COORDINATION OF VETERINARY ACTIVITIES AND VETERINARY EPIDEMIOLOGY

SURVEILLANCE OF BELGIAN HONEYBEE COLONY MORTALITY 2023-2024

Scientific Report

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Sciensano

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

Surveillance of Belgian honeybee colonoy mortality 2023-2024

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ABSTRACT

An alarming mortality of honeybee colonies (*Apis mellifera*) has been reported in many countries since early 2000. Results from a former European project,Epilobee, (2012 – 2014) showed that the Belgian honeybee colony mortality was the highest among participant countries. In September 2016, the Federal Agency for the Safety of the Food Chain (FASFC) has launched an annual program of surveillance of Belgian honeybees health. The objective of this program is to describe and monitor the annual honeybee colony mortality (i.e. between fall and summer) and the summer mortality : overwintering mortality (i.e. between fall and spring) and summer mortality (i.e. between spring and summer).

This report provides the results of the 2023-2024 campaign.

In each of the apiaries selected by the FASFC, three visits were conducted: the first one in fall 2023, when the colonies were preparing for winter, the second visit in spring 2024, after bees started foraging, and the third visit during summer 2024, the active season. The field survey included direct observations, interviews and measurements performed by trained FASFC inspectors. The 2023-2024 overwinter weighted colony mortality was estimated to be 26.7% (95% CI: 21.%-31.8%). The summer weighted colony mortality was estimated at 6.8% (95% CI: 4.1%-9.6%). The yearly weighted colony mortality, considering both winter and summer, was estimated to be 31.2% (95% CI: 25.7%-36.6%).

INTRODUCTION

An alarming mortality of honeybee colonies (*Apis mellifera*) has been reported in many countries since early 2000. A former 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) launched the program of surveillance of honeybee colony health. The 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 2023 until Summer 2024.

METHODOLOGY

1. Population frame

Since 2006, beekeepers have to be registered with the FASFC. This obligation applies to all beekeepers including hobbyists and is independent of honey production and the possible payment of a contribution. In 2024, 11300 beekeepers were registered, with more beekeepers in Flanders (n=6493) compared to Wallonia (n=4571), and 236 beekeepers in the region of Brussels capital. Figure 1 shows the density of registered beekeepers per municipality (number/km²) in 2024.

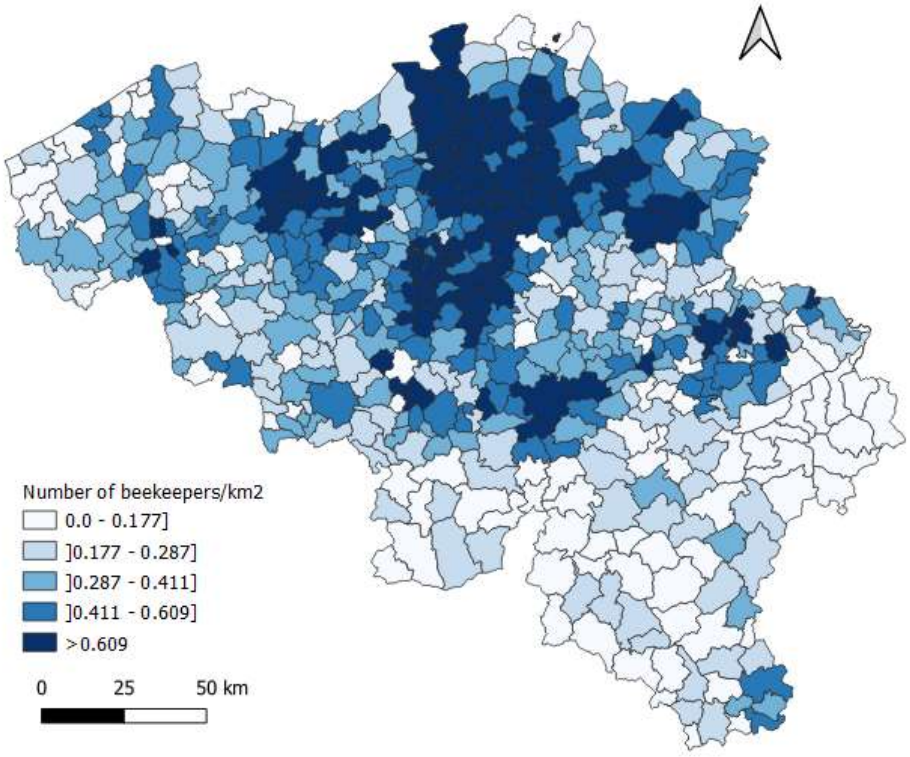

Figure 1: Density of registered beekeepers per municipality (number/km²) in Belgium, 2024

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 20 apiaries per local control unit (LCU) (Table I), 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 II below reports the number of selected apiaries and colonies for the whole country and per region and province. In 2024, the FASFC conducted visits to a total of 181 apiaries, monitoring 722 colonies. Two beekeepers were excluded from the database: one due to inaccurately recorded data and the other because no follow-up visits were documented. After these exclusions, the dataset comprised 179 apiaries and 717 colonies (Table II).

Table I Number of apiaries sampled per local control unit

Local control unit (LCU) *	Number of sampled apiaries
ANTWERP (ANT)	**22**
BRUSSELS (BRU)	**13**
EAST FLANDERS-FLEMISH BRABANT (OVB)	**22**
FLEMISH BRABANT-LIMBURG (VLI)	**23**
HAINAUT (HAI)	**23**
LIEGE (LIE)	**12**
LUXEMBOURG-NAMUR (LUN)	**20**
WALLOON BRABANT-NAMUR (BNA)	**25**
WEST FLANDERS(WVL)	**19**

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

Table II Number of apiaries and colonies sampled per geographical entity

Geographical entity	Number of beekeepers in 2024 (N)	Number of apiaries sampled (n)	Number of colonies within sampled apiaries (Mi)	Number of sampled colonies (mi)
Belgium	**11300**	**179**	**1130**	**717**
Brussels-Capital region	236	13	30	30
Flanders region	6493	86	483	335
Walloon region	4571	80	617	352
Hainaut	1107	23	147	101
Liege	1017	13	125	34
Luxembourg	835	18	111	76
Namur	1036	11	83	55
Walloon Brabant	576	15	151	86
Antwerp	*1858*	*22*	*109*	*90*
East Flanders	1385	16	113	70
Flemish Brabant	1203	16	81	54
Limburg	1094	13	89	53
West Flanders	953	19	91	68

3. Data collection

For each of the selected apiaries, three visits were conducted: the first one in fall 2023, when the colonies were preparing for winter, the second visit in spring 2024, after bees started foraging, and the third visit during summer 2024, the active season.

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). However, the analysis of questionnaire results is not included in the present study which focuses on quantitative analysis of bee mortality.

4. Statistical analysis

The mortality was evaluated over two periods: between fall 2023 and spring 2024, i.e. winter mortality, and between spring and summer 2024, i.e. summer mortality. During the first visit, only colonies assessed to have the potential of overwintering 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 is a prevalence that represents the number of (new) mortality cases in the Belgian honeybee colony population over a given period, divided by the number of honeybee colonies at the beginning of the study period. We calculated the weighted colony mortality to take into account the sampling design.

4.1. WEIGHTED COLONY MORTALITY

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 winter colony mortality (Pi_{v2}):

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

Per apiary (i), the recorded colony sample mortality (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 or province);
  n= selected apiaries within this sampling frame (country, region or 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.

The FASFC inspectors recorded also mortalities for each apiary (i) during visit 3 ($Xdead_{v3}$). A colony was considered suffering from summer mortality using the same criteria as those used to assess winter mortality. Similar methodology as described for the winter weighted mortality were performed to assess the summer weighted mortality. The following formula was used to calculate the summer colony mortality (spring-summer)(Pi_{v3}):

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

The yearly weighted colony mortality prevalence (fall-summer)(Pi_{vy}) was calculated with similar methodology, 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

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1. Monitoring of honeybee weighted colony mortality incidence risk across Belgium

Out of the 179 shortlisted apiaries, one was affected by an outbreak of European foulbrood during winter and was destroyed. Two others chose to relocate or merged colonies during winter and were subsequently removed from the list. Therefore, in total 176 apiaries were kept in the survey for subsequent analysis, representing 703 colonies monitored. From those 703 colonies, 505 (71.8%) had survived the winter.

1.1. OVERWINTERING WEIGHTED COLONY MORTALITY (FALL 2023-SPRING 2024)

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 III and Figures 2 gives an overview of the mortality estimates in each geographical entity.

The estimate mortality for Belgium was 26.7% (95% CI: 21.6%-31.8%).
The highest winter colony mortality was observed in the provinces of Limburg (51.0%, 95% CI: 31.2%-70.7%), where 29 out of 53 colonies perished, and West Flanders (39.3%, 95% CI: 18.2%-60.4%). The prevalence of mortality in Limburg was statistically significantly higher compared to provinces of Liège, Hainaut, and Namur whereas the prevalence in West Flanders did not differ significantly from other provinces. The lowest winter colony mortality was recorded in Liège (12.0%, 95% CI: 0.0%-25.6%) (Table III).
When comparing regions, Flanders shows a higher prevalence of mortality compared to Brussels and Wallonia. This difference is statistically significant when compared to Wallonia (Figure 2).

Table III. Overwintering honeybee weighted colony mortality from Fall 2023 until Spring 2024

Geographical entity	Number of sampled colonies (mi)	Estimate weighted mortality (%)	95% CI Lower Limit	95% CI Upper Limit
Belgium	**703**	**26.7**	21.6	31.8
Brussels-Capital region	**30**	**33.3**	5.0	61.6
Flanders region	**323**	**36.3**	27.7	44.9
Walloon region	**350**	**19.0**	13.0	24.9
Hainaut	**101**	**18.8**	9.2	28.4
Liege	**32**	**12.0**	0.0	25.6
Luxembourg	**76**	**17.7**	2.5	32.9
Namur	**55**	**15.7**	5.3	26.0
Walloon Brabant	**86**	**27.3**	10.2	44.3
Antwerp	**90**	**34.1**	18.5	49.7
East Flanders	**58**	**27.9**	4.4	51.5
Flemish Brabant	**54**	**30.1**	10.3	50.0
Limburg	**53**	**51.0**	31.2	70.7
West Flanders	**68**	**39.3**	18.2	60.4

95% CI: 95% Confidence Interval

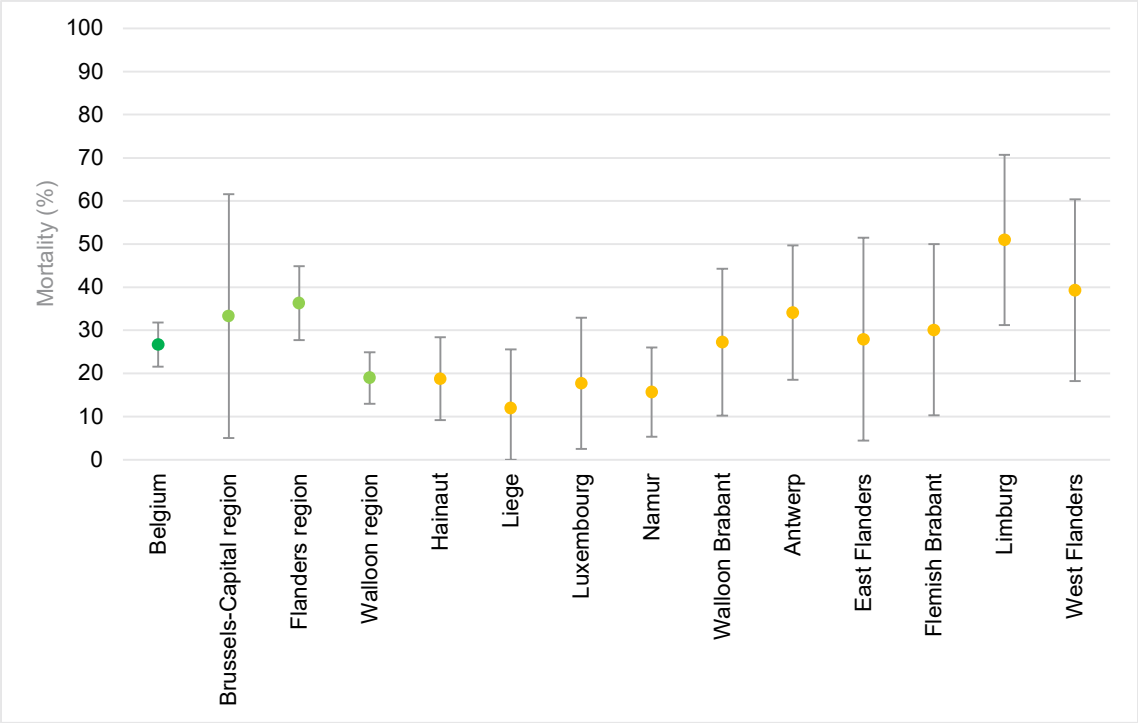

Figure 2 Overwintering honeybee weighted colony mortality (with 95% CI) from Fall 2023 until Spring 2024

1.2. SUMMER WEIGHTED COLONY MORTALITY (SPRING 2024-SUMMER 2024)

The summer colony mortality was illustrated in Table IV and Figure 3. The estimate mortality for Belgium was 6.8% (95% CI: 4.1%-9.6%). We observed that Limburg had the highest level of mortality (19.2%, 95% CI: 6.0%–32.4%), but this difference was not statistically significant compared to other provinces (not considering Walloon Brabant where mortality is 0.0%). When comparing regions, Brussels shows the highest level of mortality (almost three times higher than in Wallonia), but mortality is not statistically significant difference between regions.

Table IV Summer honeybee weighted colony mortality from Spring until Summer 2024

Geographical entity	Number of sampled colonies (mi)	Estimate mortality (%)	95% CI Lower Limit	95% CI Upper Limit
Belgium	703	**6.8**	4.1	9.6
Brussels-Capital region	30	**13.0**	0.0	34.8
Flanders region	323	**9.8**	4.1	15.4
Walloon region	350	**4.5**	2.1	6.9
Hainaut	101	**4.9**	0.0	10.2
Liege	32	**3.6**	0.0	9.8
Luxembourg	76	**5.1**	0.0	10.9
Namur	55	**11.4**	2.0	20.8
Walloon Brabant	86	**0.0**	0.0	0.0
Antwerp	*90*	***5.1***	*0.0*	*13.9*
East Flanders	58	**8.2**	0.0	22.4
Flemish Brabant	54	**6.6**	0.0	18.1
Limburg	53	**19.2**	6.0	32.4
West Flanders	68	**12.9**	0.0	28.8

95% CI: 95% Confidence Interval

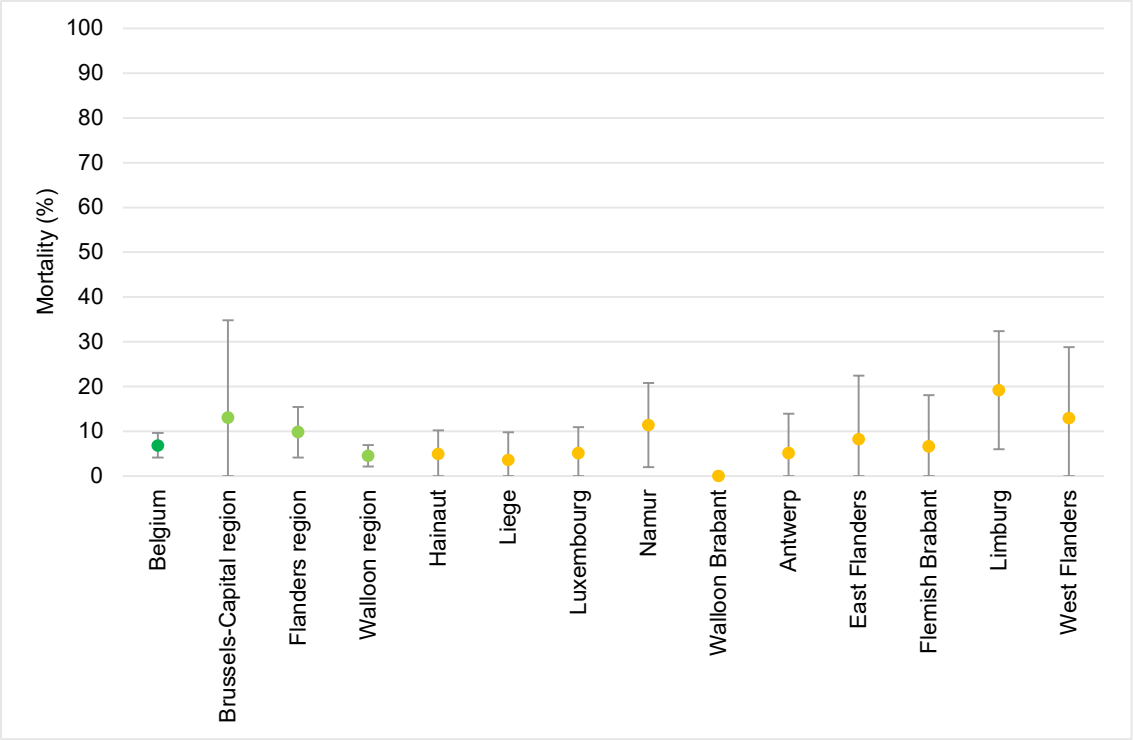

Figure 3 Summer honeybee weighted colony mortality (with 95% CI) from Spring until Summer 2023

1.3. YEARLY WEIGHTED COLONY MORTALITY (FALL 2023-SUMMER 2024)

Yearly weighted colony mortality for 2023-2024 is presented in Table V and Figure 4. The estimate for Belgium was 31.2% (95% CI: 25.7%-36.6%).

The highest mortality prevalence was observed in Limburg, where 60.0% (95% CI: 43.3%–76.6%) of colonies died (32/53 colonies) from fall 2023 to summer 2024. The other highest prevalences were recorded in Antwerp (36.9%, 95% CI: 20.1%–53.6%) and West Flanders (47.1%, 95% CI: 26.5%–67.6%). The lowest mortality prevalences were observed in Liège (15.4%, 95% CI: 1.0%–29.8%), Namur (23.9%, 95% CI: 9.3%–38.5%), and Hainaut (22.3%, 95% CI: 11.5%–33.1%). