

Bee Informed Partnership: Sentinel Apiary Program

2021 End-of-Year Report

2/4/2022

College Park, MD

2021 Sentinel Apiary Program



Dear Sentinel Participant,

Thank you for joining us for the 2021 Sentinel Apiary Program season!

Last year brought several big changes to the program, including:

- A long-awaited mobile app that allows participants to upload inspection data to our database.
- An online dashboard that allows participants to download results directly from our database.
- Monthly webinars exclusively for participants.
- A 12-colony kit.
- A t-shirt free with registration.

We also completed our three-year partnership with the American Beekeeping Federation, who once again generously sponsored \$100 Sentinel discounts for their participating members. Along with ABF, we are grateful that several other organizations offered sponsorships to their members—thank you to the individuals and organizations who made this possible! We're thrilled to continue expanding this exciting opportunity in 2022, so please reach out to rkuipers@umd.edu if your club is interested in learning more.

In 2022, we look forward to continuing the improvement of our new additions to the program as well as adding one more big change: **we're excited to announce that instead of six months of *Nosema* results, we'll be providing two months of *Nosema* results in the early part of the season and one composite pesticide sample later in the year. We will continue to provide six months of *Varroa* results as usual.** We will discuss this research-based change in one of our monthly webinars once the season begins. The educational portions of the webinars will be recorded and linked on our site (beeinformed.org/sentinel). Please contact us with questions or concerns. In addition, this year kits will again include paper datasheets.

As always, we want to extend our deepest gratitude for your participation in the program. Every year we strive to better serve beekeepers and honey bee research, and we are incredibly thankful to have such passionate, involved participants helping us further develop Sentinel!

This report is a summary of the *Varroa*, *Nosema*, and colony management information we collected in 2021. In the spring of 2022, we will contact you to assess the state of your Sentinel colonies (survival) over the winter. We hope you enjoy this delve into the 2021 season; don't forget to stay on the lookout for more updates about the program and future studies!

Happy beekeeping,

A handwritten signature in black ink, appearing to read "Rachel Kuipers".

Rachel Kuipers,
Sentinel Apiary Program Coordinator

A handwritten signature in black ink, appearing to read "Nathalie Steinhauer".

Nathalie Steinhauer,
Research Coordinator

And the whole Bee Informed Partnership team.

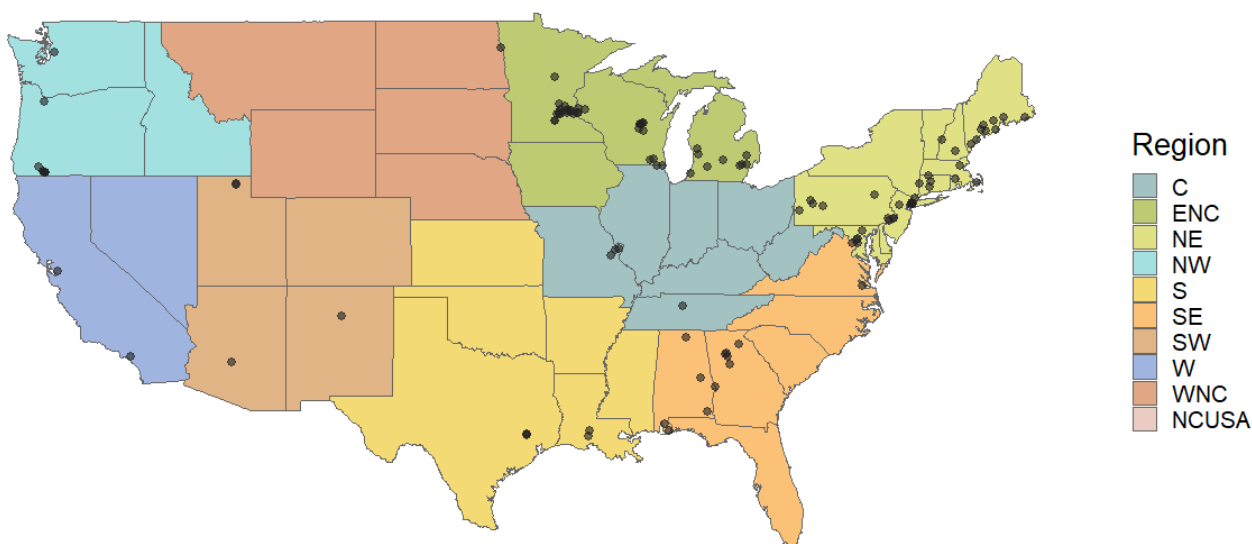
Sentinel Apiaries



This year, **92 participants** took part in the program, collecting data from **531 honey bee colonies** placed in **129 different locations**. A total of **2,433 records** were received and processed by the University of Maryland Honey Bee Lab between the months of April and November 2021, an increase of 28% from the previous year. This total includes inspection data uploads as well as management data uploads.

Most samples came from the East North Central region of the U.S., followed by the Northeast and Southeast regions. We received samples from eight of the nine NOAA climatic regions¹, as well as from the non-continental U.S. (not mapped)!

Figure 1. Distribution of 2021 Sentinel Apiaries by Region



Legend: C = Central; ENC = East North Central; NE = Northeast; NW = Northwest; S = South; SE = Southeast; SW = Southwest; W = West; WNC = West North Central; NCUSA = Non-Continental USA (not mapped).

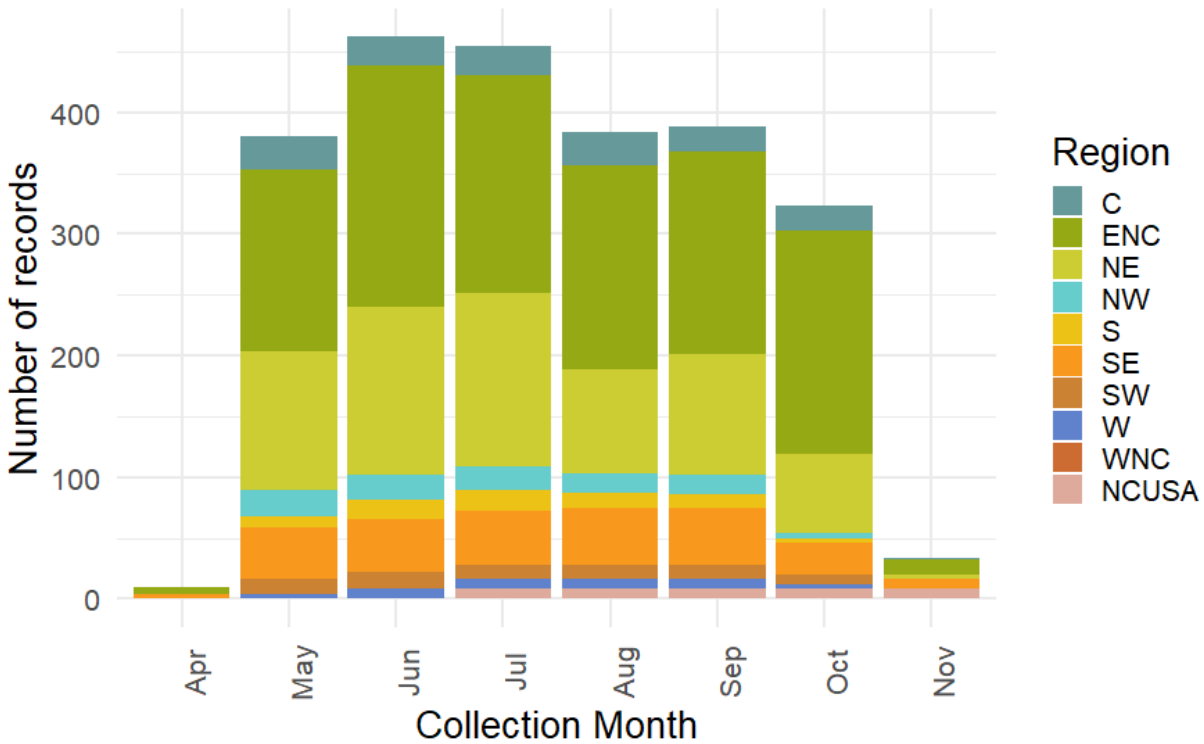
Table 1. Distribution of 2021 Sentinel Samples by Region

	C	ENC	NE	NW	S	SE	SW	W	WNC	NC USA	Total
Participants	6	29	31	3	3	13	3	2	NA	2	92
Locations	6	45	42	8	5	13	4	2	NA	3	128
Colonies	29	199	172	21	17	56	13	8	NA	16	531
Records	144	1,062	648	98	70	261	70	40	NA	40	2,433

¹ NOAA climatic regions: <https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php>

On average, participants sent in just under five months' worth of samples out of the six sampling months. Samples were received from April to November, but the most intensive sampling months were June and July.

Figure 2. Records Submitted by Region, Sample Collection Month



Legend: C = Central; ENC = East North Central; NE = Northeast; NW = Northwest; S = South; SE = Southeast; SW = Southwest; W = West; WNC = West North Central; NCUSA = Non-Continental USA.

Table 2. Distribution of Participants, Locations, Colonies, and Records by Sample Collection Month

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Participants	2	71	81	83	72	70	56	8
Locations	2	98	109	115	95	92	71	10
Colonies	8	373	441	441	384	388	304	32
Records	9	380	462	454	384	388	323	33



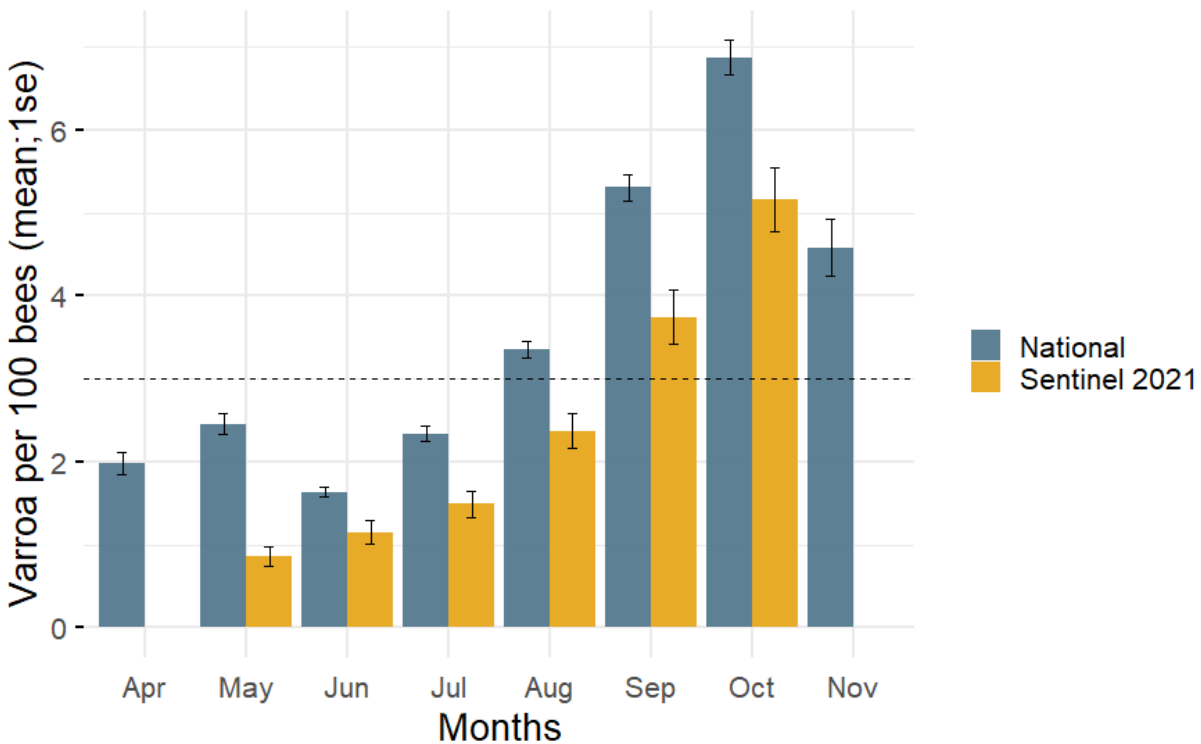
Varroa Summary

In 2021, the lab processed a total of **2,312 Varroa samples**. Figure 3 (below) shows the average *Varroa* load by month compared to national averages. The national averages originated from an independent survey effort: the **National Honey Bee Disease Survey (NHBS)**², funded by USDA APHIS and organized by the University of Maryland Honey Bee Lab in collaboration with the Apiary Inspectors of America. The NHBS averages include data collected from 2009 to 2020 (2021 data not available at the time of analysis).

The dotted line represents the threshold of 3 mites per 100 bees, usually considered the damage threshold of *Varroa* infestations (though action thresholds vary by locality and time of year). For more details about action and damage thresholds, please refer to the latest version of the Honey Bee Health Coalition *Varroa* Management Guide (honeybeehealthcoalition.org/resources/varroa-management/).

This year’s Sentinel apiaries showed *Varroa* loads on par with the trend of increasing *Varroa* pressure over the season, with a peak in the fall. Sentinel participants showed systematically lower detectable *Varroa* loads than the national average levels (from 2009 to 2020).

Figure 3. Average Detected Varroa Load by Sample Collection Month



Months with fewer than 30 samples are not represented.
1se (y-axis label) = 1 standard error (i.e., 1 approximate standard deviation).

² For more information about the National Honey Bee Disease Survey (NHBS):
<https://ushoneybeehealthsurvey.info/>
https://research.beeinformed.org/state_reports/

Table 3. Summary Statistics for Varroa Samples Collected from the 2021 Sentinel Season

Month	Number of samples	Mean infestation load [95% CI*] (mites per 100 bees)	Prevalence [95% CI] (% of samples)	% above threshold (3%) [95% CI] (% of samples)
Apr	<30	[R]**	[R]	[R]
May	373	0.9 [0.6 - 1.1]	39.4 [34.5 - 44.6]	7.8 [5.4 - 11.1]
Jun	437	1.1 [0.9 - 1.4]	48.3 [43.5 - 53.1]	9.6 [7.1 - 12.9]
Jul	425	1.5 [1.2 - 1.8]	57.2 [52.3 - 61.9]	15.8 [12.5 - 19.7]
Aug	372	2.4 [2 - 2.8]	78.8 [74.2 - 82.7]	21.2 [17.3 - 25.8]
Sep	384	3.7 [3.1 - 4.4]	82.6 [78.3 - 86.1]	33.9 [29.2 - 38.9]
Oct	298	5.2 [4.4 - 5.9]	81.9 [76.9 - 86]	49.3 [43.5 - 55.1]
Nov	<30	[R]	[R]	[R]
Overall	2,312	2.3 [2.2 - 2.5]	63.7 [61.7 - 65.6]	21.6 [20 - 23.4]

* CI = Confidence Interval: the probability that the true mean (i.e., the mean of the entire population) falls within the given range (the margin of error). For example, 1.1 [0.9 - 1.4] means that the observed average is 1.1 mites per 100 bees and the margin of error is 0.9 - 1.4, so there's a 95% chance that the true overall population mean falls between 0.9 and 1.4. This does not mean that 95% of samples will fall within the given range.

** [R] = Redacted; months with fewer than 30 samples are not represented.

Figure 4. Average Detected Varroa Load by Sample Collection Month, Years 2018 to 2021

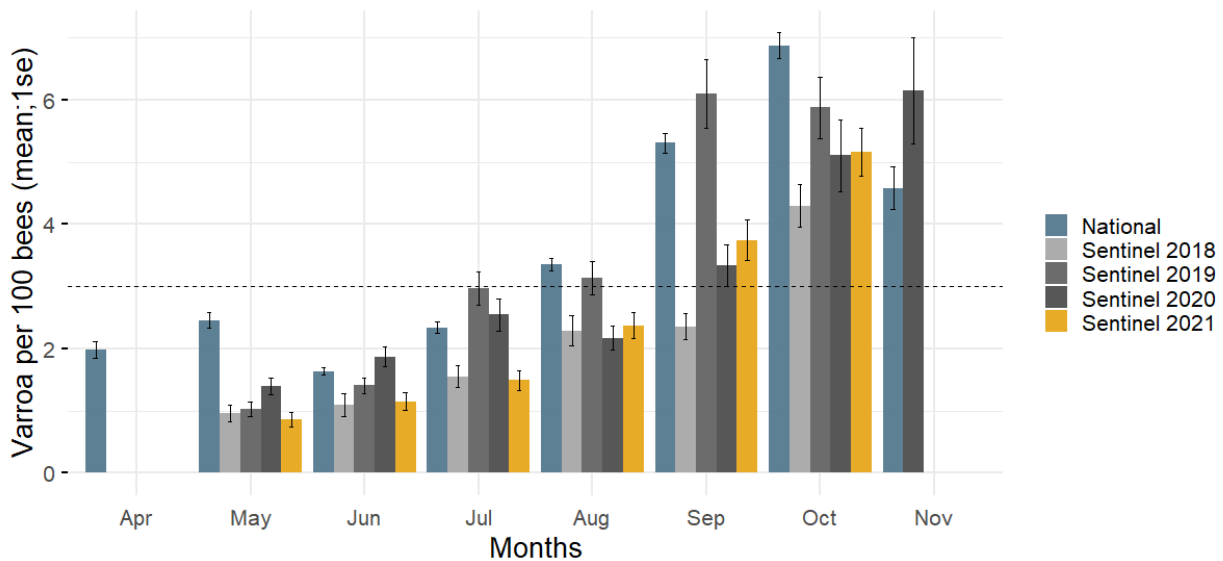
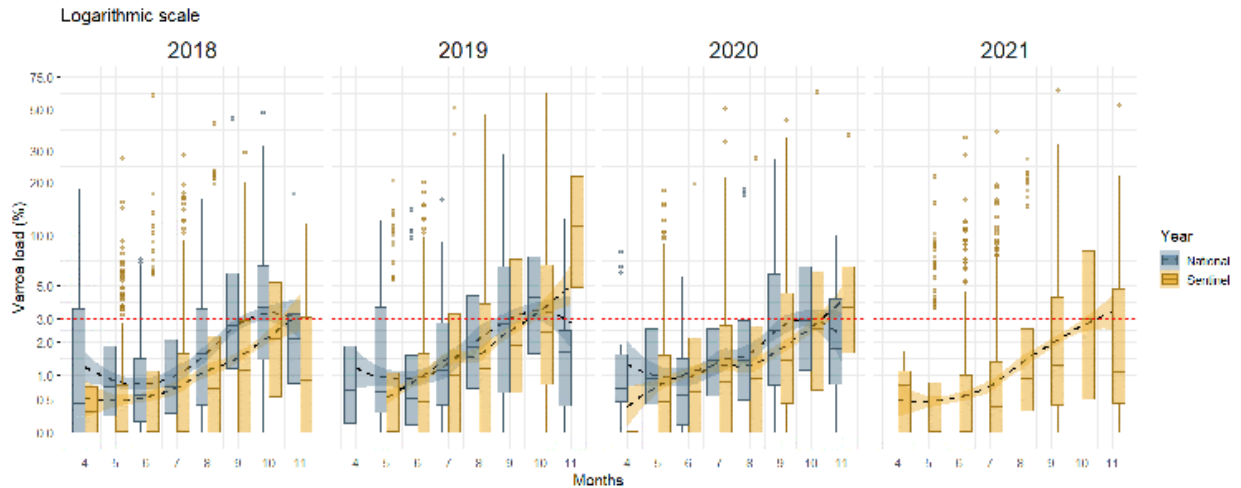


Figure 4 shows the same data as Figure 3, with the addition of previous years (2018 to 2020) of Sentinel Apiary Program data for comparison. National numbers originated from the APHIS NHBS and include survey years 2009 to 2020.

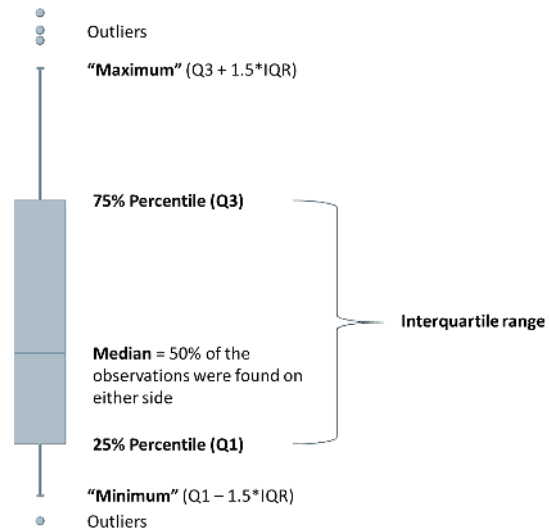
Figure 5. Distribution of Varroa Loads (in Mites per 100 Bees) per Sample



Distribution of Varroa infestation loads per sample collected through the Sentinel Apiary Program and the NHBS from 2018 to 2021 (2021 NHBS data not available at the time of analysis). Smoothed estimate provided by the locally weighted regression method (LOESS). See Figure 5.1 (below) for more information about quartiles.

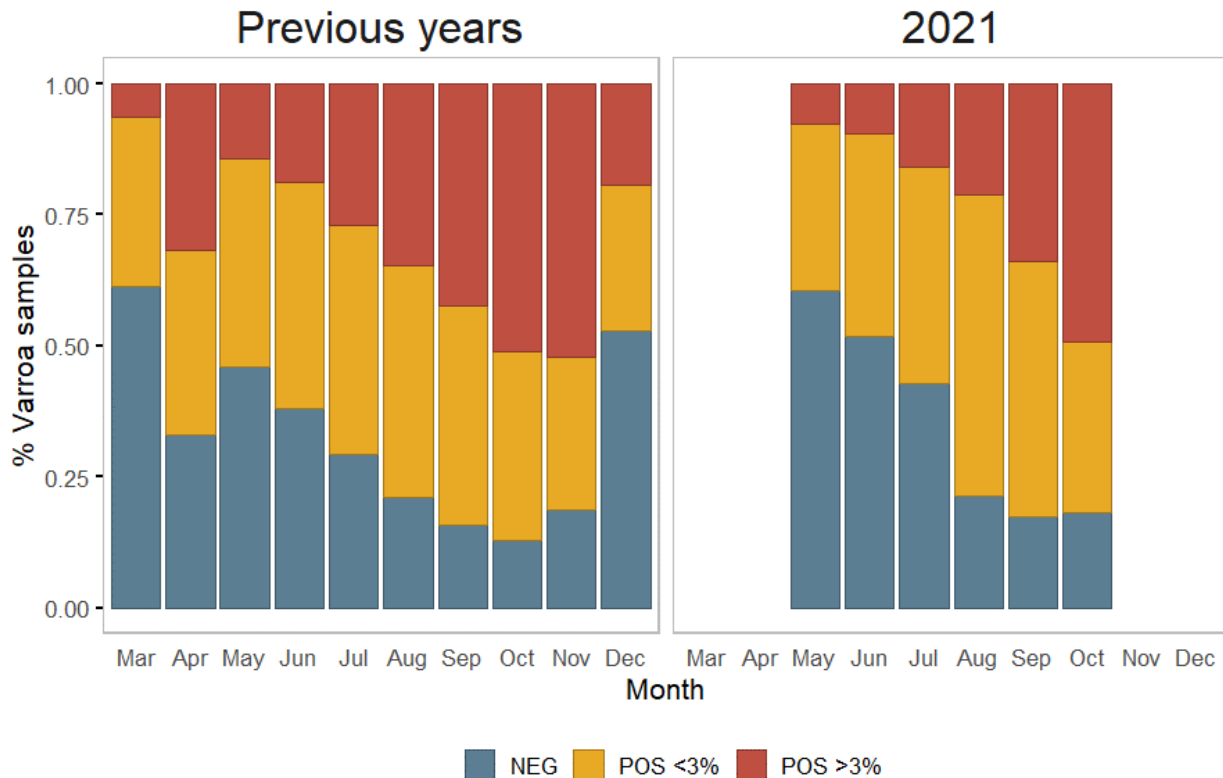
Figure 5.1. Explanation of Quartiles

Figure 5 (above) represents the range of the *Varroa* loads observed for each month, as opposed to the average shown in Figure 4 (page 6). The horizontal central line of each rectangle represents the median, with the top and bottom sections representing the 75th and 25th percentiles (respectively) of the observations. The vertical lines above and below the rectangle extend to the maximum and minimum (respectively). Observations that are too distant from the rest of the distribution are referred to as outliers and are presented as individual dots.



We detected *Varroa* in **over 60% of the Sentinel samples** received in 2021 (Table 3, Figure 6). The percentage of samples (POS) containing *Varroa* increased throughout the season (orange and red in Figure 6). From those samples with detectable mite loads, the fraction of those reaching the threshold value of 3 mites per 100 bees (red) also increased over the months. By October 2021, 82% of samples were found to be positive, with 50% of samples above the action threshold of a 3% mite infestation. This trend is on par with previous years of Sentinel data.

Figure 6. Fraction of Samples as Categorized by *Varroa* Infestation Level

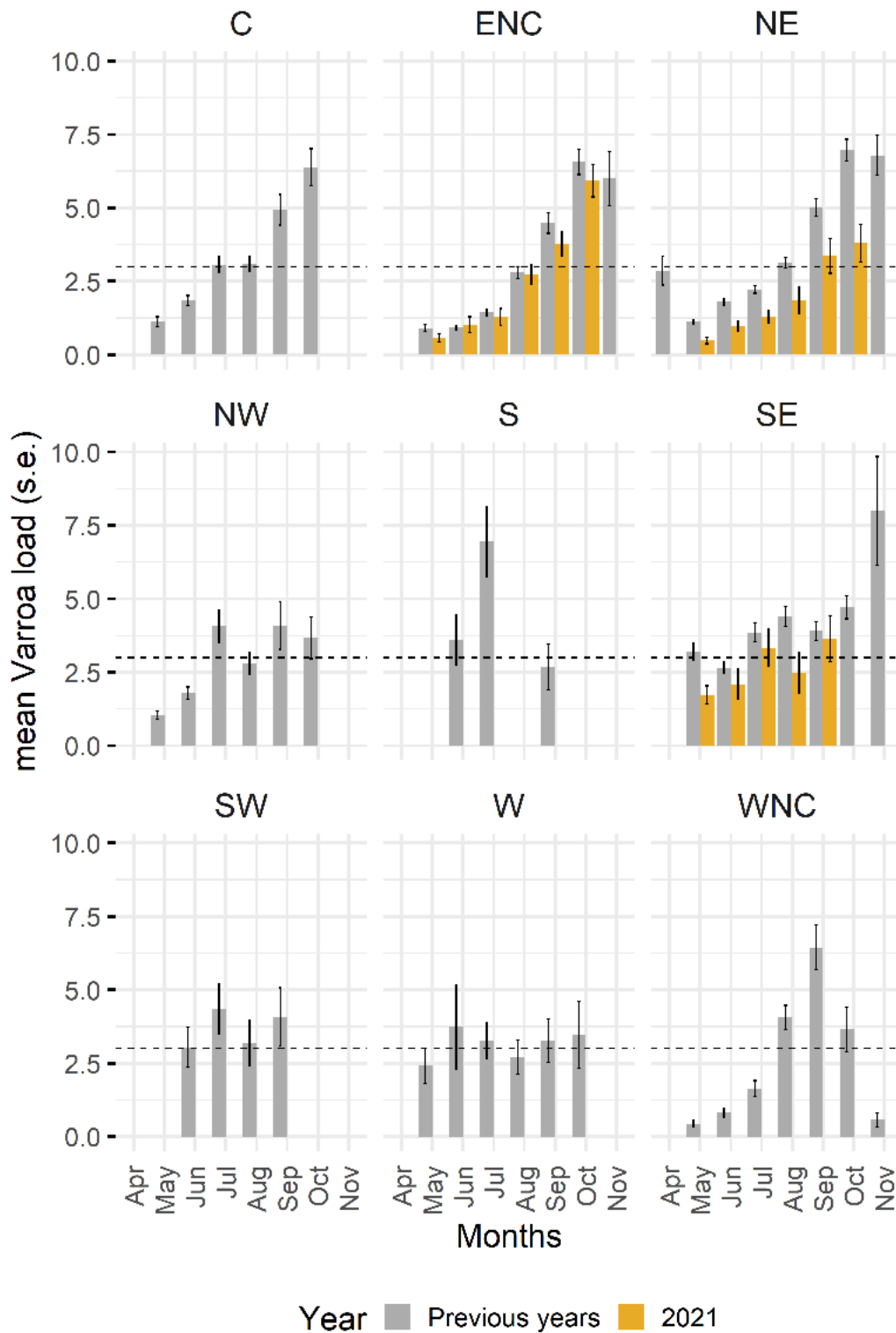


Data from previous years (left) include results from the 2013 to 2020 Sentinel seasons.

Legend: NEG = negative: no mites were found; POS <3% = positive: below threshold level of 3% mite infestation; POS >3% = positive: above threshold level of 3% mite infestation.

Over the years, we have noted different seasonal trends of *Varroa* loads by region. In 2021, we had multiple participants from three out of the nine NOAA regions (ENC, NE and SE). Below are the regional monthly averages of *Varroa* loads compared with the monthly average *Varroa* loads observed in previous years of Sentinel. We hope that future participation throughout the nine regions will allow us to fill in the gaps of our regional baselines.

Figure 7. Comparing Previous Sentinel Data (2013 to 2020) with 2021 Average Varroa Load Infestations (in Mites per 100 Bees) by Region, Sample Collection Month



Groups with fewer than 30 samples are not represented.

Legend: C = Central; ENC = East North Central; NE = Northeast; NW = Northwest; S = South; SE = Southeast; SW = Southwest; W = West; WNC = West North Central; NCUSA = Non-Continental USA; s.e. = standard error (i.e., approximate standard deviation).

Nosema Summary

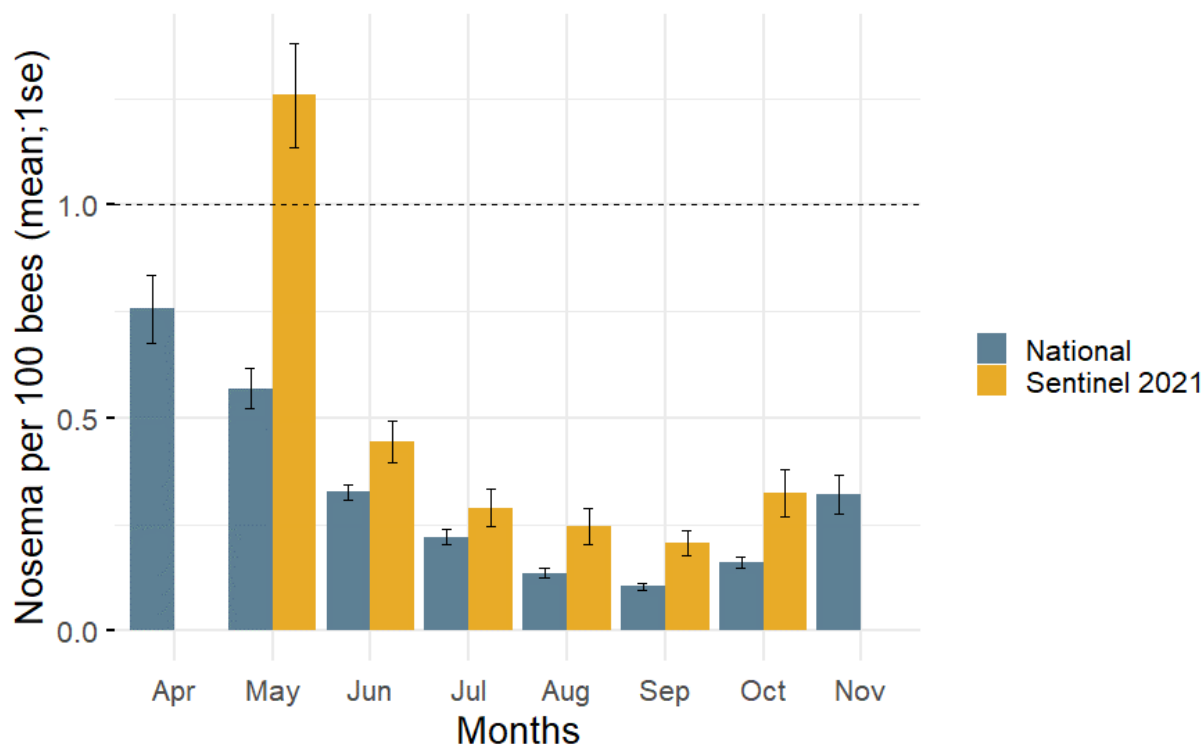


In 2021, the lab processed a total of **2,249 *Nosema* samples** at the time of analysis. Figure 8 (below) shows the average *Nosema* loads by month (Table 4). Those monthly averages of participating Sentinel colonies are compared with national averages that originated from an independent survey effort: the **National Honey Bee Disease Survey (NHBS)**³, funded by USDA APHIS and organized by the University of Maryland Honey Bee Lab in collaboration with the Apiary Inspectors of America. The NHBS averages include data collected from 2009 to 2020 (2021 data not available at the time of analysis).

The dotted line represents the threshold of 1 million spores per bee, sometimes considered the action threshold of *Nosema* infestations.

This year, Sentinel participants showed elevated levels of *Nosema* compared to the national average from 2009 to 2020 (Figure 8). After 2020's Sentinel averages, which were above those observed in earlier years, 2021's monthly averages returned to levels more similar to those seen in previous years of Sentinel (Figure 9).

Figure 8. Average Detected *Nosema* Loads (in Millions of Spores per Bee) by Sample Collection Month



For comparison purposes, national numbers originated from the APHIS NHBS and include survey years 2009 to 2020.

³ For more information about the National Honey Bee Disease Survey: <https://ushoneybeehealthsurvey.info/> https://research.beeinformed.org/state_reports/

Table 4. Summary Statistics for Nosema Samples Collected from the 2021 Sentinel Season

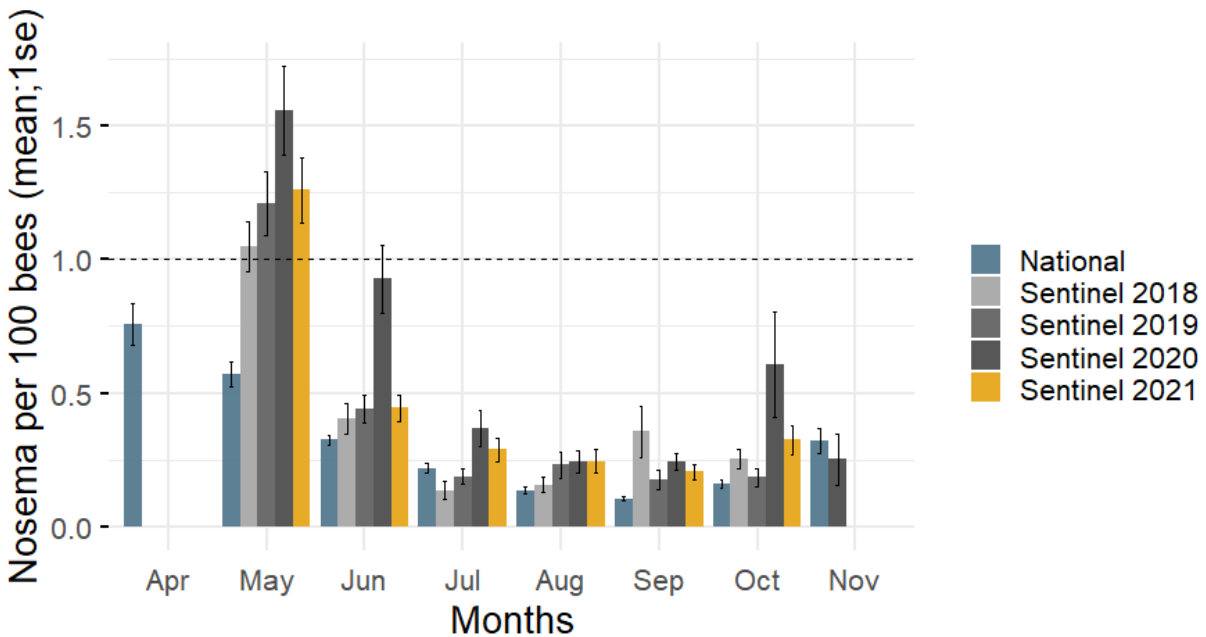
Month	Number of samples	Mean infestation load [95% CI*] (millions of spores per bee)	Prevalence [95% CI] (% of samples)	% above threshold (1 mspb**) [95% CI] (% of samples)
Apr	<30	[R]***	[R]	[R]
May	373	1.3 [1 - 1.5]	73.5 [68.6 - 77.8]	30.8 [26.2 - 35.8]
Jun	437	0.44 [0.35 - 0.54]	64.3 [59.6 - 68.8]	10.1 [7.5 - 13.4]
Jul	425	0.29 [0.2 - 0.38]	56 [51.1 - 60.8]	6.4 [4.3 - 9.2]
Aug	372	0.25 [0.16 - 0.33]	39 [34 - 44.2]	6.2 [4 - 9.3]
Sep	376	0.21 [0.15 - 0.26]	41.5 [36.5 - 46.7]	5.9 [3.8 - 8.9]
Oct	257	0.32 [0.22 - 0.43]	42.8 [36.7 - 49.1]	8.6 [5.6 - 12.8]
Nov	<30	[R]	[R]	[R]
Overall	2,249	0.48 [0.43 - 0.54]	53.9 [51.8 - 56]	11.5 [10.2 - 12.9]

*CI = Confidence Interval (see Table 3 note on page 6 for further explanation).

**mspb = Million spores per bee (unit)

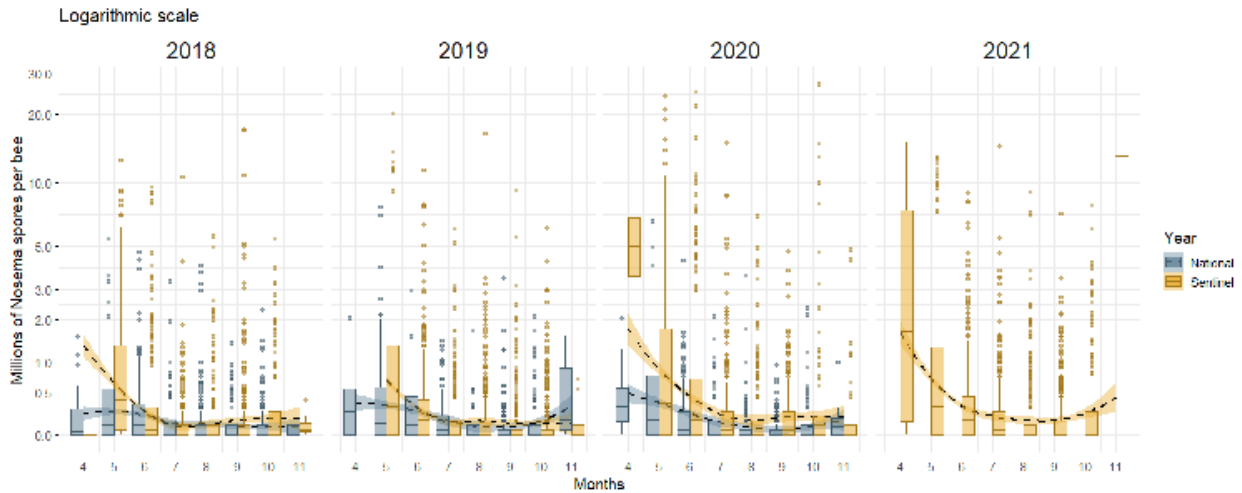
*** [R] = Redacted; months with fewer than 30 samples are not represented.

Figure 9. Average Detected Nosema Loads from 2018 to 2021 by Sample Collection Month



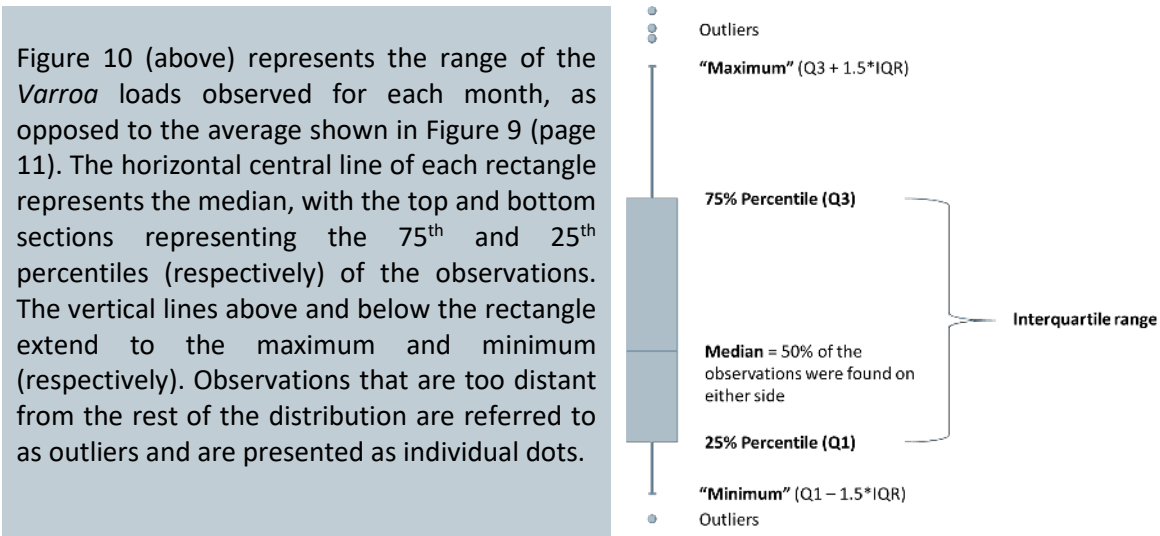
For comparison purposes, national numbers originated from the APHIS NHBS and include survey years 2009 to 2020.

Figure 10. *Distribution of Nosema Loads (in Millions of Spores per Bee) per Sample*



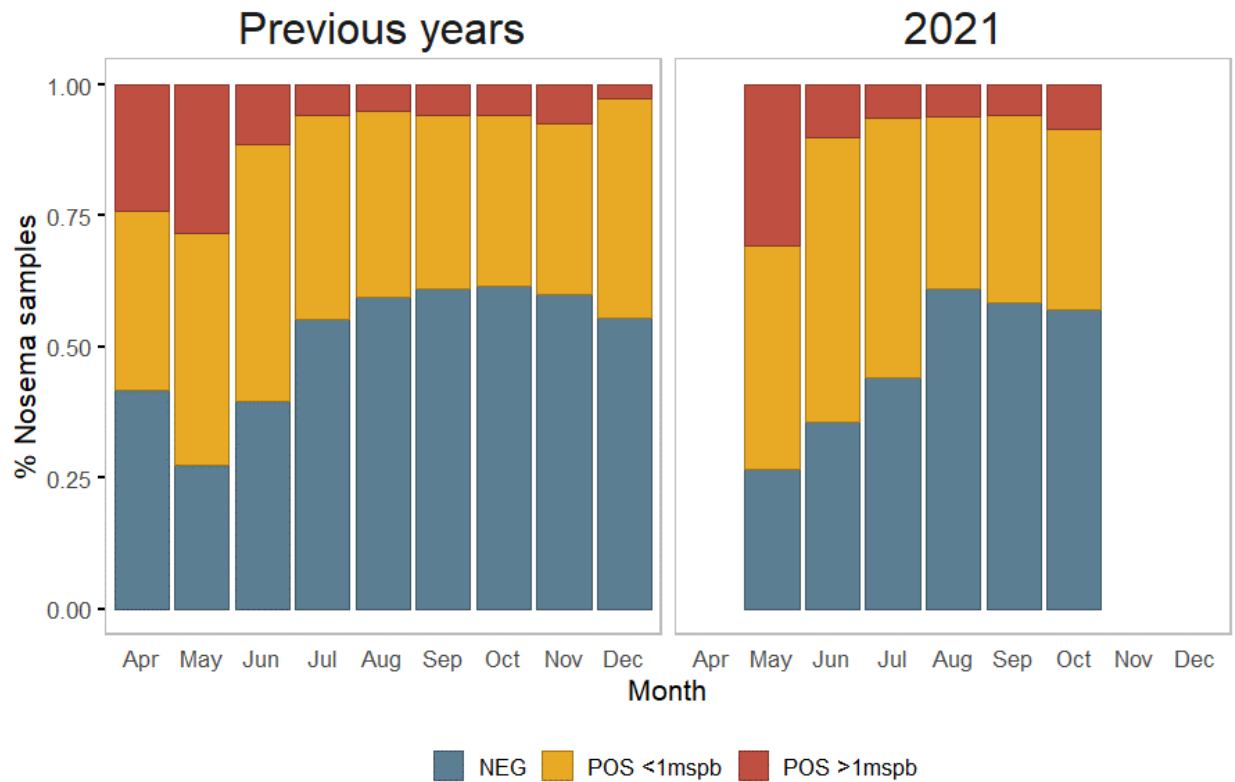
Distribution of the Nosema infestation loads per sample collected through the Sentinel Apiary Program and the NHBS from 2018 to 2021 (2021 NHBS data not available at the time of analysis). Smoothed estimated provided by the locally weighted regression method (LOESS). See Figure 10.1 (below) for more information about quartiles.

Figure 10.1. *Explanation of Quartiles*



We detected *Nosema* in **about 54% of the Sentinel samples** received in 2021 (Table 4, Figure 11). In previous years, the percentage of samples (POS) containing *Nosema* peaked early in the year (April-May), and then decreased throughout the rest of the season. A similar trend was observed this year.

Figure 11. Fraction of Samples as Categorized by *Nosema* Infestation Level

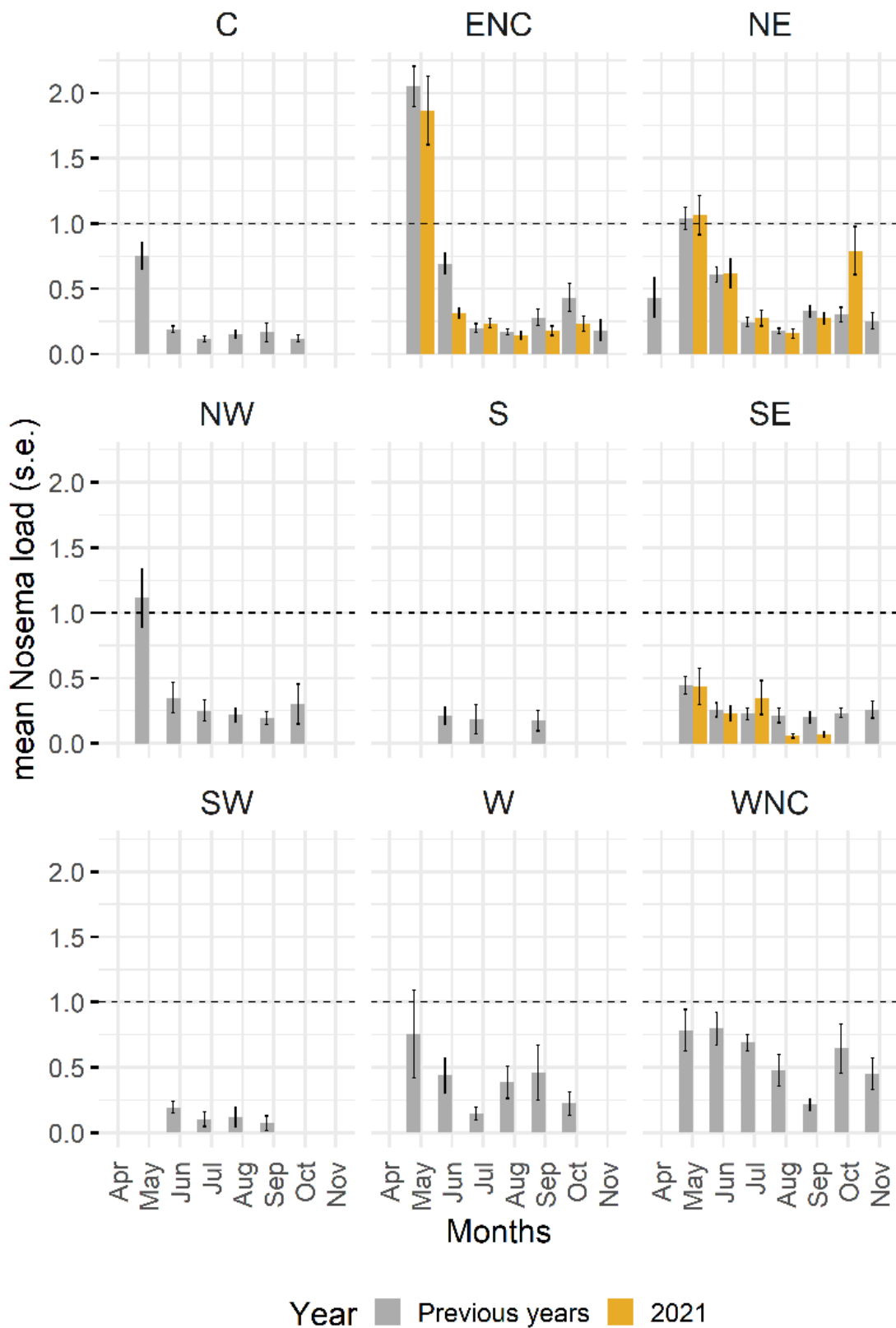


Data from previous years (left) include results from the 2013 to 2020 Sentinel seasons.

Legend: NEG = negative: no *Nosema* spores were detected; POS <1mspb = positive: below threshold level of 1 million of spores per bee; POS >1mspb = positive: above threshold level.

Over the years, we have noted different seasonal trends of *Nosema* loads by region. In 2021, we had multiple participants from three of the nine NOAA regions (ENC, NE and SE). Figure 12 (below) shows the 2021 regional monthly averages of *Nosema* loads compared with observed results from previous years of Sentinel data (2013 to 2020).

Figure 12. Average Nosema Loads (in millions of spores per bee) by Region, Sample Collection Month



Groups with fewer than 30 samples are not represented.

Legend: C = Central; ENC = East North Central; NE = Northeast; NW = Northwest; S = South; SE = Southeast; SW = Southwest; W = West; WNC = West North Central; NCUSA = Non-Continental USA.

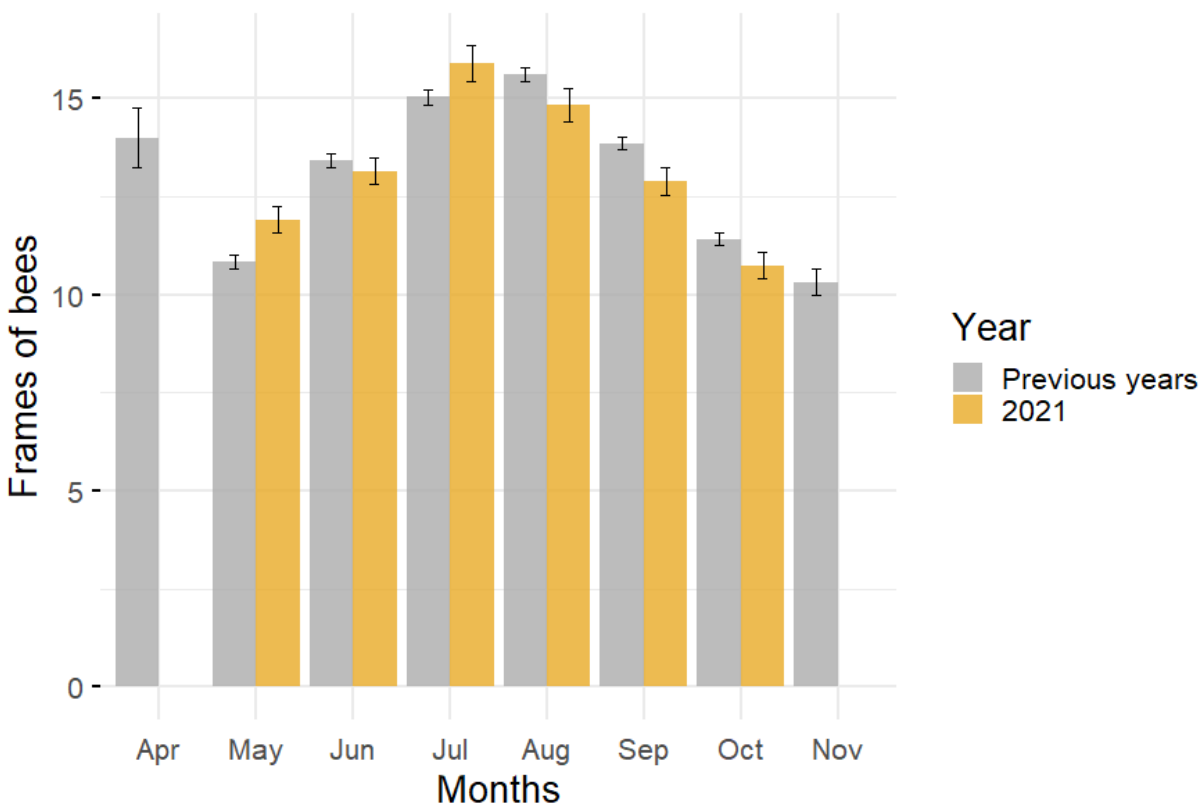


Colony Strength Summary

In 2021, participating beekeepers performing their own colony inspections reported **1,649 measurements** of colony strength. Figure 13 below shows the average colony strength in estimated frames of bees (FoB) by month (Table 5) as reported by Sentinel participants. Those 2021 monthly averages are compared with previous monthly averages that originated from previous Sentinel years (2013 to 2020).

2021 Sentinel colonies' strength peaked in July, with an average of 15.9 frames of bees (± 0.5 s.e.⁴). In all previous years combined (2013 to 2020), the peak of 15.5 frames of bees (± 0.2) occurred in August.

Figure 13. Average Colony Strength (in FoB) by Sample Collection Month



Months with fewer than 30 samples are not represented. For comparison purposes, previous averages originated from previous Sentinel data (2013 to 2020).

⁴ s.e. (also seen as S.E. or SE) = standard error (i.e., approximate standard deviation)

Table 5. Summary Statistics for Colony Strength Estimates (in FoB) Collected from 2021 Sentinel Apiaries

Month	Number of samples	Mean [95% CI*] (frames of bees)
Apr	<30	[R]**
May	325	11.9 [11.3 - 12.6]
Jun	327	13.1 [12.5 - 13.8]
Jul	260	15.9 [15 - 16.8]
Aug	250	14.8 [14 - 15.7]
Sep	264	12.9 [12.2 - 13.6]
Oct	190	10.7 [10.1 - 11.4]
Nov	<30	[R]
Overall	1,649	13.2 [12.9 - 13.5]

*CI = Confidence Interval (see Table 3 note on page 6 for further explanation).

** [R] = Redacted; months with fewer than 30 samples are not represented.

Figure 14. Average Colony Strength (in FoB) by Year, Sample Collection Month

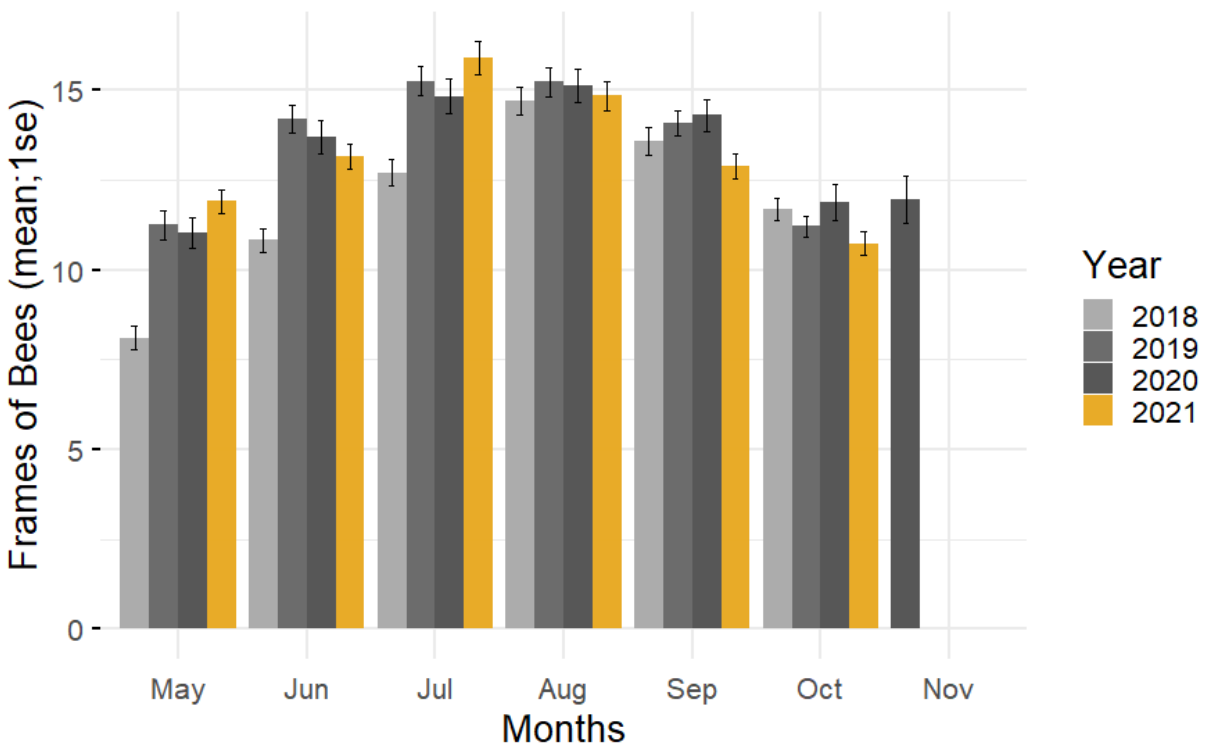
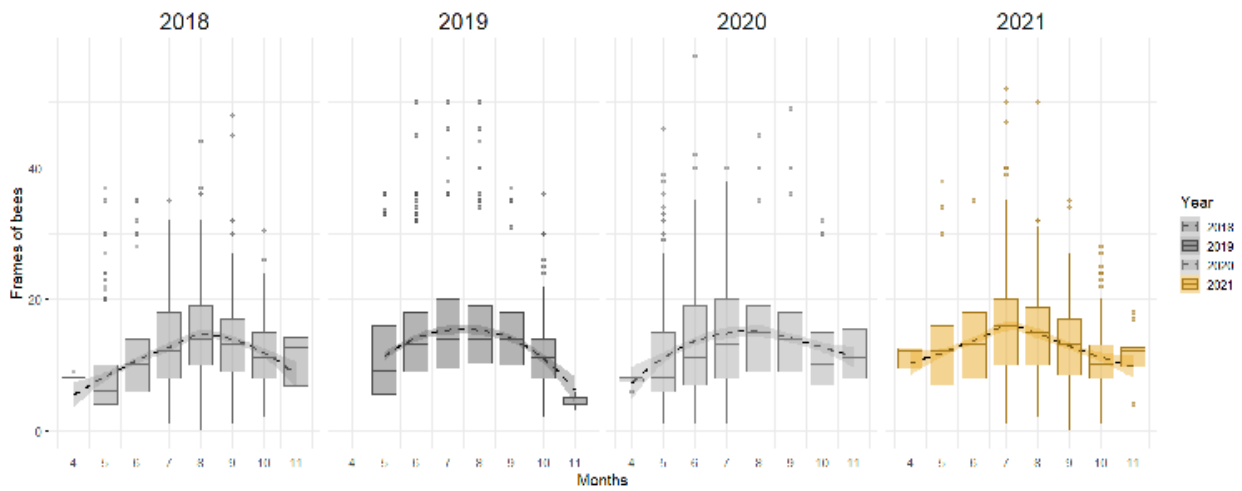


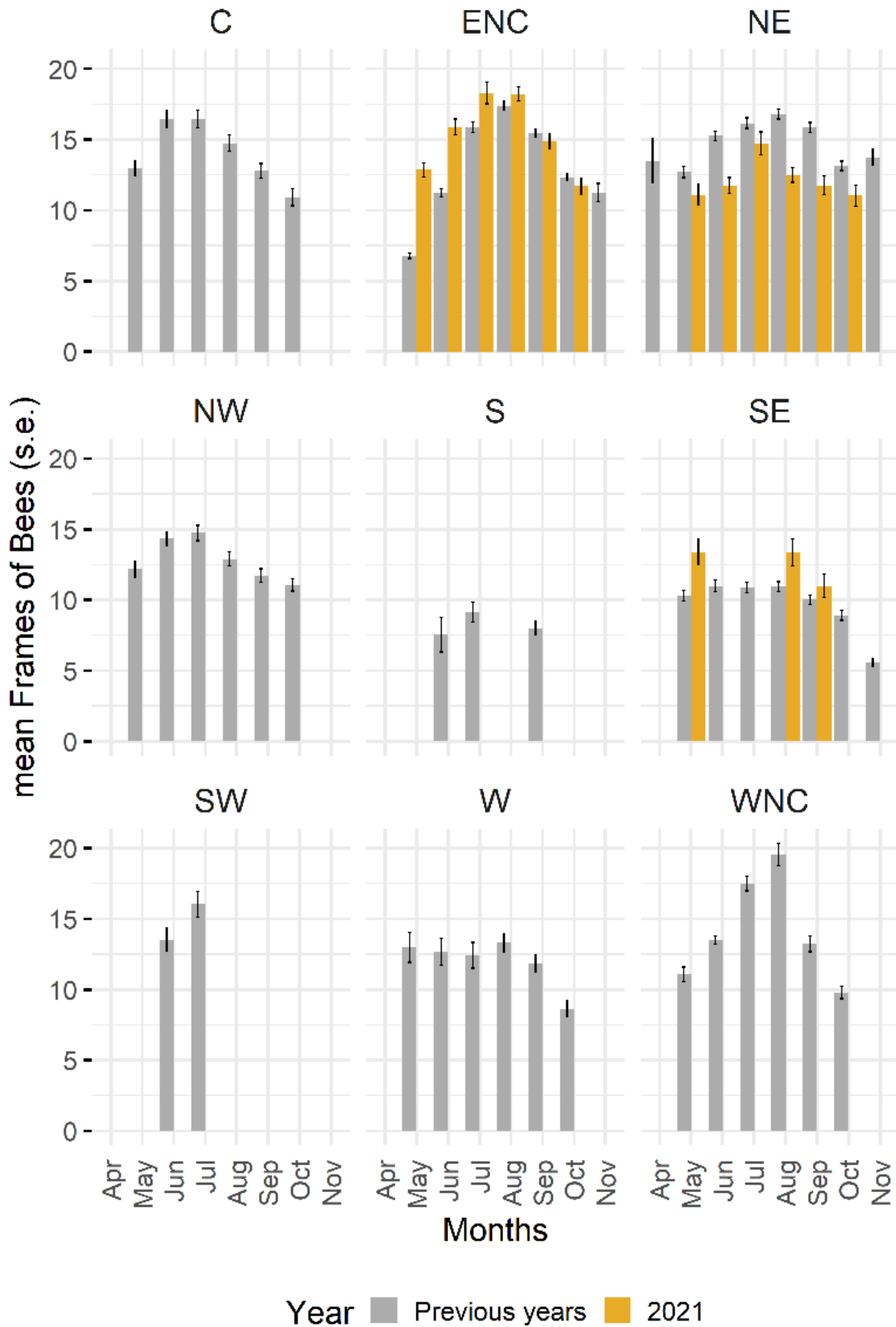
Figure 15. *Distribution of Colony Strength (in FoB) by Year, Sample Collection Month*



Smoothed estimated provided by the locally weighted regression method (LOESS).

Thanks to multiple years of data collection from multiple regions, we are able to contrast variable seasonal trends in colony strength from region to region. Below are the regional monthly averages of colony strength from the Sentinel program compared with the monthly averages reported in previous years of Sentinel (2013 to 2020).

Figure 16. Average Colony Strength (in FoB) by Region, Sample Collection Month



Groups with fewer than 30 samples are not represented.

Legend: C = Central; ENC = East North Central; NE = Northeast; NW = Northwest; S = South; SE = Southeast; SW = Southwest; W = West; WNC = West North Central; NCUSA = Non-Continental USA.



Management Actions

In 2021, **31 participating beekeepers** reported **138 individual management actions** in **34 locations**. Of those, 52 were related to treatment applications, 44 to changes in equipment, 22 to feeding, 14 to requeening, and 6 to harvesting (Figure 17, Table 6). The participants who used the app to report their management practices reported an average of four actions per location over the season.

Figure 17. Individual Action Events Recorded by Month of the 2021 Sentinel Season

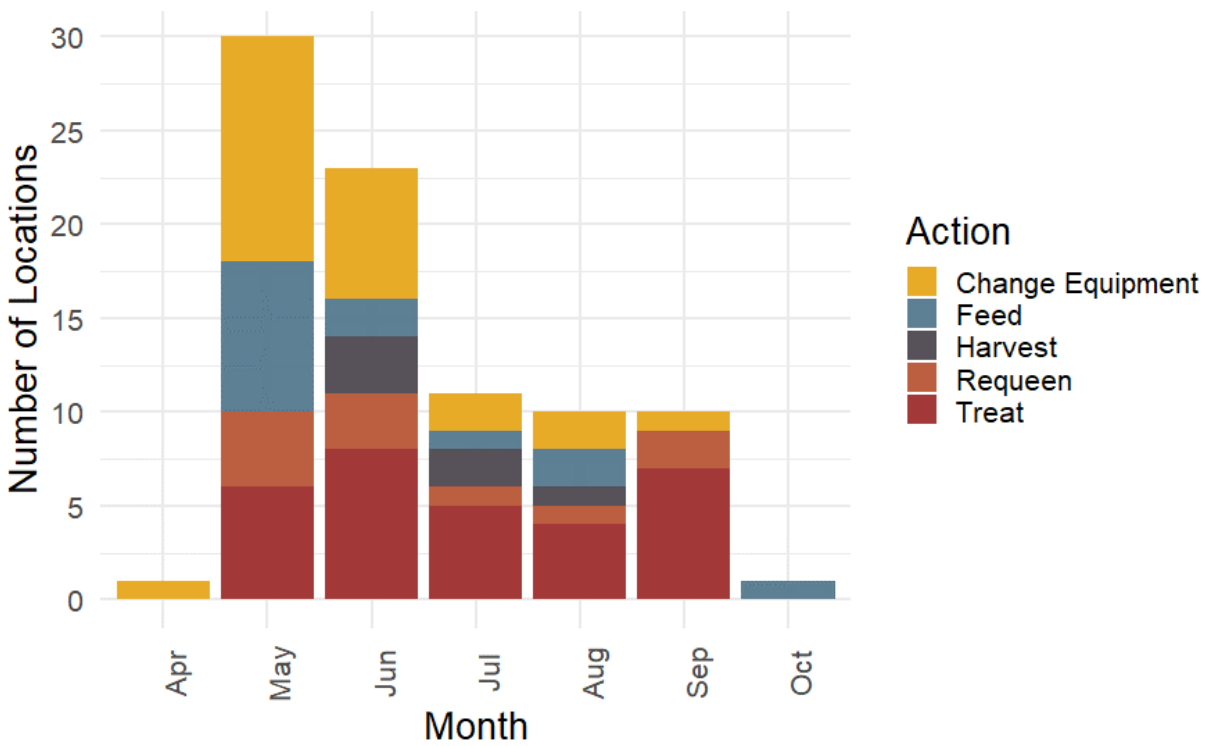


Table 6. Summary of Management Actions Reported Throughout the 2021 Sentinel Season

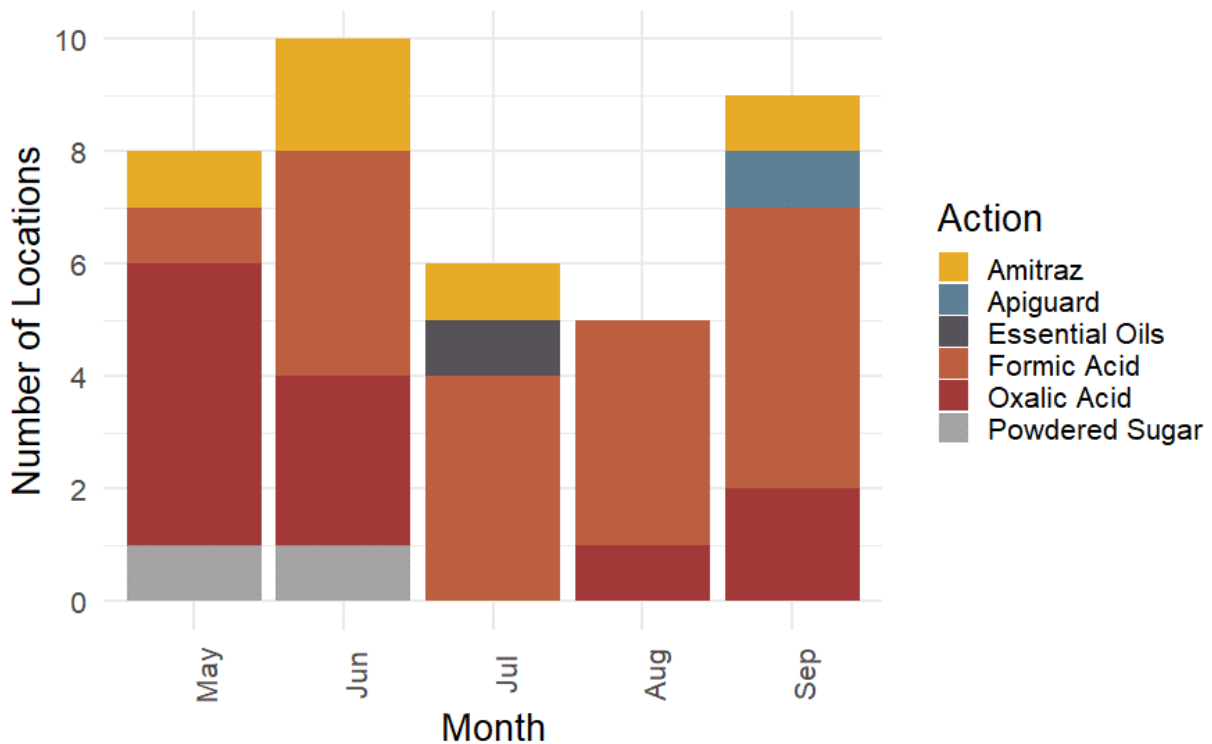
Management action type	Number of entries	Number of participants	Number of locations
Change Equipment	44	16	18
Feed	22	11	11
Harvest	6	5	5
Requeen	14	9	9
Treat	52	17	20
All	138	31	34

Participants recorded treatment actions in 20 unique locations between May and September 2021 (Table 7, Figure 18), with the most treatment actions occurring in June. Formic acid was the most frequently recorded treatment product (12 participants in 15 locations), followed by Oxalic acid (eight participants in nine locations).

Table 7. Summary of Treatment Actions by Product Type Reported During the 2021 Sentinel Season

Product type	Number of entries	Number of participants	Number of locations
Amitraz	7	3	3
Apiguard	1	1	1
Essential Oils	1	1	1
Formic Acid	24	12	15
Oxalic Acid	14	8	9
Powdered Sugar	4	1	1
All	51	17	20

Figure 18. Types of Varroa Treatments Recorded in Unique Locations by Month During the 2021 Season



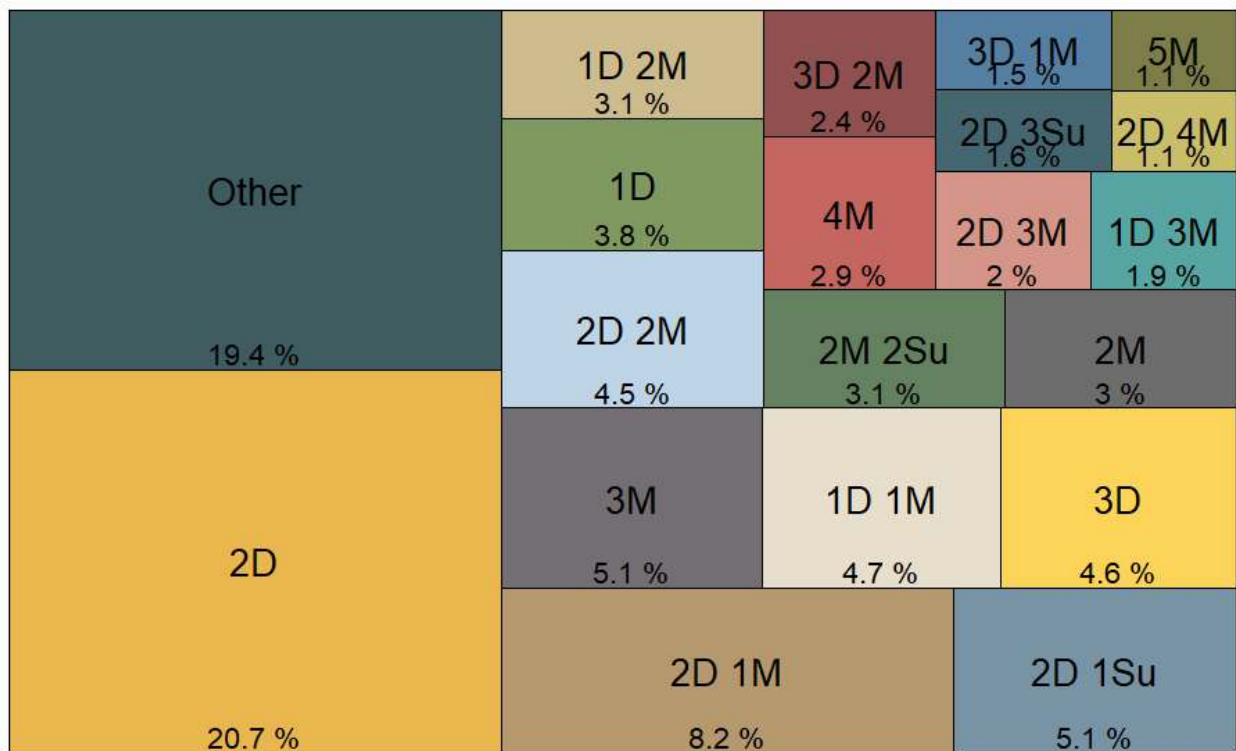


Colony Configuration

In 2021, participating beekeepers performing their own colony inspections reported **1,635 colony configurations** (in number of deeps, mediums, shallow and supers) over the course of the year. Figure 19 (below) represents the frequency of the most popular entries. It’s not a pie chart, it’s a cake chart—the size of each piece represents the relative frequency of the associated response.

Of the 1,536 records on the number of frames (5-10 frames per box) of the colonies inspected in 2021, 70.7% of records indicated the colonies were composed of 10-frame boxes, 24.8% were from 8-frame boxes, 3.3% were from 9-frame boxes, 1.0% of records came from 5-frame nucs, and just 0.1% of records indicated 6-frame boxes.

Figure 19. *Counts of Colony Configurations Recorded During the 2021 Sentinel Season*



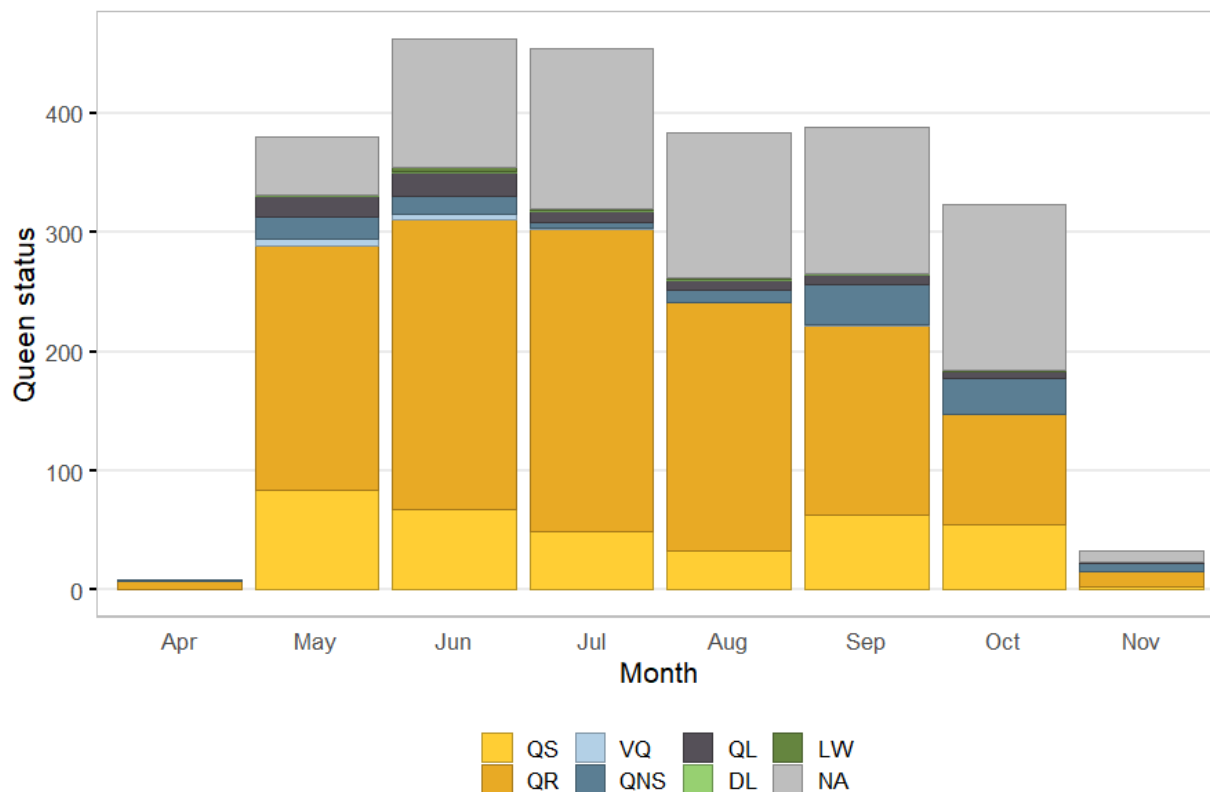
Legend: D = Deep; M = Medium; Su = Super.

Queen Status



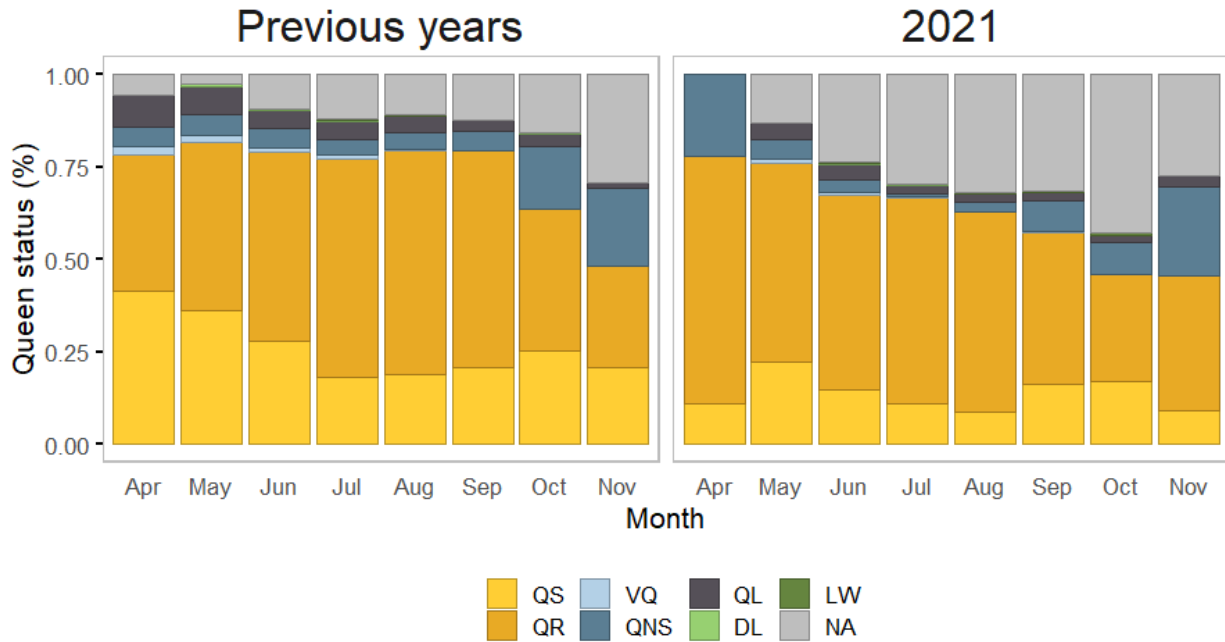
In 2021, participating beekeepers performing their own colony inspections reported **1,751 queen statuses** over the course of the year. Figure 20 (below) represents the count and relative proportion of each by month.

Figure 20. Counts of Queen Statuses Recorded During the 2021 Sentinel Season



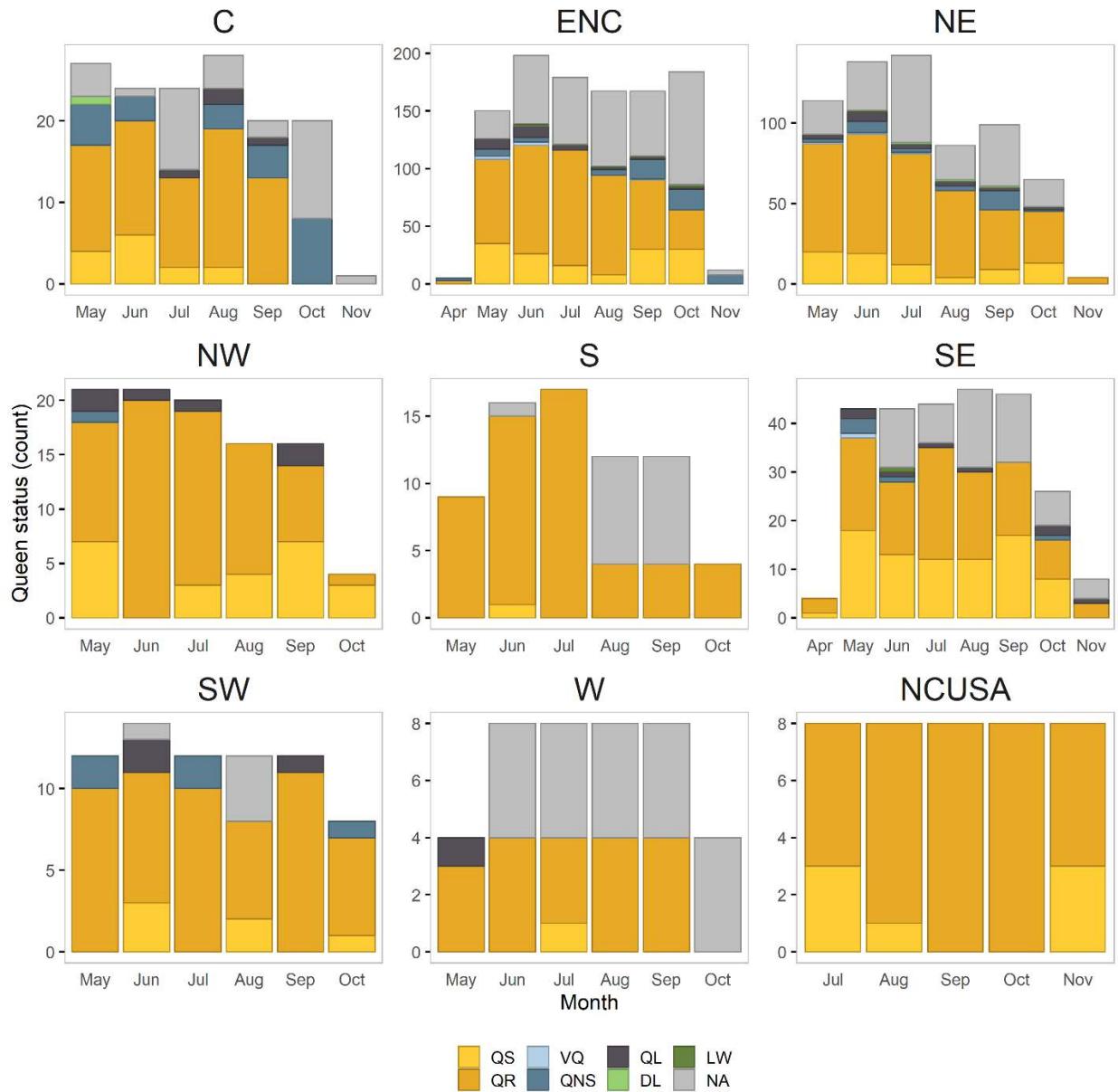
Legend: QS = Queen Seen; QR = Queen Right (queen not seen but presence of eggs); VQ = Virgin Queen, QNS = Queen Not Seen (nor eggs present, but colony not believed to be queenless); QL = Queenless; DL = Drone Layer; LW = Laying workers, NA = No information recorded.

Figure 21. Comparing Queen Statuses Recorded During the 2021 Season to Previous Years (2014-2020)



Legend: QS = Queen Seen; QR = Queen Right (queen not seen but presence of eggs); VQ = Virgin Queen, QNS = Queen Not Seen (nor eggs present, but colony not believed to be queenless); QL = Queenless; DL = Drone Layer; LW = Laying workers, NA = No information recorded.

Figure 22. Queen Statuses Recorded During the 2021 Season by Region



Legend: C = Central; ENC = East North Central; NE = Northeast; NW = Northwest; S = South; SE = Southeast; SW = Southwest; W = West; WNC = West North Central; NCUSA = Non-Continental USA.

QS = Queen Seen; QR = Queen Right (queen not seen but presence of eggs); VQ = Virgin Queen, QNS = Queen Not Seen (nor eggs present, but colony not believed to be queenless); QL = Queenless; DL = Drone Layer; LW = Laying workers, NA = No information recorded.