SURVEILLANCE OF BELGIAN HONEYBEE COLONY MORTALITY 2022-2023

Scientific Report

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Sciensano

Infectious diseases in animals – Coordination of Veterinary activities and Veterinary Epidemiology

Surveillance of Belgian honeybee colonoy mortality 2022-2023

December 2023 • Brussels • Belgium

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Please cite as: M. Driesen. Surveillance of Belgian honeybee colony mortality 2022-2023. Brussels, Belgium : Sciensano ; 2023 21p.

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ABSTRACT

An alarming mortality of honeybee colonies (*Apis mellifera*) has been reported in many countries since early 2000. During a recent European project, called Epilobee, between 2012 and 2014, the Belgian honeybee colony mortality was the highest of the participant countries. In September 2016, the Federal Agency for the Safety of the Food Chain (FASFC) has launched the program of surveillance of Belgian honeybees health. The primary objective of the project was to describe and monitor the honeybee colony mortality and its variation between the three visits and across Belgium.

Within 190 apiaries selected, three visits were conducted: the first one in Fall 2022, when the colonies were preparing for winter, the second visit in Spring 2023, after bees started foraging, and the third visit during the Summer 2023, the active season. The field survey included direct observations, interviews and measurements performed by trained FASFC inspectors. The questionnaire provided information regarding colony attributes (such as colony mortality, demography, and known causes of winter mortality), and beekeeping management practices (such as number of managed colonies, Varroa mite treatment, provision of supplementary feeding). The 2022-2023 overwinter weighted colony mortality was estimated at 25.42% (95% CI: 19.58-31.26) for Belgium. The seasonal weighted colony mortality was estimated at 7.84% (95% CI: 3.94-11.74). The yearly weighted colony mortality, considering both winter and summer, was estimated at 21.86% (95% CI: 17.61-26.11).

ABBREVIATIONS

FASFC	Federal Agency for the Safety of the Food Chain

INTRODUCTION

An alarming mortality of honeybee colonies (*Apis mellifera*) has been reported in many countries since early 2000. A recent European project, called Epilobee, has investigated the honeybee mortality in different Member States, including Belgium (Laurent et al., 2016). During that project, i.e. between 2012 and 2014, the Belgian honeybee colony mortality was the highest of the participant countries. In order to appropriately study changes in bee health, explanatory and predictive analyses require data to be collected at different times of year, over several years and in different geographical regions.

In September 2016, the Federal Agency for the Safety of the Food Chain (FASFC) has launched the program of surveillance of honeybee colony health. The primary objective of the project was to describe and monitor the honeybee colony mortality and its spatio-temporal variation across Belgium. Standardised data collection is crucial to reduce biases in observations and to control for random variation which will allow for better explanatory and predictive analysis across the different spatial scales and better estimates of variability in bee health. This report summarizes the epidemiological results of three visits, which were conducted by trained FASFC inspectors from Fall 2022 until Summer 2023.

METHODOLOGY

1. Population frame

Since 2006, beekeepers have to be registered with the FASFC. This obligation applies to all beekeepers and is independent of honey production and the possible payment of a contribution. In 2023, 10428 beekeepers were registered, with more beekeepers in Flanders (n=6045) compared to Wallonia (n=4151), and 232 beekeepers in the region of Brussels capital. Figure 1 shows the density of registered beekeepers per municipality (number/km²) in 2023.

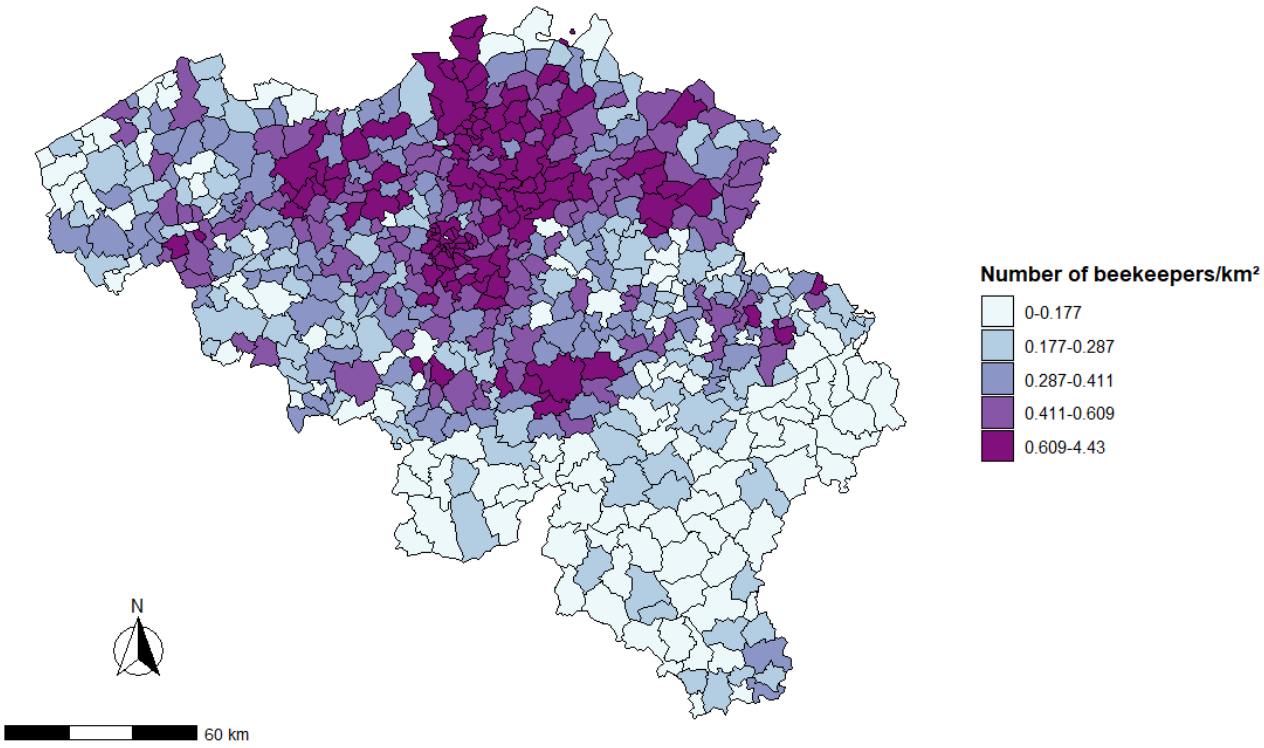

Figure 1: Density of registered beekeepers per municipality (number/km²) in Belgium, 2023

2. Sampling frame and design

The construction of a sampling frame was designed taking into account the Epilobee project and EU-RL recommendations. A two-stage sampling strategy was chosen, with approximately 25 apiaries per local control unit (LCU) (Table 1), and up to 6 hives per apiary. The distribution of beekeepers to visit first takes into account a fair distribution of work between the 9 LCUs (linked to the control capacity of each LCU). Within each LCU the distribution of beekeepers to be visited is done as much as possible, avoiding visits of neighboring beekeepers. Table 2 below reports the number of selected apiaries and colonies for the whole country and per region and province. In 2023, the FASFC visited a total of 190 apiaries and monitored 787 colonies.

