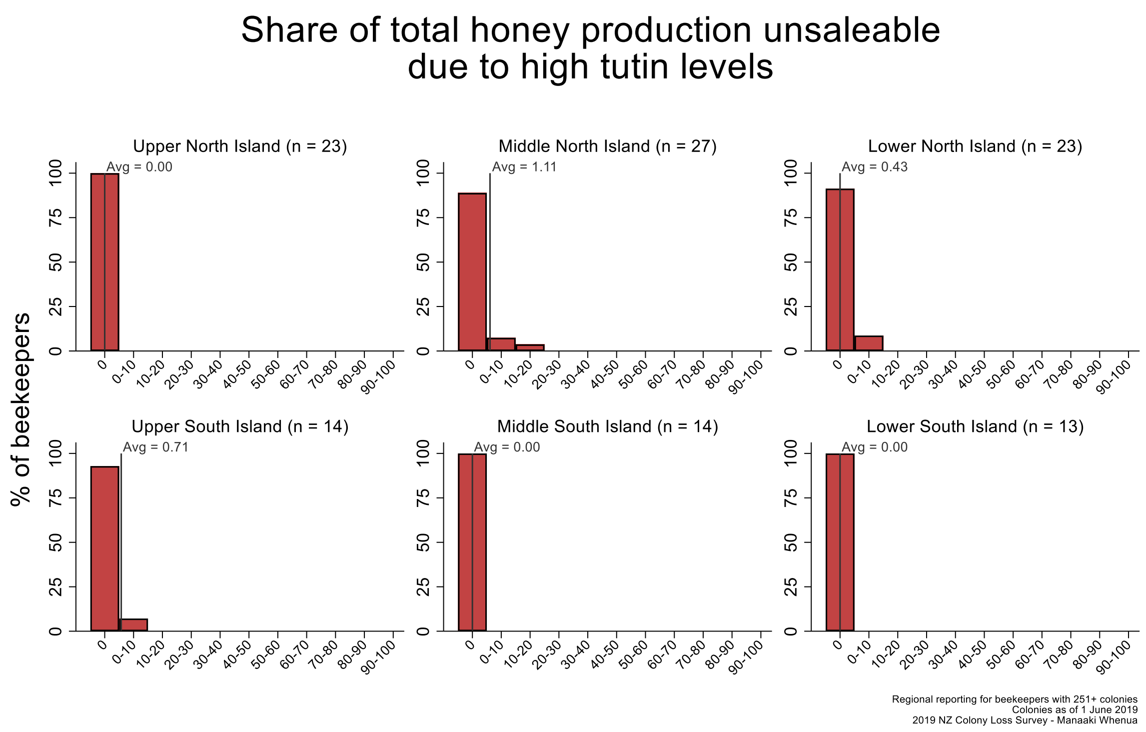

Figure 37: Share of honey that could not be sold during the 2018/19 season due to tutin contamination, based on reports from respondents with more than 250 colonies, by region.

