Beezz! Renovation and Change in Colony Growth

Abstract

Bees play a crucial role in maintaining the biodiversity of our ecosystem. Our goal was to investigate how the time of year- categorized by season- impacts the difference between the mean number of bee colonies lost vs. colonies gained (colony growth) and the percentage of renovated colonies. Data was obtained from the USDA's National Agricultural Statistic Service through the Tidy Tuesday project. We present the data visually through box-whisker plots and conducted statistical analysis through ANOVA (Analysis of Variance) and pairwise t-test. In conclusion, we found significant differences in colony growth and loss based on the time of year and appears to be independent of when the combs are renovated.

Research Question and Purpose

In this paper, we are investigating how the count and percent of bee colonies change over seasons and how beekeeper intervention (renovation) has historically impacted colony growth. We hypothesized that during colder months (winter and fall seasons), we would see less average colony growth and more colony renovation. Our results suggest that bee colonies tend to grow during spring months and decrease over fall months independent of renovation efforts.

Background and Significance

Bees play a crucial role in the ecosystem by pollinating approximately one-third of the food we consume and around 80% of the world's flowering plants[3]. Their contributions support biodiversity, sustain ecosystems, and help maintain a functional food chain essential for both human and animal survival. However, global bee populations have been declining in recent decades due to habitat loss, intensive farming practices, changes in weather patterns, and the excessive use of agrochemicals such as pesticides[4]. In response, there has been increased interest in beekeeping professionally and as a hobby. Bees kept in captivity, however, will naturally have different living conditions than their wild counterparts, one of which is that beekeepers often force "comb renovation," removal of three to four year old darkened honeycomb, onto colonies to discourage pathogenic contamination of the colony and the honey they produce[1]. Looking at beekeeper practices, such as comb renovation, could grant new insights into how direct human intervention affects the bee colonies' ability to survive in captivity. .

Acknowledging bees' role as a keystone species in the wild and within the agricultural industry[2], we believe that investigating what environmental and interventional factors have the greatest impact on honey bees is essential to maintaining their populations and, consequently, supporting the multiple systems they maintain.

Methods

Our data is obtained from the USDA's National Agricultural Statistic Service through the Tidy Tuesday project. We first imported the CSV file into R and conducted an exploratory data analysis by creating boxplots of colony change vs seasons, noting that each data point was specific to a beekeeper's number of colonies in a state at one point in time conducted over the span of 4 years. Outliers were removed from the box plot for better visual analysis; further statistical testing kept the outliers in the dataset. Then, we evaluated the variance in mean colony growth and renovations through ANOVA (Analysis of Variance) testing and pairwise t-tests to identify the specific variance between groups and evaluate whether the initial trends we observed were statistically significant. We looked at changes in bee colonies both as the difference between colonies added and colonies lost as well as the proportional change given by

$$\frac{colonies\ added - colonies\ lost}{total\ colonies}.$$

Additionally, we were interested in when beekeepers were most likely to perform colony renovations and thus whether we could observe a potential relationship between those incidences and colony growth trends. To do this, we similarly conducted an EDA, ANOVA, and post-hoc pairwise t-tests (with multiple testing correction) on each season's percent renovations.

Data Analysis

Change in Colony Growth

Our first step was to conduct an EDA. We created a boxplot of our data to identify if there is a difference solely based on visual observations. Our initial boxplot included several outliers-likely due to some gaps in data collection which caused the calculated change in colonies to be composed solely of colony additions or colony loss. We then added a new restricted data column to exclude the outliers and we were able to observe that the April-June indicated a higher rate of colony growth compared to the other seasons (Figure 1a). Based on our analysis of the raw data, we had an outlier cutoff at ±5000 for the change in number of colonies and ±1 (i.e. 100%) for the proportional change in number of colonies. Additionally, we calculated the mean and standard deviation for the mutated data of each of our seasons (Supplemental Table 1).

To quantitatively explore if there was a relationship between mean colony growth based on season, we performed an ANOVA test on the unmutated data set. With a significance level of 0.05 and a p-value of < 2E-16, the results of the ANOVA demonstrated that there was a significant difference between at least two seasons in the percent colony growth (F = 207.7) and the change in number of colonies(F = 26.24). Knowing that there was a significant difference, we then performed a pairwise comparison t-test to determine which seasons differed significantly from the others (Table 1). Using a significance level of 0.05, we found no significant difference between average July-September and October-December colony growth (p-value = 0.20, df = 3), but there was statistically significant growth in colonies across each of the other seasons. There were analogous results found doing the same tests for the percent change group which controlled for overall number of colonies in each group.

Colony Renovation

A boxplot EDA was created to represent the percentage of colonies renovated across seasons (Figure 2). For visual clarity, the plot omits outliers larger than 40% since they severely skewed the view of the boxplot and weren't as valuable for the visual analysis. Additionally, the mean and standard deviation was calculated for the mutated data of each of our seasons (Supplemental Table 2).

We again conducted an ANOVA test to test the variability between the percentage of renovation between the multiple season groups; the unmutated dataset was utilized for this calculation. With a significance level of 0.05 and a p-value < 2E-16, the results of the ANOVA demonstrated that there was a significant difference between at least two seasons' proportion of comb renovations (F = 61.93). To test which groups were significantly different from each other, we conducted a pairwise t-test (Table 2) which indicated that–using a significance level of 0.05–all seasons were statistically different from each other except for the winter and fall.

Results and Conclusions

Overall impressions of the data suggest that, on average, there is significant colony growth during spring months and significant colony loss during fall months (Table 1). On average, most comb renovations are during spring months, followed by summer. Fall and winter months do not differ significantly and the least percent of renovations occur during those months (Table 2, Figure 2). Mean changes in colony numbers reveal that summer, while not significant, is associated with negative colony growth (Figure 1a and 1b). This may indicate comb renovation's independence from changes in colony size. Additionally, it could be that beekeepers have observed colonies are most

	January - March	April - June	July - September
January - March	—	9.1E-06	—
July - September	0.03519	2.4E-11	—
October - December	0.00081	4.3E-15	0.20038

Table 1 The results of a pairwise comparison of season and change in colony growth using t-tests with pooled SD, a family-wise significance level of 0.05, and a Holm's p-value adjustment.

	January - March	April - June	July - September
January - March	—	<2E-16	—
July - September	1.6E-06	5.7E-11	—
October - December	0.59	<2E-16	5.6E-07

Table 2 The results of a pairwise comparison of colony renovations and season using t-tests with pooled SD, a family-wise significance level of 0.05, and a Holm's p-value adjustment.

productive during spring months, so they renovate the comb either during or after their main harvesting seasons.

Change in Colony Growth

Analysis of the change in colony size and percent growth capture the same trends. This illustrates that the trend we are seeing exists with and without controlling for sample size (Figures 1a and 1b). Across both analyses, spring is the season with the most numeric and percent growth of colonies likely due to an abundance of available nectar as wildflowers begin to grow. Summer and winter seasons do not differ significantly using a significance level of 0.05, but all other groups do (Table 1). Both trends display approximately 14% growth of colonies (mean = 16,777) during spring months and approximately 8% loss of colonies (mean = 10,223) during fall months. This means that we would expect an overall increase in the number of bee colonies over the span of a year.

Colony Renovation

Colony renovation appears to be somewhat seasonally dependent, although to a lesser degree than colony growth. ANOVA testing indicated significant differences between seasons and the number of colony renovations performed, and post-hoc pairwise testing found significant differences between all seasons except for winter and fall. Differences were most significant between spring vs. winter, and spring vs. fall. This trend is not surprising considering the negative growth in colonies that were found in the previous statistical analysis during the winter and fall time periods.

Limitations

In performing our ANOVA and pairwise t-tests, we work under the assumption of independence which may not be true given the same colonies were probably resampled across the 5 year span. However, given the large number of cases within the dataset, we believe that assuming independence is reasonable to use in this context.

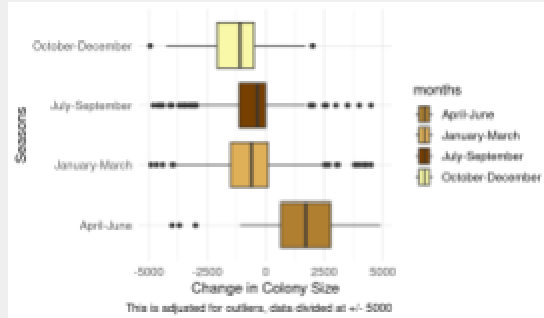


Figure 1a A boxplot of the change in number of colonies over four seasons each with 3 month durations. April-June is Spring (mean = 16777.3), July-September is Summer (mean = -6620.142), October-December is Fall (mean = -10223.07), and January-March is Winter (mean = 2381.773) for the purposes of this project.

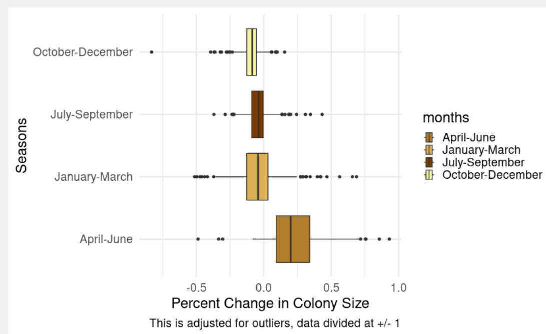


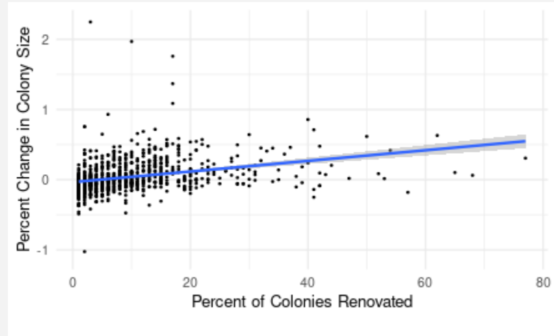
Figure 1b A boxplot of the percent change in number of colonies over four seasons each with 3 month durations. April-June is Spring (red, mean = 13.86%), July-September is Summer (blue, mean = -5.01%), October-December is Fall (purple, mean = -8.11%), and January-March is Winter (green, mean = 2.05%) for the purposes of this project.

Figure 2 A boxplot of the percent of comb renovations over four seasons each with 3 month durations. April-June is Spring (mean = 14.54%), July-September is Summer (mean = 9.38%), October-December is Fall (mean = 4.94%), and January-March is Winter (mean = 5.42%) for the purposes of this project.

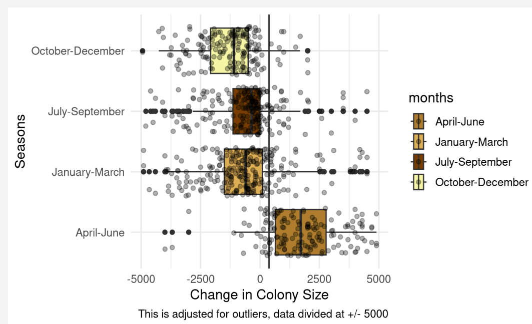
References

1. Carlson, David, et al. "Comb Renovation." *Apis Information Resource Center*, https://beekeep.info/a-treatise-on-modern-honey-bee-management/managing-diseases-and-pests/comb2-renovation/.
2. Lee, Meredith. "Bees." *The Humane Society of the United States*, 2024, www.humanesociety.org/animals/bees#:~:text=A%20keystone%20species%2C%20bees%20are,in%20agricultural%20crops%20each%20year.
3. The Bee Conservancy. "Save the Bees." *The Bee Conservancy*, 14 Nov. 2024, https://thebeeconservancy.org/?gad_source=1&gclid=CjwKCAiA3Na5BhAZEiwAzrfagOKUIs_EGC4JmIGojYukcDqsPSO2Xk9IVYyATHyuYY-AJgMmxVnQZRoC9wkQAvD_BwE.
4. UNEP. "Why Bees Are Essential to People and Planet." *UNEP Environment Programme*, 18 May 2024, www.unep.org/news-and-stories/story/why-bees-are-essential-people-and-planet.

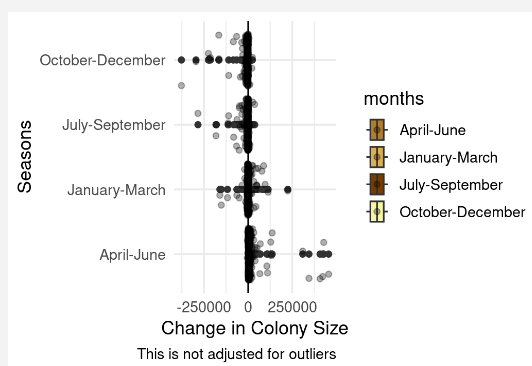
Appendix



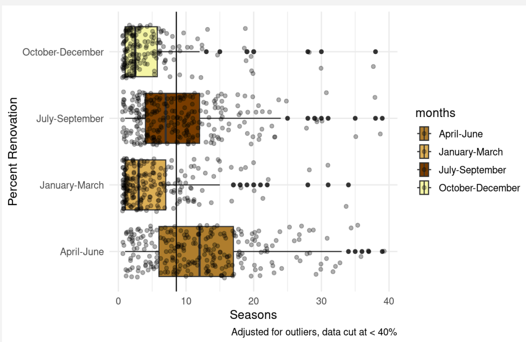
Supplemental Figure 1 A graph of the percent change in colony size vs the percent of colonies renovated. The least squares line shows an intercept of -0.034472 (p-value = 0.00104) and a slope of 0.007568 (p-value < 0.00001).



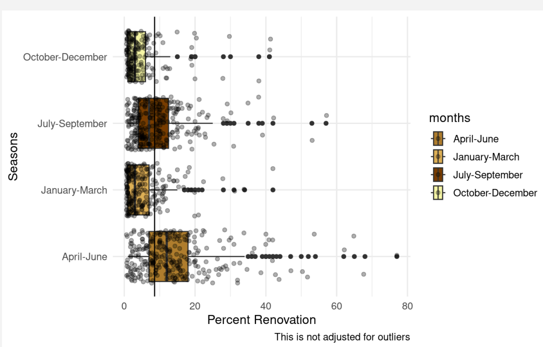
Supplemental Figure 2 A boxplot of the mutated (restricted to ± 5000) change in colony size vs. season with visual residuals and a vertical line indicating a mean value, inclusive of all values at 377.999.



Supplemental Figure 3 A boxplot of change in colony size versus season with visual residuals and a vertical line indicating a mean value of 377.999. This was created with the non-mutated data set.



Supplemental Figure 4 A boxplot of the percent renovated colony vs. visual residuals and a vertical line indicating a mean value of 7.78. This was created with the mutated data, which was restricted at 40%.



Supplemental Figure 5 A boxplot of colony percent renovation vs. season with visual residuals and a vertical line indicating a mean value of 8.57. This was created with the non-mutated data.

	Apr-Jun	Jan-Mar	Jul-Sep	Oct-Dec
	Spring	Winter	Summer	Fall
Mean	1178.38	-682.07	-577.93	-1298.84
SD	1617.11	1689.58	1480.38	1242.05
n	160	246	212	181

Supplemental Table 1 A table of the mean change in colony growth, standard deviation, and n-value for each season excluding outliers (|mean| > 5000).

	Apr-Jun	Jan-Mar	Jul-Sep	Oct-Dec
	Spring	Winter	Summer	Fall
Mean	12.47	5.26	8.92	4.5
SD	8.12	5.47	6.98	5.42
n	265	226	268	181

Supplemental Table 2 A table of the mean percent of colonies renovated, standard deviation, and n-value for each season excluding outliers (mean > 40%).