Table 1 Number of apiaries sampled per LCU

LCU*	Number of sampled apiaries
WVL	24
VLI	24
OVB	24
LUN	24
LIE	20
HAI	18
BRU	8
BNA	25
ANT	23

*https://www.favv-afsca.be/professionnels/contact/ulc/

Table 2 Number of apiaries and colonies sampled per geographical entity

Geographical entity	Number of beekeepers in 2023 (N)	Number of apiaries sampled (n)	Number of colonies within sampled apiaries (Mi)	Number of sampled colonies (mi)
Belgium	10428	190	1413	787
Brussels-Capital region	232	8	21	21
Flanders region	6045	95	637	379
Walloon region	4151	87	755	387
BRU	232	8	21	21
ANT	1685	23	208	85
OVL	1315	17	97	68
LIM	1043	19	144	92
VBR	1122	12	80	53
WVL	880	24	108	81
HAI	1023	18	196	87
NAM	963	15	175	85
LIE	899	20	159	73
LUX	742	22	134	85
BRW	524	12	91	57

Figure 2 gives an overview of the spatial distribution of the apiaries sampled in each province. Figure 3 shows the number of apiaries sampled per municipality.

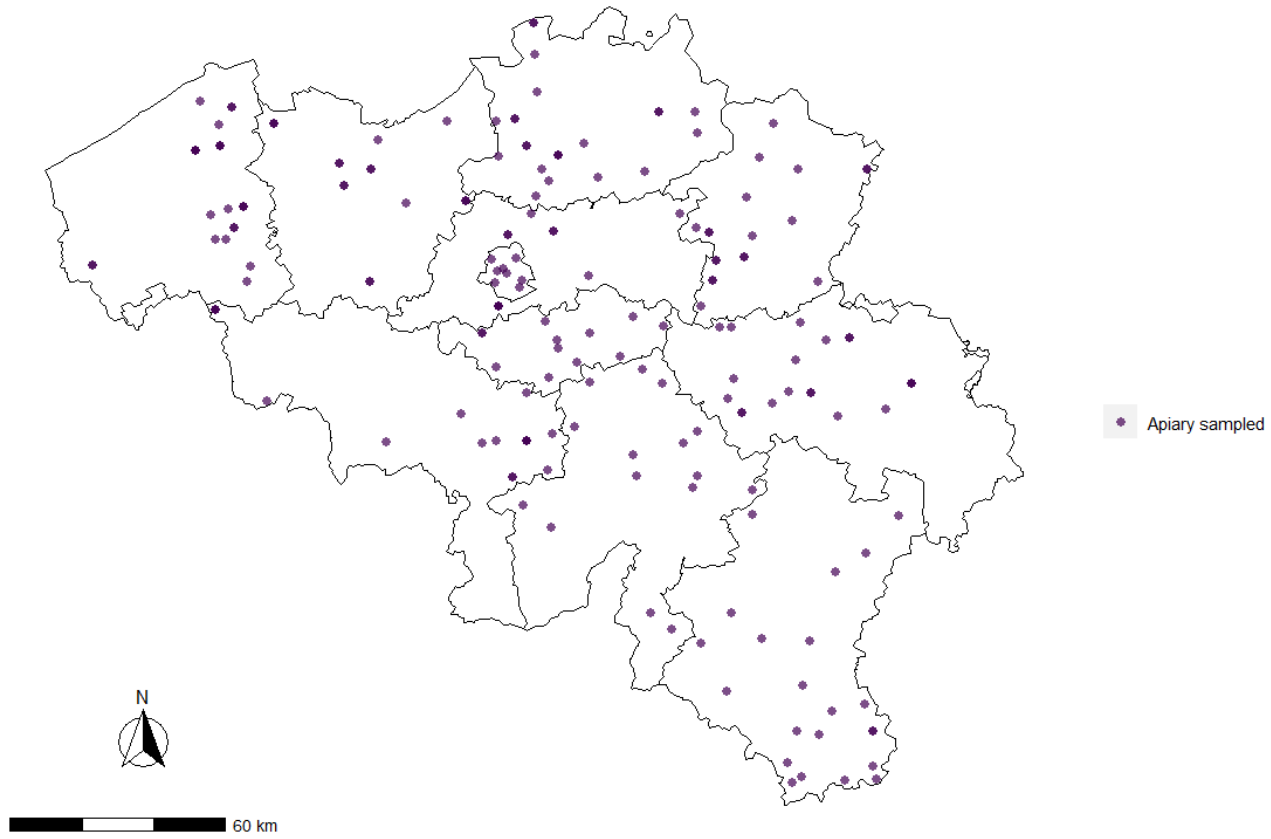

Figure 2 Spatial distribution of the apiaries sampled

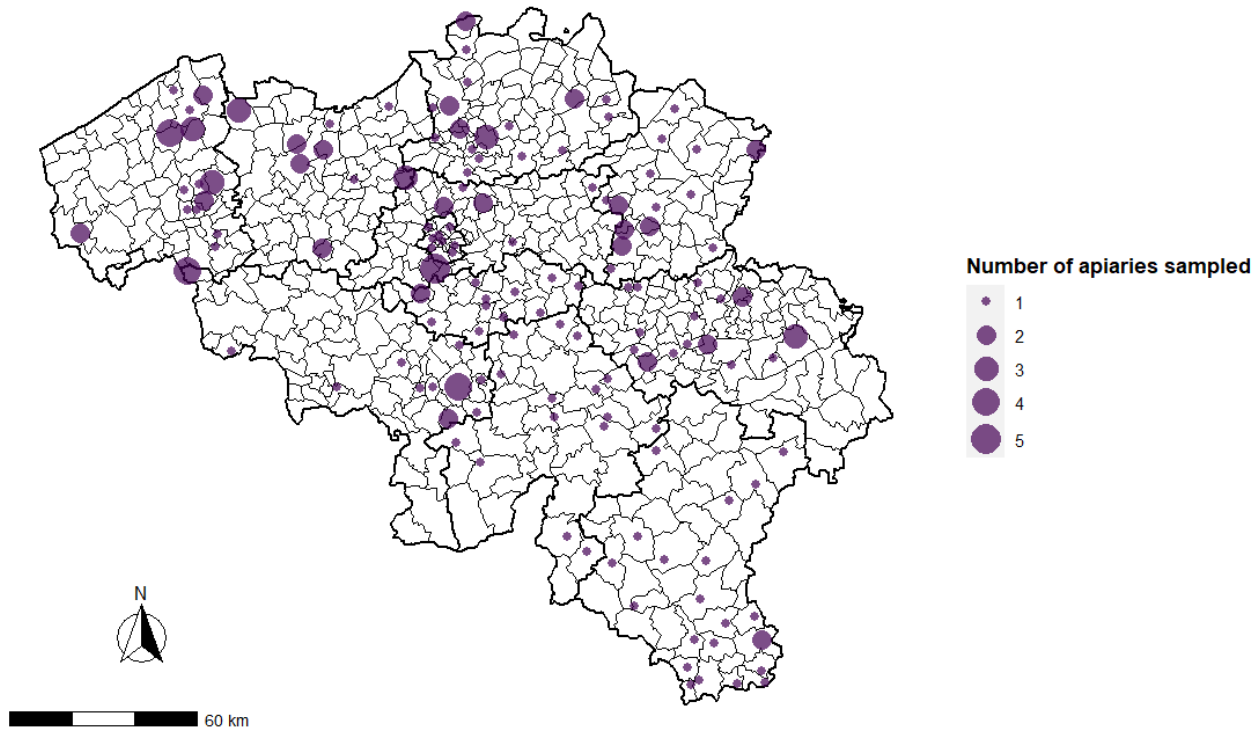

Figure 3 Number of apiaries sampled per municipality

3. Data collection

Within the selected apiaries, three visits were conducted: the first one in Fall 2022, when the colonies were preparing for winter, the second visit in Spring 2023, after bees started foraging, and the third visit during the Summer 2023, the active season. In the province of Luxembourg, several summer visits were carried out by telephone due to the large number of outbreaks of European foulbrood which had to be monitored in the field.
The field survey included direct observations, interviews and measurements performed by trained FASFC inspectors using the same questionnaire ensuring harmonisation of data collection. Since variables (indicators or factors) are linked directly or indirectly to honeybee colony mortality (e.g. disease infestation with bee mortality), a questionnaire was developed to record information regarding colony attributes (such as demography, honey production, and diseases), and beekeeping management practices (such as beekeepers experience, number of managed colonies, *Varroa* management).

4. Statistical analysis

The mortality was evaluated over two periods: between Fall 2022 and Spring 2023, i.e. winter mortality, and between Spring and Summer 2023, i.e. seasonal mortality. During the first visit, only colonies assessed to have the potential of overwintering by the beekeepers were kept in the survey. During the second and third visits, all selected colonies at the first visit were assessed for their survival. Based on the records of dead colonies, the colony mortality risk was estimated. The colony mortality risk gives the number of (new) mortality in the Belgian honeybee colonies population over a given period divided by the number of honeybee colonies at risk at the beginning of the study period. The colony mortality risk is the probability that a colony dies over a given period of time.

4.1. OVERWINTERING COLONY MORTALITY (FALL-SPRING 2022-2023)

During the second visit, all selected colonies at the first visit were assessed for their survival. The criteria, to identify a colony as dead, were the following:

- the colony hosted some honeybees but was considered non-viable (nearly dead = less than 500 honeybees in the colony), which might imped to start the next season,
- the colony was in one of the following situations: all the honeybees were dead within the hive; all the honeybees were dead and the hive was empty; the colony hosted laying workers but with no queen (orphan colony).

The inspectors recorded the number of live (Xalive) and dead (Xdead) colonies among those that were selected during visit 1 (mi_{v1} =1-6). The following formula was used to calculate the colony mortality risk (Pi_{v2}):

$$Pi_{v2} = \frac{\sum Xdead_{v2}}{\sum mi_{v1}}$$

Per apiary (i), the recorded colony sample mortality risk (Pi_{v2}) was weighted according to the total number of colonies present in the apiary at the preceding visit (Mi_{v1}). The Weighed Colony Sample Mortality (WCSM) was obtained as followed:

$$WCSM = \frac{\sum(Mi_{v1} * Pi_{v2})}{\sum Mi_{v1}}$$

The associated 95% Confidence Interval (95% CI), based on the two-stage cluster sampling design (1st stage: apiaries - 2nd stage: colonies) was calculated by making use of inverse-probability weighting, more specifically by Taylor series linearization and finite population corrections to calculate the two-stage variance (Lumley, 2018).
The weights were:

- n/N:
  N= total number of apiaries in the sampling frame (country, region, province);
  n= selected apiaries from the country (region, province)
- mi_{v2}/Mi_{v1}:
  Mi_{v1}= apiary size at Visit 1 = total number of colonies present in apiary I;

mi_{v2}= number of colonies selected during visit 1 in apiary i (min.1 – max. 6).

The weighted colony mortalities are considered as the most accurate and unbiased estimators (and confidence intervals) of colony mortality.

4.2. SEASONAL COLONY MORTALITY (SPRING-SUMMER 2022) AND YEARLY COLONY MORTALITY (FALL 2022 – SUMMER 2023)

The FASFC inspectors recorded also mortalities for each apiary (i) during visit 3 ($Xdead_{v3}$). A colony was considered suffering from seasonal mortality using the same criteria as those used to assess winter mortality and an additional criteria, which is that the colony was merged with another between visit 2 and visit 3. Similar estimations as described for the winter mortality were performed to assess the seasonal mortality. The following formula was used to calculate the seasonal colony mortality risk (Pi_{v3}):

$$Pi_{v3} = \frac{\sum Xdead_{v3}}{\sum mi_{v2}}$$

The yearly colony mortality risk (Pi_{vy}) was calculated based on the number of dead colonies during visits 2 and 3 ($Xdead_{v2} + Xdeadv3$) among those that were selected during visit 1 (mi_{v1}).

RESULTS

1. Monitoring of honeybee colony mortality incidence risk across Belgium

From the 190 shortlisted apiairies, 11 apiaries, of which three had stopped their activities, 1 disappeared, and 7 were visited a first time in December and January (i.e. outside of deadlines), were removed from the survey. Therefore, in total 179 apiaries were kept in the survey, representing 742 colonies monitored. From those 742 colonies, 554 (74.66%) had survived the winter.