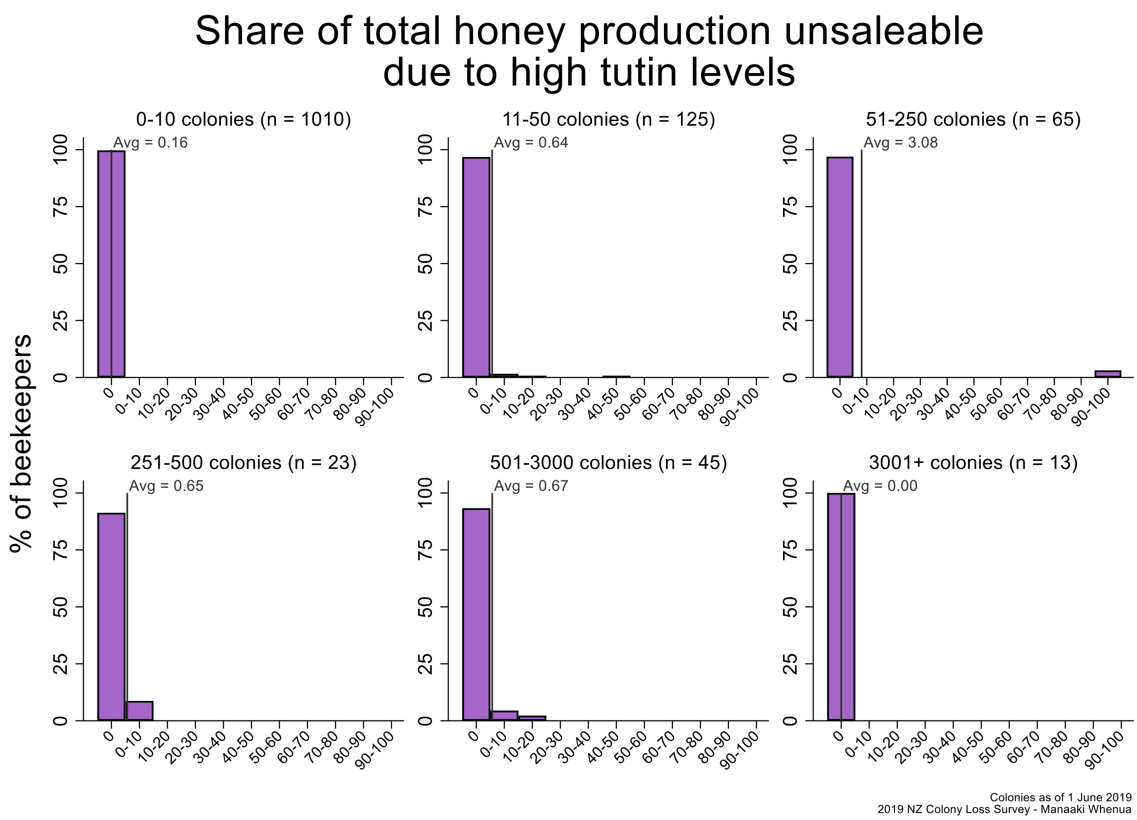

Figure 38: Share of honey that could not be sold during the 2018/19 season due to tutin contamination, based on reports from all respondents, by operation size.

4.7 Apiary losses

Beekeepers typically keep bees based on agreements with landowners. Any rearrangements in permissions by landowners can significantly affect beekeeping operations financially and/or via bee health. Removal of major pollen or nectar sources and the arrival of pests or diseases via relocation of new hives to the area can also result in apiary sites being lost or compromised.

During the 2018/19 season, 15.7 percent of beekeepers with more than 250 colonies reported losing one or more apiary sites to other beekeepers, down from 18.2 percent over the 2017/18 season and down from 32.6 percent over the 2016/17 season.

Overcrowding is another challenge, especially among beekeepers who are unsure of sustainable stocking rates[65]. While losing entire apiary sites due to overcrowding was not common, apiaries being compromised by overcrowding was common, particularly in the Upper North Island, where 52.2 percent of beekeepers with more than 250 colonies reported that overcrowding had compromised their apiaries during the 2018/19 season, down from 63.6 percent over the 2017/18 season and down from 86.3 percent over the 2016/17 season.

Tables 6 and 7 report the average share of apiaries lost or compromised by region (for beekeepers with more than 250 colonies) and operation size, respectively.

Overtaken apiaries were more pronounced in the North Island than in the South Island for beekeepers with more than 250 colonies; not a single respondent in the South Island reported having an apiary overtaken by another beekeeper.

For beekeepers with more than 3000 colonies, a reported average of only 1.6 percent of apiaries were overtaken by other beekeepers during the 2018/19 season, down from 2.8 percent over the 2017/18 season and down from 8.9 percent over the 2016/17 season.

Among small operators, apiaries being overtaken was uncommon; an average of 0.5 percent of apiaries were overtaken for beekeepers with 0-10 colonies and an average of 0.01 percent of apiaries were overtaken for beekeepers with 11-50 colonies.

Beekeepers with more than 250 colonies in the Upper North Island region reported losing an average of 2.5 percent of apiaries due to overcrowding during the 2018/19 season, up from 2.1 percent over the 2017/18 season and down from 4.3 percent over the 2016/17 season. Average apiary loss rates due to overcrowding appear to be uncorrelated with operation size: beekeepers with 0-10 colonies lost an average of 1.8 percent of apiaries to overcrowding while beekeepers with more than 3000 colonies lost an average of 2.0 percent of apiaries to overcrowding. This figure is up from the 2017/18 season for beekeepers with more than 3000 colonies, where an average of 0.6 percent of apiaries were lost.

Apiaries being compromised due to overcrowding was more problematic for larger operators than smaller operators: beekeepers with 50 or fewer colonies had an average of 4.8 percent of apiaries compromised due to overcrowding during the 2018/19 season (up from 4.6 percent over the 2017/18 season) and beekeepers with more than 3000 colonies had an average of 14.7 percent of apiaries compromised due to overcrowding (up from 9 percent over the 2017/18 season).

Losing apiary sites to compromised access to pollen and nectar sources was not a significant problem for beekeepers with more than 250 colonies over the 2018/19 season as only one operator in the Upper North Island reported losing any apiaries (reporting a loss of 2 percent of his or her apiaries).

Among beekeepers with more than 250 colonies, the Upper South Island had the highest average share of compromised apiaries due to the removal of pollen and nectar sources, at 3.2 percent.

The Lower North Island went from having the highest share of compromised apiaries due to the sudden removal of pollen and nectar sources over the 2017/18 season to having the second lowest share during the 2018/19 season, changing from 4.9 percent to 0.9 percent.

Giant willow aphids were first reported in Auckland in late December 2013 and have since spread throughout the country. These pests tap the sugar flow in willow stems, causing willow honeydew to flow, thereby attracting wasps to areas that provide important sources of flow for honey bees. In addition, giant willow aphids transform some of the willow sucrose to glucose and fructose. In this

[65] Ausseil et al. 2018.

process, enzymes attach glucose to sucrose to form the less osmotically active melezitose, which is then present in the honeydew. Bees take this honeydew back to their colonies, where the melezitose crystallises in the comb during the honey-conditioning phase. The crystals are not suitable as food for the bees and they also clog filters during honey extraction. Thus, giant willow aphid may also cause apiaries to be lost and/or compromised.

Among beekeepers with more than 250 colonies, only one operator lost any apiaries due to giant willow aphid, reporting losing 18.7 percent of their apiaries in the Lower North Island.

Although the South Island appeared to experience much higher rates of compromised apiaries due to giant willow aphid than the North Island for beekeepers with more than 250 colonies, these higher rates are driven by one beekeeper for the Upper South Island and one beekeeper for the Lower South Island, with respective compromised rates of 70 and 80 percent.

Operators with moderate to moderate-large operations had the highest rates of compromised apiaries due to giant willow aphid, with beekeepers with 251-500 colonies having the highest average rate of 3.5 percent.

Table 6: Average share of apiaries lost or compromised, based on reports from respondents with more than 250 colonies, by region

	Upper North Island	Middle North Island	Lower North Island	Upper South Island	Middle South Island	Lower South Island
Compromised due to overcrowding	21.52% [3.75%, 39.30%]	9.89% [0.00%, 20.31%]	12.86% [0.00%, 27.34%]	11.57% [0.00%, 30.04%]	4.75% [0.00%, 17.02%]	4.36% [0.00%, 16.14%]
Compromised due to lost pollen/nectar sources	0.87% [0.00%, 4.88%]	2.75% [0.00%, 8.46%]	0.93% [0.00%, 5.07%]	3.21% [0.00%, 13.40%]	1.43% [0.00%, 8.28%]	2.86% [0.00%, 12.48%]
Compromised due to giant willow aphid	0.65% [0.00%, 4.13%]	0.49% [0.00%, 2.94%]	1.17% [0.00%, 5.83%]	5.00% [0.00%, 17.58%]	0.00% [0.00%, 0.00%]	5.71% [0.00%, 19.12%]
Overtaken by other beekeepers	1.43% [0.00%, 6.69%]	1.44% [0.00%, 5.59%]	0.28% [0.00%, 2.59%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]
Lost due to overcrowding	2.54% [0.00%, 9.53%]	0.52% [0.00%, 3.03%]	1.15% [0.00%, 5.76%]	0.11% [0.00%, 2.00%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]
Lost due to lost pollen/nectar sources	0.09% [0.00%, 1.43%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]
Lost due to giant willow aphid	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]	0.81% [0.00%, 4.69%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]

Table 7: Average share of apiaries lost or compromised, based on reports from all respondents, by operation size

	0-10 colonies	11-50 colonies	51-250 colonies	251-500 colonies	501-3000 colonies	+3001 colonies
Compromised due to overcrowding	4.71% [3.52%, 5.88%]	5.94% [1.95%, 9.94%]	14.80% [6.33%, 23.26%]	15.70% [0.00%, 31.43%]	13.63% [3.88%, 23.38%]	14.68% [0.00%, 36.07%]
Compromised due to lost pollen/nectar sources	1.23% [0.61%, 1.84%]	1.12% [0.00%, 2.89%]	0.61% [0.00%, 2.46%]	4.57% [0.00%, 13.59%]	1.87% [0.00%, 5.71%]	1.15% [0.00%, 7.61%]
Compromised due to giant willow aphid	0.20% [0.00%, 0.44%]	0.26% [0.00%, 1.11%]	1.24% [0.00%, 3.89%]	3.48% [0.00%, 11.40%]	2.41% [0.00%, 6.77%]	0.39% [0.00%, 4.13%]
Overtaken by other beekeepers	0.46% [0.08%, 0.83%]	0.01% [0.00%, 0.15%]	1.28% [0.00%, 4.00%]	0.05% [0.00%, 0.95%]	1.26% [0.00%, 4.42%]	1.61% [0.00%, 9.22%]
Lost due to overcrowding	1.83% [1.08%, 2.58%]	0.76% [0.00%, 2.21%]	1.33% [0.00%, 4.11%]	1.25% [0.00%, 5.94%]	0.85% [0.00%, 3.46%]	1.96% [0.00%, 10.34%]
Lost due to lost pollen/nectar sources	0.49% [0.10%, 0.88%]	1.06% [0.00%, 2.77%]	0.09% [0.00%, 0.81%]	0.00% [0.00%, 0.00%]	0.00% [0.00%, 0.00%]	0.15% [0.00%, 2.52%]
Lost due to giant willow aphid	0.10% [0.00%, 0.28%]	0.00% [0.00%, 0.00%]	0.03% [0.00%, 0.44%]	0.00% [0.00%, 0.00%]	0.37% [0.00%, 2.11%]	0.00% [0.00%, 0.00%]

4.8 Acceptable losses

Beginning in 2017, beekeepers were asked to specify the level of over-winter losses (a concept that is referred to as 'economic injury level') that they considered to be economically sustainable. In the 2019 NZ Colony Loss Survey, responses ranged from 0 percent to 100 percent.

The median acceptable loss was 10 percent, identical to the median acceptable loss rates in 2018.

The mean acceptable loss for beekeepers with 50 or fewer colonies for 2019 was 13.0 percent (Fig. 39), down from 18.7 percent in 2018 and down from 16.3 percent in 2017.

Among beekeepers with 51-250 colonies, the mean acceptable loss rate for 2019 was 9.8 percent, down from 11.2 percent in 2018 and down from 11.0 percent in 2017.

Beekeepers with more than 250 colonies reported a mean acceptable loss rate of 12.1 percent in 2019, up from 11.9 percent in 2018 and down from 12.7 percent in 2017.

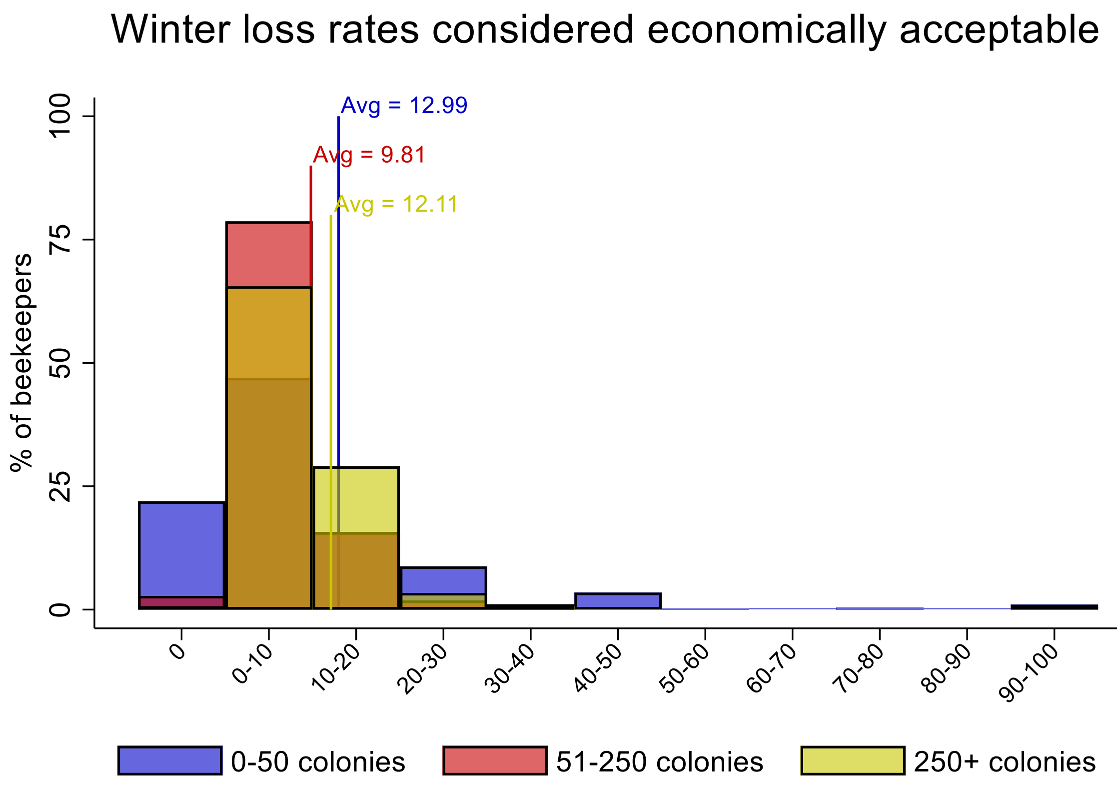

Figure 39: Winter loss rates that are considered economically acceptable, based on reports from all respondents.

5 Discussion

There were 879,178 registered colonies at the beginning of winter 2019. As described in section 2.3, we believe that this figure is overstated by 10.87 percent, i.e. that there were approximately 783,611 actual colonies that had been registered as of 1 June 2019. We estimate the overall winter loss rate to be 10.46 percent, meaning that New Zealand lost approximately 81,965 colonies over winter 2019.

This loss rate is 25 percent higher than our 2015 estimate of 8.37 percent; had the lower loss rate persisted, then New Zealand would have lost approximately 65,588 colonies over winter. Thus, the additional losses attributable to increasing loss rates total approximately 16,377 colonies.

While it is relatively straightforward to quantify losses, it is more difficult to extract the underlying causes of colony losses from a survey[66]. Moreover, economic conditions impact management practices, and thus bee health[67], and several recent studies have begun to assess the effect of management practices and beekeeper experience on colony losses[68] .[69]

Nevertheless, we believe that identifying trends in the attributions of losses is important as a means of identifying emerging threats to the industry.

6 Acknowledgements

We gratefully acknowledge beekeepers who shared their time and expertise in responding to the survey.

We are also grateful to colleagues from AsureQuality, who do yeoman's work to maintain New Zealand hive statistics.

We are further grateful to the dozens of individual beekeepers and scientists who have provided feedback on the questionnaire and who have contributed to its design in many important ways.

Finally, we acknowledge Robert Brodschneider for pointing us to the most recent literature on calculating overall loss rates and for sharing his calculation tool.

[66] Lee et al. 2019; Steinhauer et al. 2019.

[67] DeGrandi-Hoffman et al 2019.

[68] Brodschneider et al. 2016; Jacques et al. 2017; Gray et al. 2019; Sperandio et al. 2019.

[69] Indeed, according to Sperandio et al. (2019), "Knowing the influence of BMPs [beekeeper management practices] to honey bee colonies might support the development of more realistic scenarios for the assessment and management of bee health."

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8 Questionnaire

Q1 Thank you for participating in the 2018 NZ Colony Loss and Survival survey!

This survey is about colony losses over winter 2018. The questionnaire was adapted from similar surveys undertaken in more than 30 countries by the COLOSS honey bee research association. The survey is funded entirely by the Ministry for Primary Industries and Manaaki Whenua - Landcare Research, a Crown Research Institute.

The NZ Colony Loss Survey was conducted in 2015, 2016, and 2017. Last year, more than 2000 beekeepers representing about a quarter million production colonies completed the survey. Click here to see a summary of last year's results.

The survey is designed to be completed after hives have been opened in spring 2018.

Your participation will make it possible to identify trends in New Zealand beekeeping, to compare loss rates across countries, and to use international data to better understand risk factors. There are also several questions that are specific to the challenges and opportunities facing New Zealand beekeepers.

The data collected in the survey are confidential, meaning that you will not be identifiable based on answers that you provide. Read about Manaaki Whenua - Landcare Research's statement on survey privacy and ethics here.

By completing the survey, you will be eligible for a prize draw for a $100 supermarket voucher. Winners will be contacted in December and will be announced on the Manaaki Whenua - Landcare Research website.

The survey takes 10-20 minutes to complete, on average. It can be done on a computer, a tablet, or a smart phone. We think it works best on a computer.

Important note! At the end of each page of questions, click the Next button to move forward. If you don't see the Next button, please scroll down.

Q2 Please click **YES** to begin the survey.

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

Section 1: Apiary managers

Q3 Which of the following best describes your role in this beekeeping operation?

- ○ Owner/partner
- ○ Apiary manager

Q4 Do you personally manage all apiaries?

- ○ Yes
- ○ No

Q5 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 entire 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

Q6 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).

____

Section 2: Winter Losses

Q7 Did you have at least one production colony at the beginning of winter (1 June 2019)?

Please consider colonies that you considered to be queenright and likely to be strong enough to provide a honey harvest and/or pollination services as production colonies.

- ○ Yes
- ○ No

Q8 In which region(s) were your **apiary sites** located during your **first spring round** (spring 2019)?*
Select all that apply. Note that Coromandel is listed separately from Waikato and that Wairarapa is listed separately from Wellington.

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

Q9 How many production colonies did you have on **1 June 2019**? How many production colonies did you acquire or sell/give away over winter? And how many production colonies did you have during your **first spring round** (spring 2019)?

Enter whole numbers only. If you do not have an exact figure, please estimate. Note that Coromandel is listed separately from Waikato and that Wairarapa is listed separately from Wellington.

{For each region:}

_ Viable production colonies **1 June 2019**
_ Production colonies **acquired** after 1 June 2019 (if any)
_ Production colonies **sold/given away** after 1 June 2019 (if any)
_ Living production colonies **first spring round 2019**

Q11 How many **losses of production colonies** over winter 2019 do you attribute to each of the following causes?

Please use your best judgment. If you are uncertain, please list those losses under "Unsure".

{For each region:}

_ Queen problems - Drone-laying queens, no queens, etc.
_ AFB American foulbrood disease. Wasps
_ Robbing by other bees
_ Argentine ants - Ants that attack the brood and honey comb.
_ Suspected starvation - Dead workers in cells and no food present in the hive.
_ Suspected toxic exposure - Many dead bees in or in front of the hive.
_ Suspected varroa and related issues
_ Suspected Nosema - Nosema apis may be marked by a high level of faeces on the front of the hive, although Nosema ceranae has no such diagnostic.
_ Natural disasters - Gale-force winds, flooding, etc.
_ Theft or vandalism
_ Accidents - Damage from livestock, tractors, etc.
_ Other
_ Unsure

Q12 Did any of the production colonies that you had at the beginning of winter 2019 have new queens?

{For each region:}

○ Yes

○ No

Q13 How many of the production colonies that you had at the beginning of winter 2019 had new queens?
If exact numbers are not known, please estimate.
{For each region:} ____

Q14 Which of the following queen problems did you experience over winter 2019?
Select all that apply.

- ☐ New queens disappeared
- ☐ Old queens disappeared
- ☐ New queen was a drone layer
- ☐ Old queen was a drone layer
- ☐ New queen failed (poor brood pattern and/or poor hive build up)
- ☐ Old queen failed (poor brood pattern and/or poor hive build up)
- ☐ Other (please explain) ________
- ☐ Unsure

Q15 How did production colonies with new queens survive winter 2019 relative to production colonies with old queens?

- ○ Much worse than old queens
- ○ Somewhat worse than old queens
- ○ About the same as old queens
- ○ Somewhat better than old queens
- ○ Much better than old queens
- ○ Unsure
- ○ N/A

Q16 Out of all of your queenright hives in spring 2019, how many were weak?
{For each region:} ____

Section 3: 2018-2019 Season (optional)

Q17 Thank you. The part of the survey that focuses on winter 2019 colony losses is complete.
The rest of the survey focuses on topics such as queen performance, varroa monitoring and treatment, floral resources, supplemental feeding, and overcrowding during the 2018-2019 season. There are also some open-ended questions about challenges and opportunities in New Zealand beekeeping.
Are you willing to share your experiences during the 2018-2019 season?

- ○ **YES, take me to the questions about the 2018-2019 season**
- ○ No, skip to this section

Q18 Did you have at least one production colony during the 2018-2019 season?
Please consider colonies that were queenright and strong enough to provide a honey harvest and/or pollination services as production colonies.

- ○ Yes
- ○ No

Q19 How many **production colonies** did you have during your first spring round of 2018? 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 **first spring round of 2018**

_______ Production colonies **acquired by purchase or splitting** during the 2018-2019 season

_______ Production colonies **sold/given** away during the 2018-2019 season

Q20 In which region(s) did you keep your production colonies at any time during the 2018-2019 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 (apart from Coromandel)
- ☐ Bay of Plenty
- ☐ Gisborne
- ☐ Hawke's Bay
- ☐ Taranaki
- ☐ Manawatu-Wanganui
- ☐ Wairarapa
- ☐ Wellington (apart from Wairarapa)
- ☐ Tasman / Nelson
- ☐ Marlborough
- ☐ Canterbury
- ☐ West Coast
- ☐ Otago
- ☐ Southland
- ☐ Chatham Islands

Q21 In general, how do you replace your queens?
Select all that apply.

- ☐ Queen cells (without removing old queen)
- ☐ Queen cells (removing old queen)
- ☐ Mated queens
- ☐ Virgin queens
- ☐ Other (please explain below) __________
- ☐ No queen replacement strategy

Q22 Did you notice bees with signs of deformed wing virus or parasitic mite syndrome in your production colonies during the 2018-2019 season?
{For each region:}
Signs of deformed wing virus - e.g. crippled or deformed wings.

- ○ Yes
- ○ No

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

- ○ Yes
- ○ No

Q23 Did you **monitor** your production colonies for varroa during the 2018-2019 season?
{For each region:}

- ○ Yes
- ○ No

Q24 What methods did you use to monitor your production colonies for varroa during the 2018-2019 season?
Select all that apply.

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

Q25 Did you **treat** varroa during the 2018-2019 season?
{For each region:}

- ○ Yes
- ○ No

Q26 What methods did you use to treat varroa during the 2018-2019 season?
Tick all that apply.
{For each region:}

- ☐ Flumethrin - e.g. Bayverol.Sticky board (or other collection tray below the hive)
- ☐ Amitrazin strips, e.g. Apivar.Visual inspection of adult bees
- ☐ Thymol - e.g. Apigard, ApilifeVar, ThymolVar. Sent sample to a lab
- ☐ Thymol cords
- ☐ Tau-fluvalinate - e.g. Apistan
- ☐ Oxalic acid – sublimation - i.e. evaporation
- ☐ Oxalic acid - dribbling / trickling
- ☐ Oxalic acid - glycerine strips/staples
- ☐ Drone brood removal
- ☐ Formic acid - short term - 3 days or less
- ☐ Formic acid - long term - 4 days or more, e.g. Mite Away Quick Strips
- ☐ Formic acid - very long term - 42-day treatment, e.g. Nassenheider evaporator.
- ☐ Complete brood removal - including queen trapping.
- ☐ Fogging food-grade essential oils - e.g. thymol, wintergreen.
- ☐ Fogging food-grade mineral oil

- [ ] Hyperthermia - i.e. heat treatment of brood / bees.
- [ ] Other (please explain)

Q27 Did you replace any brood combs with comb foundation during the 2018-2019 season?
{For each region:}

- ○ Yes
- ○ No

Q28 Approximately what proportion of brood combs did you replace with comb foundation (per colony) during the 2018-2019 season?
{For each region:}
__ %

Q29 During the 2018-2019 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 propolis and other bee products : ______
Other (please explain) : ______
Total : _______

Q30 Did the majority of your bee colonies have a significant flow on one or more of the following plants during the 2018-2019 season?

Tick all that apply.
{For each region:}

- [ ] Mānuka
- [ ] Kānuka
- [ ] Mixed mānuka and kanuka
- [ ] Clover / pasture
- [ ] Kamahi
- [ ] Willow honey (spring)
- [ ] Willow honeydew (summer-autumn)
- [ ] Rewarewa
- [ ] Citrus
- [ ] Borage / Vipers bugloss

- ☐ Rata
- ☐ Pohutukawa
- ☐ Tawari
- ☐ Beech honeydew
- ☐ Thyme
- ☐ Nodding thistle
- ☐ Ling heather
- ☐ Native bush blend
- ☐ Urban floral and garden
- ☐ Other (please specify)

Q31 During the 2018-2019 season, approximately what share of the mānuka flow came from plantation mānuka?
{For each region:}
__ %

Q32 How did the nectar flow from selected native monoflorals in 2018-2019 compare to 2017-2018?

	M Much worse	SS omewhat worse	A About the same	SS omewhat better	M Much better	U Unsure	N N/A
KKa mahi	○	○	○	○	○	○	○
RRe warewa	○	○	○	○	○	○	○
RRat a	○	○	○	○	○	○	○
PPo hutukaw a	○	○	○	○	○	○	○
TTa wari	○	○	○	○	○	○	○

Q33 Did you have honey that could not be sold due to high tutin levels (and that you were unable to blend to acceptable levels)?

- ○ Yes
- ○ No
- ○ Unsure

Q34 Approximately what percentage of the total honey production was unsaleable due to high tutin levels (that you were unable to blend to acceptable levels)?
__ %

Q35 Did you give any of your colonies a supplemental sugar feed or protein supplements during the 2018-2019 season?
Supplemental sugar feeds include sugar solution, invert sugar, raw sugar, white sugar, and honey. Proteins supplements include FeedBee, MegaBee, dry pollen, and homemade supplements.
Supplemental sugar feed

- ○ Yes
- ○ No

Protein supplements

- ○ Yes
- ○ No

Q36 What type of sugar did you use as a supplementary feed during the 2018-2019 season?
Select all that apply.

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

Q37 What type of protein supplement did you use during the 2017-2018 season?
Select all that apply.

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

Q38 Between the first spring round of 2018 and the first spring round of 2019, 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

Q39 What percentage of all your apiary sites were compromised between the first spring round of 2018 and the first spring round of 2019 due to each of the following reasons?
If you operate in multiple regions, please report the percentage of hives in each region.

{For each region:}
Overcrowding (too many hives close to your apiaries)
Pollen and nectar sources were removed and not replaced
Effects of giant willow aphid
Other (please describe below)

Q40 What percentage of all your apiary sites were lost in their entirety between the first spring round of 2018 and the first spring round of 2019 due to each of the following reasons?
If you operated in multiple regions, please reply with the percentage of hives in each region.

{For each region:}
Overtaken by another beekeeper
Overcrowding (too many hives close to your apiaries)
Pollen and nectar sources were removed and not replaced
Effects of giant willow aphid
Other (please describe below)

Section 4: Beekeeper experience (optional)

Q41 Thank you for sharing your experience with us!
The following questions are optional, but they are very helpful for understanding the current situation for beekeeping in New Zealand.

Q42 Approximately how many years of beekeeping experience do you have?

______ years of beekeeping experience

Q43 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

Q44 What are the key challenges facing New Zealand beekeepers? Are there other problems that we should monitor in future surveys?

____

Q45 What are the key opportunities facing New Zealand beekeepers?

____

Q46 What percent of over-winter losses do you consider to be economically sustainable?

______ % of over-winter losses