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ORIGINAL RESEARCH ARTICLE

# A national survey of managed honey bee 2011-12 winter colony losses in the United States: results from the Bee Informed Partnership

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## Summary

Estimates of winter loss for managed honey bee (*Apis mellifera*) colonies are an important measure of honey bee health and productivity. We used data from 5,500 US beekeepers (5,244 backyard, 189 sideline and 67 commercial beekeepers) who responded to the April 2012 Bee Informed Partnership Winter Colony Loss Survey and calculated loss as the difference in the number of colonies between October 1, 2011 and April 1, 2012, adjusting for increases and decreases over that period. In the US, the total colony loss was 22.5% for the 2011-12 winter; 45.1% (n = 2,482) of respondents reported no colony loss. Total loss during 2011-12 was substantially lower than loss during 2010-11 (29.9%). Of the 4,484 respondents who kept bees in 2010-11 and 2011-12, 72.0% reported that the loss during 2011-12 was smaller or similar to the loss during 2010-11. There was substantial variation in total loss by state (range 6.2% to 47.7%). The average loss per beekeeping operation was 25.4%, but the average loss was not significantly different by operation type (backyard, sideline, commercial). The average self-reported acceptable loss per respondent was 13.7%; 46.8% (n = 2,259) of respondents experienced winter colony losses in excess of the average acceptable loss. Of beekeepers who reported losing at least one colony during 2011-12, the leading self-identified causes of mortality were weak condition in the fall and queen failure. Respondents who indicated poor wintering conditions, CCD, or pesticides as a leading cause of mortality suffered a higher average loss when compared to beekeepers who did not list these as potential causes.

# Encuesta nacional de 2011-12 de pérdidas invernales de colonias de abejas manejadas en los Estados Unidos: resultados de la Asociación “Estar Informado” (Bee Informed)

### Resumen

Las estimaciones de pérdidas invernales de colonias manejadas de la abeja de la miel (*Apis mellifera*) son un indicador importante de la salud y la productividad de la abeja de la miel. Se utilizaron datos de 5.500 apicultores estadounidenses (5.244 con colmenas en el jardín, 189 en linderos y 67 apicultores comerciales) que respondieron a la encuesta sobre pérdida de colonias de abril de 2012 de la Asociación *Bee*

*Informed* (Estar Informado), y se calcularon las pérdidas como la diferencia respecto al número de colonias del 1 de octubre de 2011 y el 1 de abril de 2012, ajustando para el aumento y la disminución durante ese período. En los EE.UU., la pérdida total de colonias fue de 22,5% para el invierno 2011-12; el 45,1% (n = 2.482) de los encuestados informó que no hubo pérdida de colonias. La pérdida total en 2011-12 fue sustancialmente menor que la pérdida durante 2010-11 (29,9%). De los 4.484 encuestados que mantenían abejas en 2010-11 y 2011-12, el 72,0% informó que la pérdida durante 2011-12 fue inferior o similar a la pérdida durante 2010-11. Hubo una variación sustancial en la pérdida total por estado (rango de 6,2% a 47,7%). La pérdida media por asentamiento apícola fue de 25,4%, pero el promedio de pérdida no fue significativamente diferente según el tipo de asentamiento (colmenas en el jardín, en linderos y comerciales). El promedio de pérdida aceptable comunicada por encuestado fue de 13,7%; 46,8% (n = 2.259) de los encuestados experimentó pérdidas invernales de colonias por encima de la pérdida promedio aceptable. De los apicultores que informaron de la pérdida de al menos una colonia en 2011-12, las principales causas de mortalidad identificadas por ellos fueron una débil condición en otoño y el fracaso de la reina. Los encuestados que indicaron malas condiciones invernales, CCD o pesticidas como causa principal de mortalidad sufrieron una ligera pérdida media en comparación con los apicultores que no incluyeron éstos como causas potenciales.

**Keywords:** Honey bee, overwinter, mortality, colony losses, USA, 2011-12

# Introduction

For each of the past five years, high rates of overwintering mortality among honey bee (*Apis mellifera*) colonies have been reported in many European and North American countries (vanEngelsdorp *et al.*, 2007, 2008, 2010, 2011a, 2012; Currie *et al.*, 2010; Neumann and Carreck, 2010; Nguyen *et al.*, 2010; Potts *et al.*, 2010, van der Zee *et al.*, 2012). In the United States (US), high total overwintering losses of 32%, 36%, 29%, 34% and 30% for the winters of 2006-7, 2007-8, 2008-9, 2009-10, and 2010-11 respectively, have been reported (vanEngelsdorp *et al.,* 2007, 2008, 2010, 2011a, and 2012). The reasons for colony losses vary widely by region or country and researchers continue to try to understand the variety of factors that lead to colony loss in honey bees.

Despite a 29% or greater total overwintering loss during the past survey years, there has not been an apparent pronounced decrease in the reported number of honey producing colonies managed by US beekeepers in the subsequent summers (USDA-NASS, 2009, 2010, 2011). In fact, from 2008-10, the United States Department of Agriculture – National Agricultural Statistics Service (USDA –NASS) reported an *increase* in total number of honey-producing colonies starting from 2.34 million colonies in 2008; to 2.50 million in 2009; to 2.68 million in 2010 (USDA-NASS, 2009, 2010, 2011). The most recent USDA-NASS report showed a modest decline of 7% from 2.68 million honey- producing colonies in 2010 to 2.49 million honey-producing colonies in 2011 (USDA-NASS, 2012).

The apparent lack of a direct relationship between reported overwintering losses and total honey producing colony numbers is perhaps best explained by beekeeper behaviour. Beekeepers compensate against high losses by purchasing nucleus colonies, packages or by making splits from their own colonies to increase the number of overwintering colonies. In this way, beekeepers are better able to supply adequate colony numbers to honour spring pollination contracts (vanEngelsdorp and Meixner, 2010). A recent survey of Pacific Northwest beekeepers revealed that in both 2008 and 2009, beekeepers replaced more colonies than they lost in the preceding winter (Caron *et al.,* 2010).

While annual overwintering colony loss surveys do not identify factors responsible for losses, previous surveys have asked beekeepers to self-identify the reasons their colonies died. Among the most mentioned factors have been queen failure, starvation, and varroa (*Varroa destructor*) mites (vanEngelsdorp *et al.*, 2007, 2008, 2010, 2011a). These reports suggest that colony loss is not attributable to a single factor, but rather that multiple factors contribute to colony mortality, indicating that efforts to reduce losses should be diverse.

The purpose of the current report is to estimate the total colony loss as well as the average number of colonies lost per beekeeper during the winter of 2011-12. Further, we sought to identify factors that beekeepers perceived to be associated with their winter losses.

# Materials and methods

## Survey

To estimate winter colony loss for 2011-12, we conducted an online survey of a convenience (non-probability sample of subjects that are easily accessible by the researcher) and snowball (a form of sampling where existing study subjects recruit new subjects from their known acquaintances) sample of beekeepers. A similar method to estimate winter loss has been used since 2006 (vanEngelsdorp *et al.*, 2007, 2008, 2010, 2011b, 2012, 2013). We solicited the response of beekeepers through professional beekeeping and entomology organizations; professional and vocational meetings and presentations; and national (n = 2), state (n = 47), and local (n = 466) beekeeping organizations. In each case, we requested that the link for the survey be forwarded to additional mailing lists or to any individuals that kept bees. We also solicited responses from individual beekeepers through a beekeeping supply company's email list and

| Box 1 | |
|---|---|
| **1.** | In what state(s) did you keep your colonies in 2011? |
| **2.** | How many living colonies did you have on 1 October 2011? |
| **3.** | How many living colonies did you have on 1 April 2012? |
| **4.** | Did you make splits, increases or buy / sell colonies between 1 October 2011 and 1 April 2012? |
| **5.** | How many splits, increases, and / or colonies did you make / buy between 1 October 2011 and 1 April 2012? |
| **6.** | How many splits, increases, and / or colonies did you sell between 1 October 2011 and 1 April 2012? |
| **7.** | What percentage of the colonies that died between 1 October and 1 April were lost without dead bees in the hive or apiary? |
| **8.** | What percentage of loss, over this time period, would you consider acceptable? |
| **9.** | In your opinion, which factor(s) was the main cause(s) of colony death in your operation between 1 October 2011 and 1 April 2012? |
| **10.** | What percentage of your hives did you send to California for almond pollination? |
| **11.** | How many times, on average, did you move your colonies last year? |
| **12.** | Would you be willing to be contacted by our survey team in order to participate in other honey bee related surveys and/or to validate this survey and to receive a summary of survey results? |

through honey bee brokers (n = 16; for almond pollination in California). For further solicitation, we posted announcements in online forums on social media sites like Facebook. For the first time, the Bee Informed Partnership also advertised the survey and the survey link in two beekeeping journals, *American Bee Journal* and *Bee Culture* and had the survey sent to their subscription listservs (Catch the Buzz and ABF Alert). Beekeepers (n = 898) were contacted from the sign-up page on the Bee Informed Partnership website (www.beeinformed.org). A total of 3,498 individual emails were sent to participants from previous year's surveys that had requested they be included in subsequent surveys. All email solicitations requested that the recipient also send the request to other beekeepers. At the end of the survey, additional requests were made for the respondent to 'tell a friend' about the survey and the respondent was allowed to enter email addresses of other beekeepers. We also provided social networking links which we encouraged participants to utilize in order to help recruit participants.

The survey was hosted and stored on our research server (http://participate.beeinformed.org/Surveys/) and was available for response from March 30, 2012 through April 20, 2012. The questions in 2011-12 (Box 1) were similar to questions from previous years.

### Outcomes and other variables

In our analysis, the primary outcome measure was total colony loss (total loss), expressed as a percentage. Total loss was the mean of the difference between the respective sums of the self-reported number of hives on 1 October 2011 and 1 April 2012, minus the sum of the number of splits or additions, plus the number of hives sold, between these dates. A second outcome measure was average colony loss (average loss), which was the mean of the loss for each respondent, also expressed as a percentage. These measures have been outlined by vanEngelsdorp *et al.* (2011b, 2013).

Beekeeping operations were classified into the following types: "backyard beekeepers" - beekeepers managing 50 or fewer colonies; "sideline beekeepers" - beekeepers managing between 51 and 500 colonies; or "commercial beekeepers" – beekeepers managing 501 or more colonies. The number of colonies lost with one of the symptoms of colony collapse disorder (CCD), that is "no dead bees in the hive or apiary" was calculated by multiplying the number of colonies lost in an operation by the reported percentage lost without dead bees in the hive. For state-specific estimates, colonies belonging to operations which managed colonies in more than one state were counted once in each state reported. This same method is used by the USDA-NASS to calculate the state-specific number of honey-producing colonies (USDA-NASS, 2011).

### Statistical analysis

For total loss, we conducted a weighted analysis, using the number of colonies on 1 October 2012 plus splits/additions, minus splits/colonies sold as the weight. We used the Taylor series method to calculate the 95% confidence interval (95% CI) for each estimate of total loss (Woodruff, 1971), which adjusts for the non-independence of the colonies reported by each respondent, resulting in a wider confidence interval than would result if a binomial adjustment was used. We used multiple linear regression, adjusted for operation size, to identify statistically significant differences in total loss for various groups (e.g. self-attributed factors for loss, acceptable colony loss, loss without dead bees present in the hive/apiary). This approach differed from past years' approaches in that the multivariable statistical methods adjusted for possible confounders. We used logistic regression to identify statistically significant differences in the odds of losing colonies without dead bees in the hive. The Kruskal-Wallis rank sum tested the statistical significance of the differences in average loss for self-reported factor for colony death. We compared weighted total losses instead of un-weighted total losses or average losses (as has been done in previous years) in order to adjust for the inherent biases involved in calculating both of these outcomes (see vanEngelsdorp *et al.*, 2010). All analyses were conducted with SAS 9.3®. All statistical tests were two-sided and used $p < 0.05$ to identify statistical significance. Responses for any group with fewer than five respondents were not published to protect the privacy of respondents.

# Results

### Losses

The survey recorded 6,839 responses, of which 1,061 did not indicate residence in the US, 176 did not provide information sufficient to calculate winter loss, and 102 were duplicate responses. The analytic sample was 5,500.

***Table 1.*** Self-reported 2011-12 winter colony loss in comparison to 2010-11 winter colony loss (n = 4,484). This excludes respondents who indicated they did not keep bees in during 2010-2011.

| Winter Loss Comparison | n | Percent |
|---|---|---|
| Lower | 1749 | 41.49 |
| Same | 1285 | 30.49 |
| Higher | 1033 | 24.51 |
| Don't Know | 148 | 3.51 |
| *Missing* | 269 | |

***Table 2.*** Total colony loss (%)[1], by self-reported acceptable level of loss and by operation type (n = 4,826)[2]. [1]Calculated by weighted analysis using proc surveyreg to adjust for operation size and including colony number as the weight. [2]Includes beekeepers who responded to the question "what percentage of loss, over this time period would you consider acceptable?" [3]<50 Colonies Managed [4]50-500 Colonies Managed. [5]>500 Colonies Managed. CI: Confidence Interval.

| Operation Type | Loss Higher than Acceptable | Total Colony Loss (%) | | | p-value |
|---|---|---|---|---|---|
| | | Mean | Lower 95% CI | Upper 95% CI | |
| Backyard[3] | No | 6.21 | 5.61 | 6.81 | <.0001 |
| | **Yes** | 42.17 | 40.62 | 43.72 | |
| Sideline[4] | No | 9.58 | 7.51 | 11.64 | <.0001 |
| | **Yes** | 29.86 | 25.98 | 33.73 | |
| Commercial[5] | No | 6.97 | 4.49 | 9.46 | <.0001 |
| | **Yes** | 27.30 | 23.22 | 31.38 | |

Respondents reported managing 355,532 living colonies on 1 October 2011 (14.2% of the estimated 2.49 million honey-producing colonies being managed in the US in 2011 (USDA-NASS, 2011)) and 365,407 living colonies on 1 April 2012. After adjustment for newly formed colonies (n = 123,789), minus those sold (n = 7,892), respondents reported 365,407 living colonies on 1 April 2012. Thus we calculate a total loss of 22.5% (95% CI: 16.2-28.8) and an average loss of 25.4% (95% CI: 24.5-26.2). Approximately 45% (99.3% of which were backyard beekeepers) reported no colony loss (zero total loss).

Of the 4,484 respondents who kept bees in 2010-11 and 2011-12, 72.0% (n = 3,034) indicated their overwinter loss as smaller or similar compared to the 2010-11 winter (Table 1). Responding beekeepers (4,826 (87.8%)) reported what they considered an acceptable loss over this period; the mean self-reported acceptable loss was 13.7% (95% CI: 13.2-14.2). However, 46.8% (n = 2,259) of respondents experienced actual winter colony losses higher than that mean acceptable loss. The total losses reported by this group were significantly higher than the total losses reported by respondents with losses below what they considered acceptable for each operation size category (Table 2).

## Operational factors associated with loss

There was substantial variation in total and average losses reported by beekeepers in different states. The total loss by state ranged from 6.2% to 47.7% with a median of 22.7% (Table 3; Fig. 1) and average loss by state ranged from 12.2% to 45.2% with a median of 22.5% (Table 3; Fig. 2). While backyard beekeepers reported slightly higher total losses than sideline and commercial beekeepers, the difference was not significant (p = 0.24) (Table 4). Only 118 (2.2% of total) respondents reported maintaining colonies in more than one state and the difference in total loss for managing colonies in one (20.4%; 95% CI: 17.7-23.0) or multiple states (28.8%; 95% CI: 20.7-36.9) was not different (p = 0.09). The difference in average loss for respondents maintaining colonies in more than one state (21.8%; 95% CI: 18.3-25.4) was not significantly different from respondents managing colonies in one state (22.9%; 95% CI: 20.9-25.0)(p = 0.62). Similarly, the overwinter total losses for beekeepers who used their colonies to pollinate almonds (n = 93; 1.8%) were not different from those who did not pollinate almonds, with a 20.1% total loss (95% CI: 13.1-27.1) for almond pollinators and a 22.2% total loss (95% CI: 17.7-26.6) for beekeepers who did not pollinate almonds (p = 0.71). The average loss for beekeepers who did not use their colonies to pollinate almonds (20.8%; 95% CI: 18.1-23.43) was not significantly different from the average loss experienced by almond pollinators (26.6%; 95% CI: 22.0-31.2) (p = 0.07). The total loss for beekeepers who moved their colonies across state lines (n = 739; 14.3%) (21.1%; CI: 17.5-24.8) was not significantly different than the total loss for beekeepers who did not move their colonies across state lines (21.7%; CI: 17.5-25.9) (p = 0.87). Comparably, average loss did not differ significantly between beekeepers who moved their colonies across state lines (22.8%; 95% CI: 20.8-24.9) and those who did not (22.1%; 95% CI: 19.9-24.2) (p = 0.53).

## Reported cause of loss

A total of 3,018 (54.9%) beekeepers reported winter loss and provided a response on whether there was a complete absence of dead bees in the hive or apiary. Of these, 1,073 (35.6%) reported that at least some of their dead colonies were found without dead bees in the hive or apiary. Of the 106,022 colonies that were reported to have died during the survey period, 21,716 (20.5%) died with the symptom of no dead bees in the hive/apiary. Backyard and sideline beekeepers who reported colony loss without dead bees in the hive/ apiary reported significantly higher total losses than beekeepers who did not indicate this factor (Table 5). However, commercial beekeepers had lower total loss when experiencing the lack of dead bees (a symptom of CCD) in comparison to commercial beekeepers without this symptom. We found no significant interaction with operation size when calculating the average loss for beekeepers who did or did not report colony death with the absence of dead bees in the hive; therefore the

***Table 3.*** Number of operations, operation location, number of colonies, average colony loss per operation (%), and total colony loss (%), by state of operation[1]. Note: Respondents who managed colonies in more than one state had all of their colonies counted in each state in which they reported managing colonies. [1]Calculated by weighted analysis using proc surveyreg to adjust for operation size and including colony number as the weight. [2]Data not presented for states with fewer than 5 respondents.

| State | Number of Operations | Operations Exclusively in State (%) | Total Number of Colonies | Colonies Exclusively in State (%) | Average Colony Loss (%) | | | Total Colony Loss (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean | Lower 95% CI | Upper 95% CI | Mean | Lower 95% CI | Upper 95% CI |
| United States | 5500 | N/A | 355,532 | N/A | 25.37 | 24.52 | 26.22 | 22.49 | 16.15 | 28.83 |
| Alabama | 40 | 95.00 | 628 | 98.57 | 13.29 | 5.86 | 20.73 | 7.15 | 1.01 | 13.29 |
| Alaska[2] | 1 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Arizona | 8 | 75.00 | 453 | 49.01 | 22.94 | 6.32 | 39.56 | 24.91 | 11.45 | 38.36 |
| Arkansas | 43 | 97.67 | 446 | 84.98 | 27.99 | 18.59 | 37.39 | 22.70 | 12.55 | 32.85 |
| California | 302 | 85.43 | 340361 | 15.16 | 29.49 | 25.89 | 33.08 | 25.65 | 17.42 | 33.88 |
| Colorado | 130 | 98.46 | 1348 | 78.12 | 38.72 | 32.99 | 44.45 | 31.01 | 23.08 | 38.94 |
| Connecticut | 60 | 91.67 | 701 | 73.04 | 35.23 | 25.43 | 45.03 | 23.24 | 13.26 | 33.22 |
| Delaware | 29 | 89.66 | 471 | 49.47 | 31.64 | 19.22 | 44.05 | 47.72 | 25.25 | 70.18 |
| District of Columbia | 11 | 90.91 | 3066 | 94.19 | 12.24 | 0.00 | 26.98 | 24.62 | 0.00 | 59.87 |
| Florida | 109 | 90.83 | 52406 | 27.06 | 22.54 | 17.42 | 27.66 | 25.55 | 16.47 | 34.63 |
| Georgia | 148 | 93.92 | 17410 | 10.28 | 22.19 | 17.78 | 26.60 | 40.85 | 34.75 | 46.95 |
| Hawaii | 30 | 100.00 | 11719 | 100.00 | 22.82 | 12.10 | 33.54 | 6.16 | 1.36 | 10.95 |
| Idaho | 42 | 90.48 | 12983 | 53.38 | 34.82 | 23.13 | 46.51 | 12.03 | 5.28 | 18.78 |
| Illinois | 94 | 97.87 | 1145 | 68.65 | 29.10 | 22.35 | 35.84 | 41.07 | 28.13 | 54.02 |
| Indiana | 89 | 96.63 | 2251 | 38.47 | 20.40 | 14.61 | 26.19 | 10.87 | 6.99 | 14.75 |
| Iowa | 39 | 97.44 | 2004 | 82.29 | 15.02 | 8.50 | 21.53 | 40.75 | 31.73 | 49.77 |
| Kansas | 23 | 91.30 | 615 | 45.53 | 21.46 | 9.27 | 33.65 | 22.64 | 10.73 | 34.55 |
| Kentucky | 47 | 97.87 | 957 | 94.78 | 25.02 | 16.16 | 33.87 | 30.52 | 15.63 | 45.41 |
| Louisiana | 24 | 100.00 | 6246 | 100.00 | 18.99 | 7.38 | 30.61 | 14.92 | 7.03 | 22.81 |
| Maine | 141 | 95.04 | 37991 | 2.78 | 13.67 | 9.75 | 17.59 | 26.65 | 15.60 | 37.71 |
| Maryland | 338 | 97.93 | 2676 | 75.60 | 18.50 | 15.22 | 21.78 | 25.94 | 15.77 | 36.10 |
| Massachusetts | 222 | 96.40 | 18312 | 11.59 | 30.32 | 25.61 | 35.03 | 20.08 | 15.28 | 24.87 |
| Michigan | 237 | 98.31 | 11597 | 32.65 | 28.62 | 24.13 | 33.11 | 18.16 | 8.03 | 28.29 |
| Minnesota | 63 | 98.41 | 794 | 97.61 | 42.75 | 32.91 | 52.59 | 30.54 | 24.76 | 36.32 |
| Mississippi | 13 | 84.62 | 128119 | 0.07 | 14.33 | 4.54 | 24.12 | 38.66 | 35.45 | 41.86 |
| Missouri | 98 | 97.96 | 1526 | 87.35 | 14.53 | 10.40 | 18.66 | 11.53 | 7.58 | 15.47 |
| Montana | 33 | 81.82 | 27266 | 5.89 | 12.21 | 4.82 | 19.60 | 7.59 | 1.10 | 14.09 |
| Nebraska | 9 | 88.89 | 15083 | 0.25 | 39.81 | 11.96 | 67.67 | 24.19 | 18.93 | 29.45 |
| Nevada | 19 | 78.95 | 1783 | 3.87 | 37.66 | 18.11 | 57.20 | 28.81 | 24.43 | 33.19 |
| New Hampshire | 64 | 90.63 | 943 | 76.03 | 17.72 | 10.92 | 24.53 | 20.28 | 13.55 | 27.01 |
| New Jersey | 72 | 87.50 | 10511 | 7.25 | 18.08 | 11.50 | 24.67 | 19.19 | 14.62 | 23.77 |
| New Mexico | 14 | 100.00 | 229 | 100.00 | 22.80 | 7.77 | 37.83 | 36.09 | 29.27 | 42.91 |
| New York | 193 | 92.75 | 25468 | 9.40 | 25.57 | 21.14 | 29.99 | 29.56 | 17.43 | 41.68 |
| North Carolina | 431 | 97.91 | 4764 | 81.15 | 21.22 | 18.55 | 23.88 | 25.92 | 16.22 | 35.61 |
| North Dakota | 12 | 16.67 | 79599 | 2.65 | 17.50 | 8.06 | 26.94 | 17.96 | 7.52 | 28.40 |
| Ohio | 230 | 98.26 | 5444 | 73.64 | 27.40 | 23.09 | 31.71 | 26.59 | 11.34 | 41.83 |
| Oklahoma | 28 | 100.00 | 166 | 100.00 | 20.63 | 8.81 | 32.45 | 17.59 | 4.39 | 30.78 |
| Oregon | 144 | 91.67 | 37327 | 19.97 | 36.08 | 30.01 | 42.16 | 13.50 | 6.37 | 20.63 |
| Pennsylvania | 707 | 97.03 | 17741 | 29.10 | 28.55 | 25.94 | 31.15 | 37.73 | 31.98 | 43.48 |
| Rhode Island | 31 | 96.77 | 155 | 98.06 | 17.75 | 7.09 | 28.42 | 11.19 | 3.13 | 19.26 |
| South Carolina | 88 | 95.45 | 11431 | 8.50 | 22.17 | 16.21 | 28.14 | 19.50 | 15.46 | 23.54 |
| South Dakota | 7 | 71.43 | 39149 | 0.13 | 19.04 | 0.49 | 37.59 | 15.39 | 0.00 | 30.98 |
| Tennessee | 102 | 95.10 | 1464 | 83.67 | 14.07 | 10.36 | 17.79 | 15.79 | 9.61 | 21.96 |
| Texas | 48 | 91.67 | 136615 | 0.47 | 19.81 | 11.48 | 28.13 | 36.41 | 32.19 | 40.63 |
| Utah | 85 | 97.65 | 4984 | 10.15 | 45.23 | 37.36 | 53.09 | 14.03 | 6.99 | 21.06 |
| Vermont | 90 | 94.44 | 2008 | 38.25 | 34.95 | 27.75 | 42.14 | 17.84 | 4.56 | 31.11 |
| Virginia | 538 | 98.33 | 4105 | 97.98 | 19.74 | 17.35 | 22.12 | 16.73 | 13.01 | 20.45 |
| Washington | 130 | 93.08 | 52656 | 5.73 | 34.81 | 28.67 | 40.95 | 18.51 | 8.77 | 28.26 |
| West Virginia | 51 | 88.24 | 863 | 37.20 | 18.05 | 11.88 | 24.23 | 31.29 | 11.62 | 50.96 |
| Wisconsin | 140 | 96.43 | 1853 | 81.54 | 28.25 | 22.86 | 33.65 | 18.48 | 11.44 | 25.52 |
| Wyoming | 6 | 100.00 | 3772 | 100.00 | 14.28 | 0.00 | 35.35 | 11.43 | 6.38 | 16.49 |

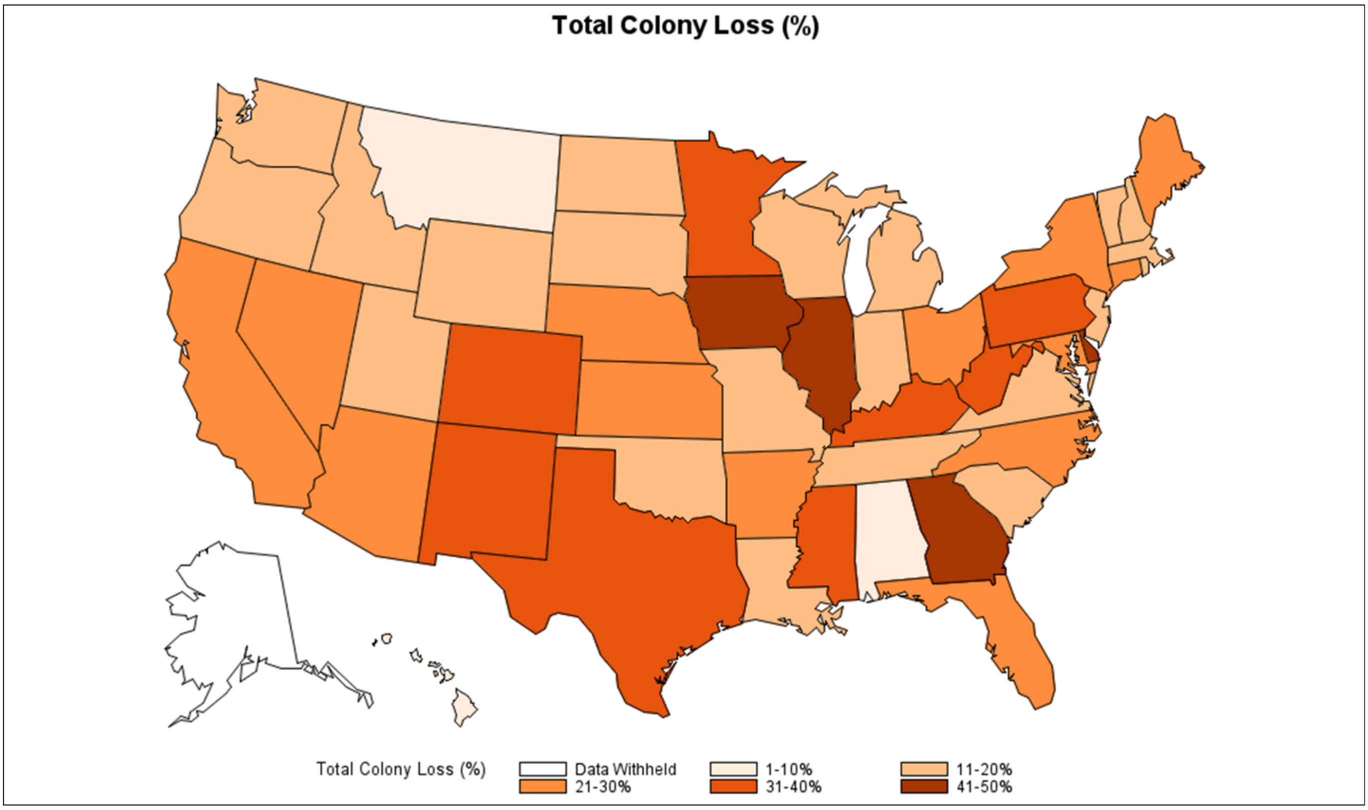


***Fig. 1.*** Total Colony Loss (%), by state. Note: Calculated by weighted analysis using proc surveyreg to adjust for operation size and included colony number as the weight. Respondents who managed colonies in more than one state had all of their colonies counted in each state in which they reported managing colonies. Data for states with fewer than five respondents are withheld.

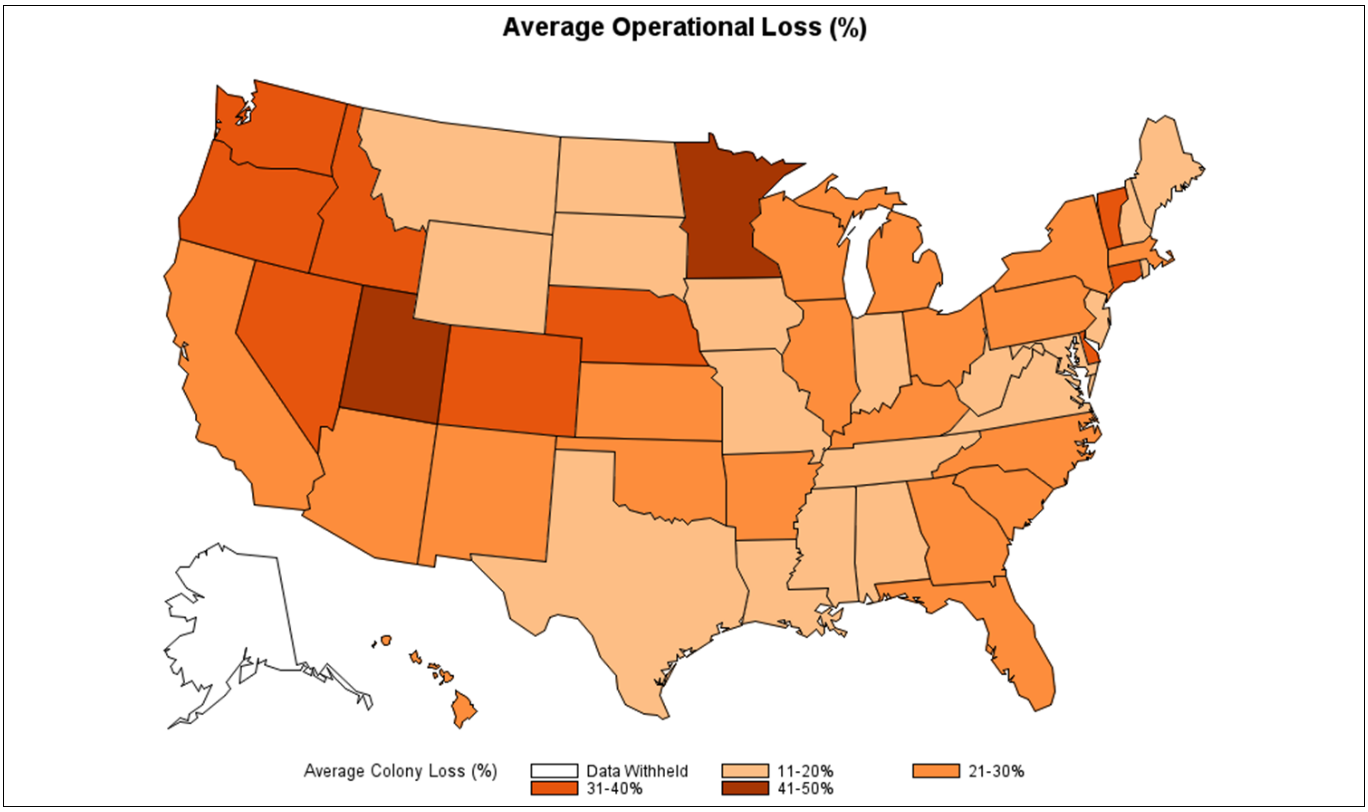


***Fig. 2.*** Average Colony Loss (%), by state. Note: Respondents who managed colonies in more than one state had all of their colonies counted in each state in which they reported managing colonies. Data for states with fewer than five respondents are withheld.

***Table 4.*** Total colony loss (%)[1], by operation type. [1]Calculated by weighted analysis using proc surveyreg to adjust for operation size and including colony number as the weight. [2]<50 Colonies Managed. [3]50-500 Colonies Managed. [4]>500 Colonies Managed.

| Operation Type | Respondents | Total Colony Loss (%) | | |
|---|---|---|---|---|
| | | Mean | Lower 95% CI | Upper 95% CI |
| Backyard[2] | 5244 | 24.79 | 23.73 | 25.85 |
| Sideline[3] | 189 | 22.25 | 19.30 | 25.20 |
| Commercial[4] | 67 | 22.31 | 14.86 | 29.77 |

***Table 5.*** Total colony loss (%)[1], by CCD symptoms and by operation type (n = 3,018)[2]. [1]Calculated by weighted analysis using proc surveyreg to adjust for operation size and including colony number as the weight. [2]Included beekeepers who reported winter colony loss and indicated whether there was a complete absence of dead bees in the hive or apiary. CI: Confidence Interval.

| Operation Type | CCD Symptoms | Total Colony Loss (%) | | | p-value |
|---|---|---|---|---|---|
| | | Mean | Lower 95% CI | Upper 95% CI | |
| Backyard | No | 31.34 | 29.63 | 33.05 | <.0001 |
| | **Yes** | 40.48 | 38.18 | 42.79 | |
| Sideline | No | 18.95 | 15.21 | 22.69 | 0.0099 |
| | **Yes** | 26.41 | 22.15 | 30.67 | |
| Commercial | No | 28.36 | 21.37 | 35.35 | 0.0218 |
| | **Yes** | 18.14 | 12.91 | 23.37 | |

results are not stratified by operation size. Beekeepers who did not report this symptom (27.5%; 95% CI: 25.5-29.5) had a significantly lower average loss than beekeepers who did indicate this factor (34.8%; 95% CI: 32.8-36.9) ($p < 0.01$).

Of the 3,018 survey respondents who reported loss, 95.7% (n = 2,887) recorded a response to the question, "In your opinion, what factors were the main cause (or causes) of colony death in your operation between 1 October 2011 and 1 April 2012?". The most frequently indicated factors attributing to death included: colonies weak in the fall; queen failure; starvation; varroa mites; poor wintering conditions; CCD; pesticides; nosema; and small hive beetles (Tables 6 and 7). Survey respondents who selected poor wintering conditions, CCD or pesticides as a reason for winter colony loss, suffered significantly higher total losses than respondents who did not select these items ($p < 0.0001$, $p = 0.004$, $p = 0.004$, respectively). Beekeepers who indicated queen failure or starvation as a factor contributing to winter loss, experienced significantly lower total losses than beekeepers who selected other factors ($p = 0.03$ and $p = 0.04$, respectively; Table 6). Survey respondents who selected poor wintering conditions, CCD and "don't know", suffered significantly higher average colony losses than respondents who did not select those items ($p < 0.0001$). Beekeepers who indicated weakness in the fall, queen failure and pesticides experienced significantly lower average losses than beekeepers who selected other factors ($p < 0.0001$).

***Table 6.*** Total colony loss (%)[1], by factors reported as a main cause of mortality (n = 2,887)[2]. [1]Calculated by weighted analysis using proc surveyreg to adjust for operation size and including colony number as the weight. [2]Includes respondents who indicated some winter colony loss (> 0%) and who recorded a response to the question "In your opinion, what factors were the main cause (or causes) of colony death in your operation between 1 October 2011 and 1 April 2012?" CI: Confidence Interval.

| Factor | Factor Not Selected | | | | Factor Selected | | | | p-value |
|---|---|---|---|---|---|---|---|---|---|
| | n | Total Colony Loss (%) | | | n | Total Colony Loss (%) | | | |
| | | Mean | Lower 95% CI | Upper 95% CI | | Mean | Lower 95% CI | Upper 95% CI | |
| Weak in the Fall | 1894 | 26.08 | 22.37 | 29.78 | 993 | 24.10 | 18.94 | 29.26 | 0.628 |
| Queen Failure | 1972 | 30.74 | 25.69 | 35.80 | 915 | 21.81 | 18.04 | 25.58 | 0.029 |
| Starvation | 2003 | 27.47 | 24.63 | 30.32 | 884 | 20.89 | 16.64 | 25.13 | 0.037 |
| Varroa | 2382 | 25.10 | 21.51 | 28.69 | 505 | 25.64 | 20.67 | 30.61 | 0.891 |
| Poor Wintering Conditions | 2599 | 24.73 | 22.81 | 26.65 | 288 | 36.71 | 32.14 | 41.28 | <.0001 |
| CCD | 2640 | 23.65 | 21.44 | 25.86 | 247 | 35.99 | 28.65 | 43.33 | 0.004 |
| Pesticides | 2687 | 23.37 | 20.98 | 25.76 | 200 | 33.72 | 28.21 | 39.24 | 0.004 |
| Nosema | 2720 | 25.37 | 22.98 | 27.77 | 167 | 25.13 | 17.39 | 32.88 | 0.718 |
| Small Hive Beetle | 2772 | 25.66 | 23.61 | 27.72 | 115 | 19.78 | 8.50 | 31.05 | 0.337 |
| Don't Know | 2554 | 25.46 | 23.50 | 27.41 | 333 | 21.58 | 13.75 | 29.40 | 0.365 |

***Table 7.*** Average colony loss (%), by factors reported as a main cause of mortality (n = 2,887)[1]. [1]Includes respondents who indicated some winter colony loss (> 0%) and who recorded a response to the question "In your opinion, what factors were the main cause (or causes) of colony death in your operation between 1 October 2011 and 1 April 2012?" CI: Confidence Interval.

| | **Factor Not Selected** | | | | **Factor Selected** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Average Colony Loss (%)** | | | | **Average Colony Loss (%)** | | | |
| **Factor** | **n** | **Mean** | **Lower 95% CI** | **Upper 95% CI** | **n** | **Mean** | **Lower 95% CI** | **Upper 95% CI** | **p-value** |
| Weak in the Fall | 1894 | 48.06 | 46.67 | 49.45 | 993 | 42.10 | 40.32 | 43.89 | <.0001 |
| Queen Failure | 1972 | 49.18 | 47.83 | 50.53 | 915 | 39.19 | 37.34 | 41.03 | <.0001 |
| Starvation | 2003 | 46.43 | 45.09 | 47.78 | 884 | 45.05 | 43.12 | 46.98 | 0.4757 |
| Varroa | 2382 | 46.25 | 45.03 | 47.47 | 505 | 44.86 | 42.25 | 47.48 | 0.3404 |
| Poor Wintering Conditions | 2599 | 41.55 | 37.46 | 45.64 | 288 | 56.98 | 53.50 | 60.46 | <.0001 |
| CCD | 2640 | 45.06 | 43.90 | 46.21 | 247 | 56.20 | 52.55 | 59.85 | <.0001 |
| Pesticides | 2687 | 56.98 | 53.50 | 60.46 | 200 | 53.59 | 49.58 | 57.60 | <.0001 |
| Nosema | 2720 | 46.28 | 45.14 | 47.43 | 167 | 41.55 | 37.46 | 45.64 | 0.1007 |
| Small Hive Beetle | 2772 | 46.08 | 44.95 | 47.21 | 115 | 44.29 | 38.86 | 49.71 | 0.6083 |
| Don't Know | 2554 | 44.63 | 43.47 | 45.79 | 333 | 56.59 | 53.20 | 59.98 | <.0001 |

# Discussion

This survey is the latest of six consecutive annual estimates of overwintering colony losses for the US. This past winter, for the first time, total losses (22.5%) were considerably less than 30.5%, the six-year mean total loss documented by past winter loss survey efforts. This survey was not designed to elucidate the causes of winter colony losses; therefore attempts to explain the apparent decrease are speculative. The difference may be a result of a change in our respondent pool. Like past surveys, this survey cannot be considered representative of all beekeepers. Without a comprehensive census of US beekeepers the use of a convenience sample of respondents may have biased results. However, our finding that 72% of responding beekeepers who kept bees over 2010-11 as well as 2011-12 reported losing the same or fewer colonies this last winter suggests that the decreased rate of loss reported here is, in fact, real.

Another factor which may have helped keep losses low was the comparatively mild winter during 2011-12 experienced across the contiguous US (Climate Watch Magazine). The 2011-12 winter was the fourth warmest of the past 117 for which records have been kept. Previously, milder winter temperatures were found to be related to increased winter survivorship in the state of Pennsylvania (vanEngelsdorp *et al.*, 2008). Further, since the winter of 2008-09 "poor wintering conditions" has been ranked among the top three self-identified causes for winter losses, with an average of 33% of beekeepers identifying it as an important cause of colony death. However, during 2011-12, only 9% of respondents listed poor winter weather as an important contributor to colony losses. Interestingly, beekeepers who indicated this factor lost significantly more colonies than those who did not list poor winter conditions as a cause of colony mortality (Table 6 and 7).

The decrease in total winter colony loss seen for the 2011-12 winter (in comparison to the previous five winters) is encouraging. However, this loss rate still remains well above what beekeepers consider "acceptable". Almost 47% experienced losses above this acceptable level. Indeed the average loss reported in this study (25.4%) is 11.7 percentage points, or 86%, higher than the rate of loss beekeepers report consider acceptable (13.7%). Thus, despite reduced losses as we report here, efforts aimed at understanding and reducing winter colony losses should remain a high priority.

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