Additionally, 23 out of 179 apiaries were excluded from the seasonal colony mortality analysis. 18 of these apiaries weren't visited a third time because no selected live colonies were recorded at the second visit (spring). Of the five apiaries with selected live colonies at the second visit, one had stopped its activities, one had not received a third visit due to social circumstances, two were unreachable and one was affected by an outbreak of European foulbrood.

1.1. OVERWINTERING WEIGHTED COLONY MORTALITY (FALL 2022-SPRING 2023)

Per apiary, the winter colony mortality recorded at visit 2 (Pi_{v2}), was weighted according to the recorded number of colonies present in the apiary at visit 1 (Mi_{v1}). The Table 3 and Figures 4 and 5 gives an overview of the mortality estimates in each geographical entity. The estimate for Belgium was 25.42% (95% CI: 19.58-31.26).

The highest winter colony mortality was found in the provinces of Antwerp (39.66%, 95% CI: 27.34-52.00) and West-Flanders (39.49, 95% CI:19.05-59.93). The surveyed colonies of 26.09% (6/23) of the sampled apiaries in Antwerp, and 20.83% (5/24) in West-Flanders, had not survived during winter. However, this high mortality was not significantly statistically different from other provinces except from Luxemburg. The lowest winter colony mortality was observed in Luxemburg (2.11%, 95% CI: 0.00-5.01) and it was significantly statistically lower than in other provinces except from Namur.

Table 3 Overwintering weighted honeybee colony mortality from Fall 2022 until Spring 2023

Geographical entity	Number of sampled colonies (mi)	Estimate mortality (%)	95% CI_LL	95% CI_UL
Belgium	**742**	**25.42**	**19.58**	**31.26**
Brussels-Capital region	21	19.05	0.00	46.56
Flanders region	379	32.90	25.10	40.69
Walloon region	342	18.69	10.97	26.41
BRU	21	19.05	0.00	46.56
ANT	85	39.66	27.34	51.99
OVL	68	24.73	5.97	43.48
LIM	92	24.39	13.61	35.16
VBR	53	31.63	13.85	49.40
WVL	81	39.49	19.05	59.93
HAI	53	21.61	5.08	38.14
NAM	85	17.05	0.00	35.71
LIE	62	29.73	8.02	51.44
LUX	85	2.11	0.00	5.01
BRW	57	23.81	6.88	40.74

95% CI: 95% Confidence Interval with Survey R package for complex survey, LL: Lower Limit, UL: Upper Limit

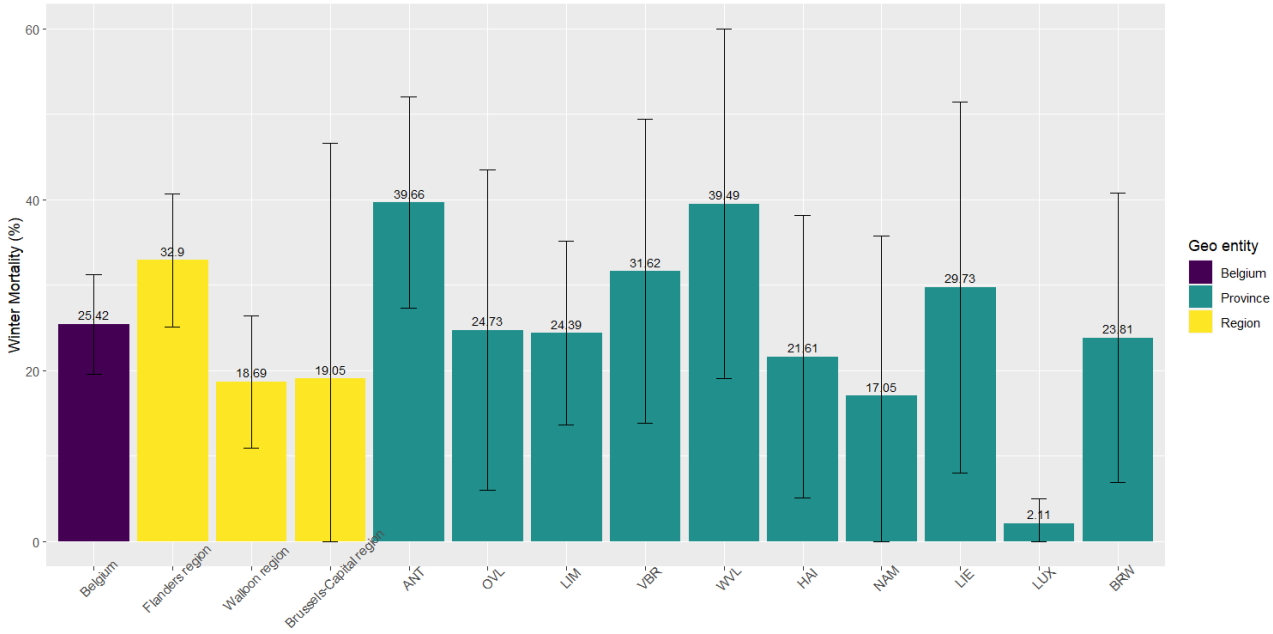

Figure 4 Overwintering weighted honeybee colony mortality (with 95% CI) from Fall 2022 until Spring 2023

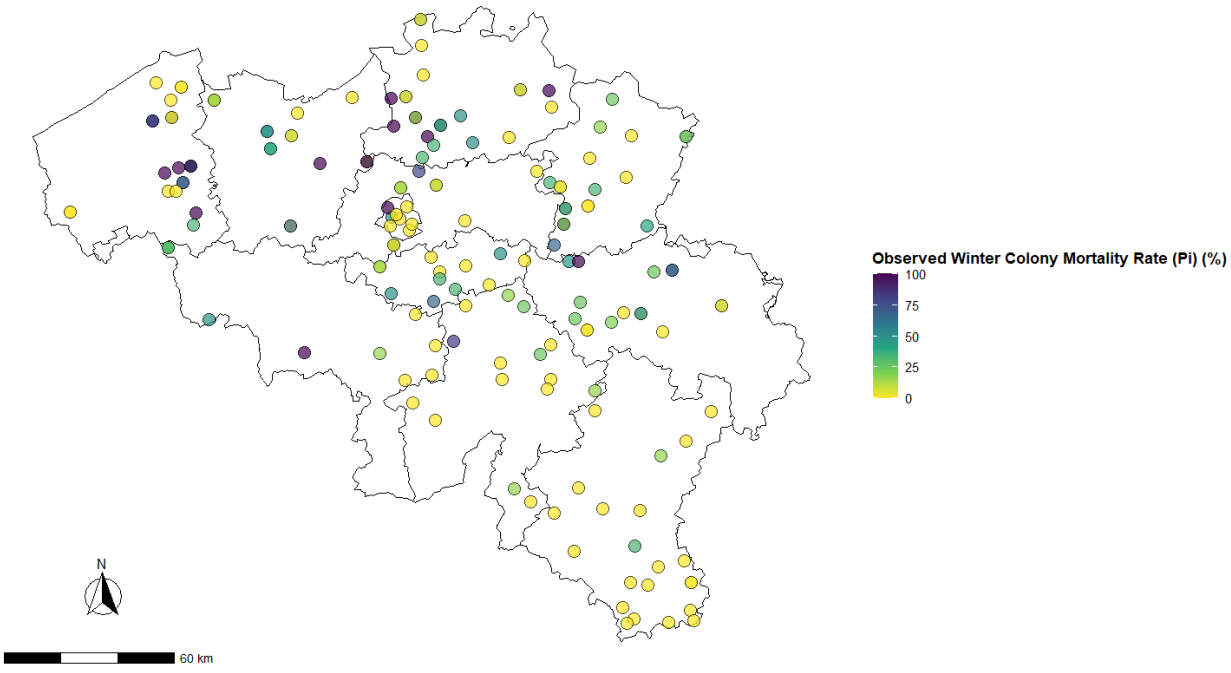

Figure 5 Overwintering mortality of honeybee colonies from Fall 2022 until Spring 2023

1.2. SEASONAL WEIGHTED COLONY MORTALITY (SPRING-SUMMER 2023)

The seasonal colony mortality was illustrated in Table 4 and Figures 6 and 7. The estimate for Belgium was 7.84% (95% CI: 3.94-11.74).

Table 4 Seasonal weighted honeybee colony mortality from Spring until Summer 2023

Geographical entity	Number of sampled colonies (mi)	Estimate mortality (%)	95% CI_LL	95% CI_UL
Belgium	**539**	**7.84**	**3.94**	**11.74**
Brussels-Capital region	14	0.00	0.00	0.00
Flanders region	248	5.38	1.67	9.08
Walloon region	277	10.16	3.66	16.66
BRU	14	0.00	0.00	0.00
ANT	54	0.00	0.00	0.00
OVL	45	3.10	0.00	9.44
LIM	68	5.57	0.00	12.36
VBR	34	19.05	4.94	33.16
WVL	47	8.54	0.00	20.75
HAI	40	5.34	0.00	13.31
NAM	75	8.27	0.32	16.21
LIE	42	6.65	0.00	15.55
LUX	75	18.01	0.00	42.03
BRW	45	15.38	0.00	38.25

95% CI: 95% Confidence Interval with Survey R package for complex survey, LL: Lower Limit, UL: Upper Limit

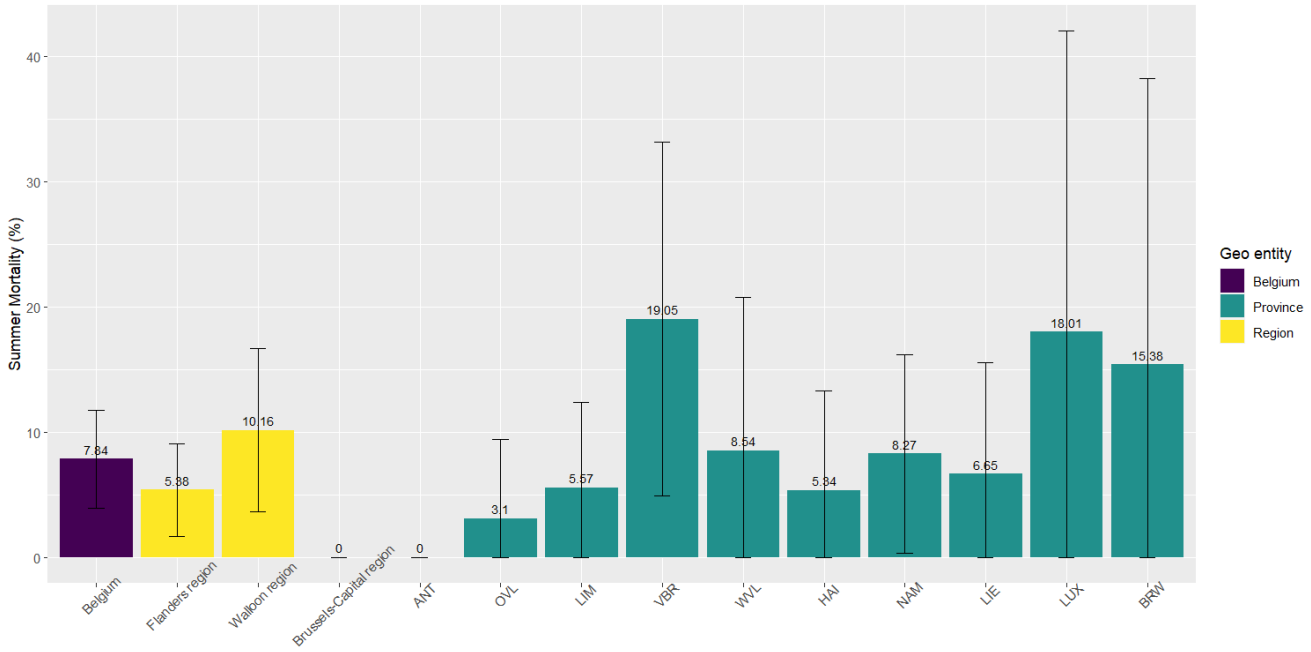

Figure 6 Seasonal weighted honeybee colony mortality (with 95% CI) from Spring until Summer 2023

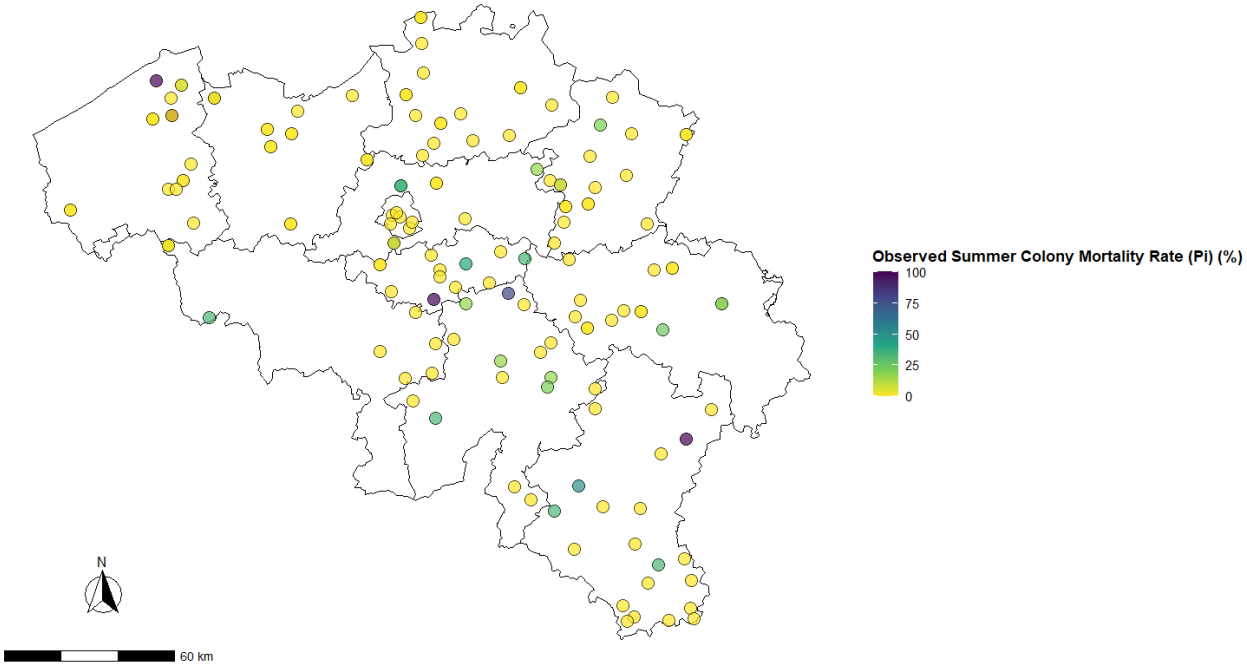

Figure 7 Seasonal mortality of honeybee colonies from Fall 2022 until Spring 2023

1.3. YEARLY WEIGHTED COLONY MORTALITY (FALL 2022-SUMMER 2023)

Yearly colony mortality for 2021-2022 (previous year) was presented in Table 5. Yearly colony mortality for 2022-2023 was presented in Table 6, and Figures 8 and 9. Overall, the mortality for 2022-2023 has increased as compared to the previous year (2021-2022) but the difference between both years was not statistically significant.

Table 5 Yearly weighted honeybee colony mortality from Fall 2021 until Summer 2022

Geographical entity	Number of sampled colonies (mi)	Estimate mortality (%)	95% CI_LL	95% CI_UL
Belgium	**724**	**21.86**	**17.61**	**26.11**
Brussels-Capital region	22	17.36	5.63	29.09
Flanders region	345	27.79	21.57	34.02
Walloon region	357	15.67	10.21	21.13
BRU	22	17.36	5.63	29.09
ANT	82	24.11	11.77	36.45
OVL	86	32.47	19.81	45.13
LIM	53	19.62	7.83	31.40
VBR	52	28.85	20.96	36.75
WVL	72	33.82	16.38	51.27
HAI	53	28.71	10.37	47.05
NAM	63	18.02	0.00	36.41
LIE	77	2.82	0.00	6.05
LUX	97	11.66	4.01	19.30
BRW	67	24.29	11.19	37.40

95% CI: 95% Confidence Interval with Survey R package for complex survey, LL: Lower Limit, UL: Upper Limit

Table 6 Yearly weighted honeybee colony mortality from Fall 2022 until Summer 2023

Geographical entity	Number of sampled colonies (mi)	Estimate mortality (%)	95% CI_LL	95% CI_UL
Belgium	**654**	**27.26**	**21.30**	**33.22**
Brussels-Capital region	15	6.67	0.00	20.12
Flanders region	326	30.22	22.25	38.19
Walloon region	328	25.15	16.63	33.68
BRU	15	6.67	0.00	20.12
ANT	72	35.64	20.74	50.54
OVL	57	17.42	3.84	31.01
LIM	88	26.87	16.10	37.64
VBR	44	38.33	24.69	51.97
WVL	65	29.57	11.24	47.90
HAI	51	18.89	3.21	34.58
NAM	85	24.86	6.98	42.73
LIE	58	31.83	15.06	48.61
LUX	77	20.30	0.00	43.93
BRW	57	31.14	9.07	53.20

95% CI: 95% Confidence Interval with Survey R package for complex survey, LL: Lower Limit, UL: Upper Limit

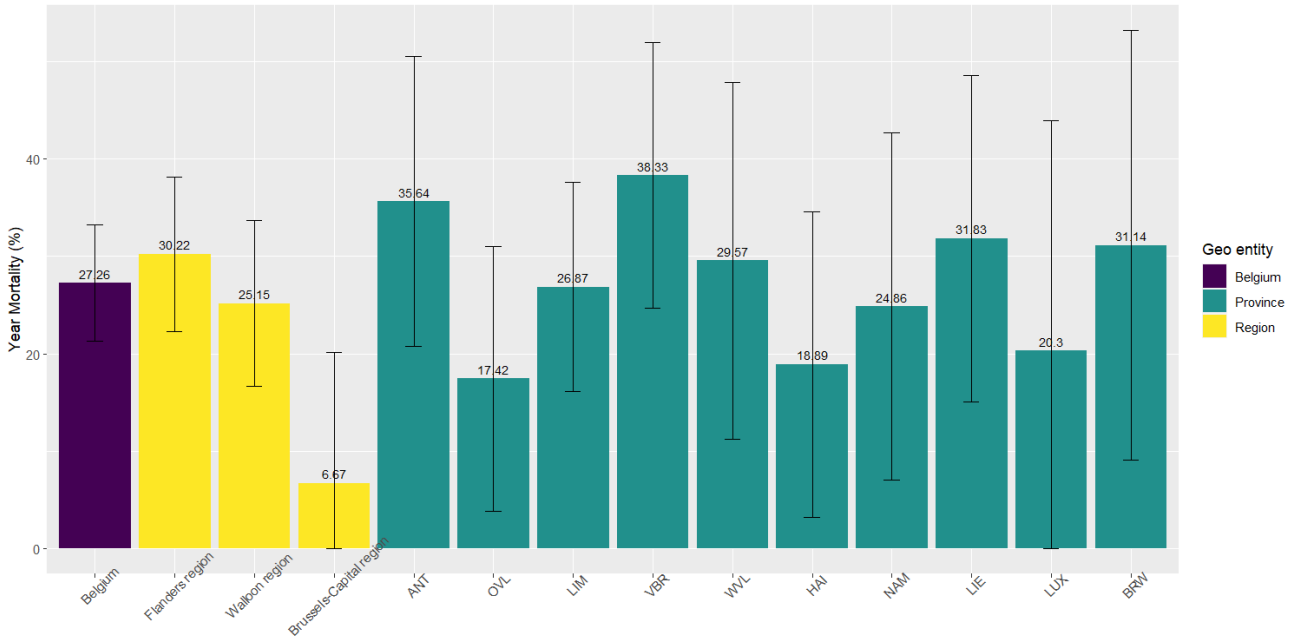

Figure 8 Yearly weighted honeybee colony mortality (with 95% CI) from Fall 2022 until Summer 2023

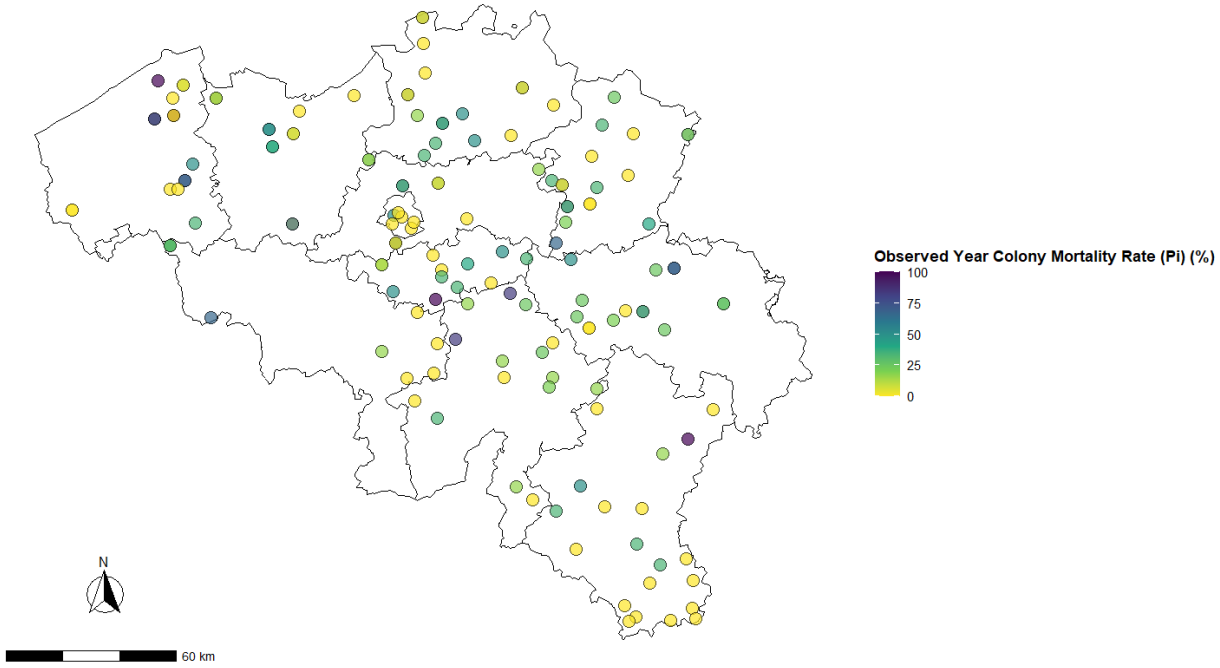

Figure 9 Yearly mortality of honeybee colonies from Fall 2022 until Spring 2023

2. Evolution of honeybee colony mortality between 2016-2023

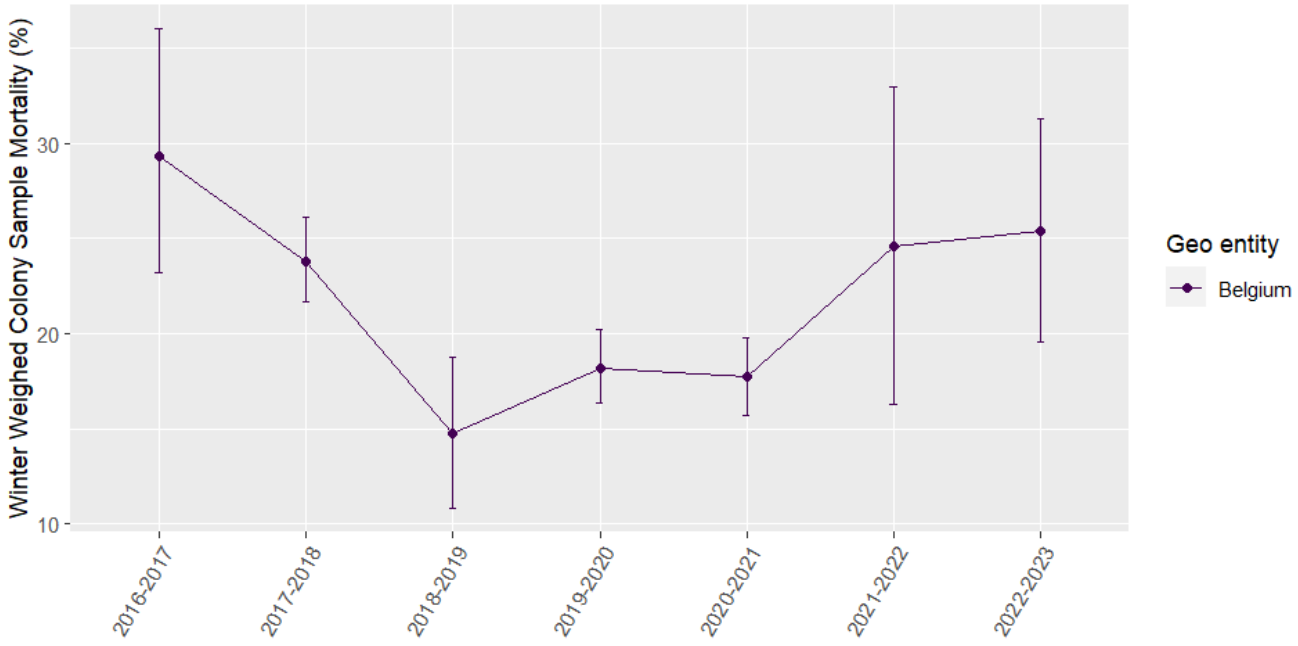

Figure 10: Evolution of winter weighted colony sample mortality (%) in Belgium between 2016-2023

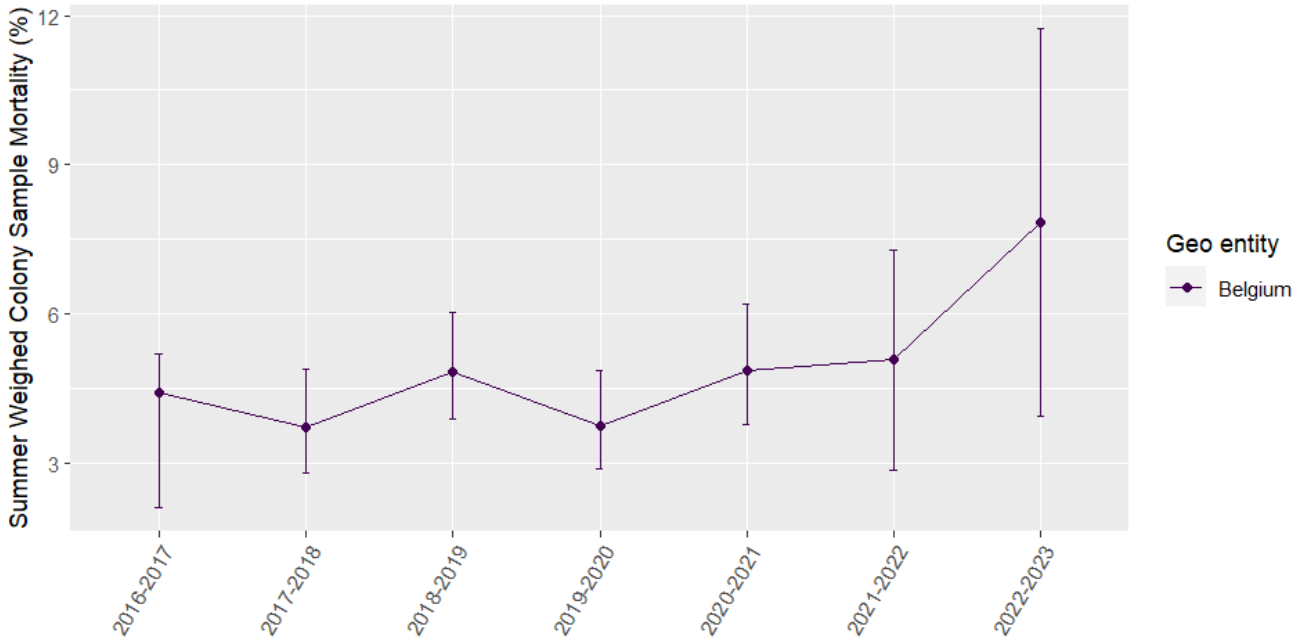

Figure 11: Evolution of seasonal weighted colony sample mortality (%) in Belgium between 2016-2023

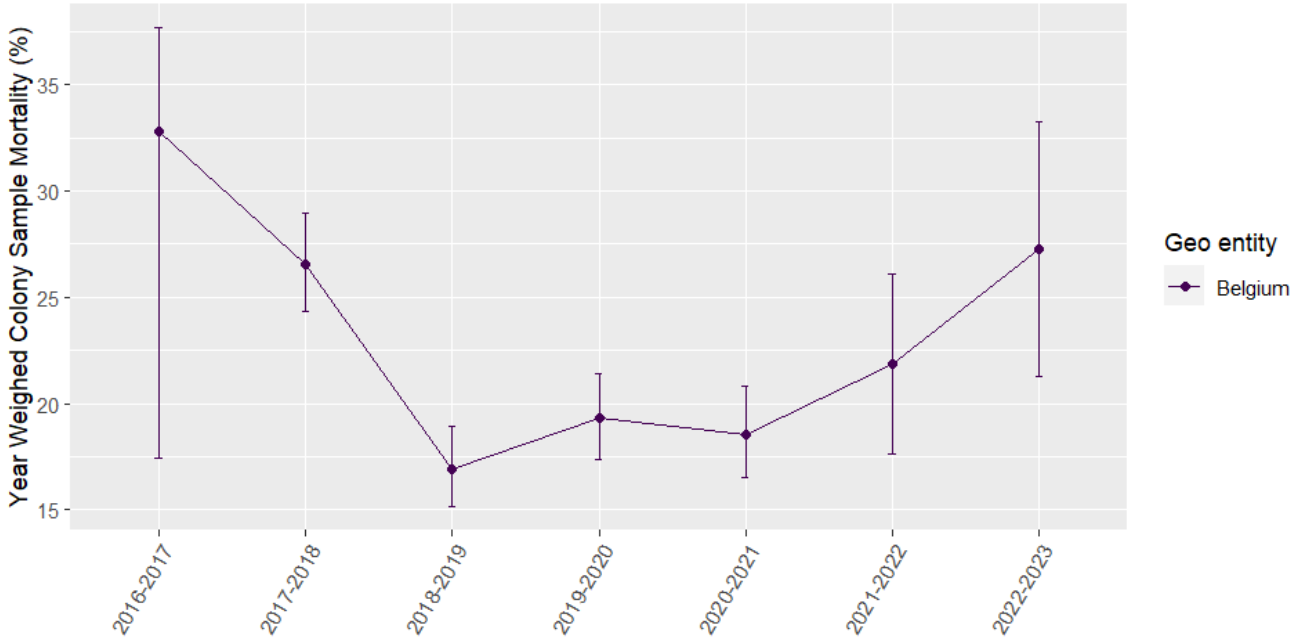

Figure 12: Evolution of yearly weighted colony sample mortality (%) in Belgium between 2016-2023

DISCUSSION

The estimated winter weighted colony mortality of 2022-2023 was 25.42% (95% CI: 19.58-31.26) for Belgium, while the seasonal weighted colony mortality was 7.84% (95% CI: 3.94-11.74). The yearly weighted colony mortality, considering both winter and summer, was estimated at 21.86% (95% CI: 17.61-26.11). The provincial-level analysis was constrained by a limited number of samples from each province, leading to wide confidence intervals. While the sampling design may not allow to identify differences between provinces, it provides a good estimation at the national level.

With data spanning from 2016 to today, a prospective trend analysis becomes feasible. This approach would allow to discern whether there is a consistent decreasing, increasing, or stable trend in colony mortality over the years. Such an analysis would help in uncovering patterns, contributing factors, and supporting decision-making for the effective management of colony health.

In addition, it would be interesting to analyse more in details the data registered during field sampling of apiaries (treatments, diseases, hornets attacks, …) in order to find potential correlations and risk factors between observed mortality and registered variables.

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MORE INFORMATION

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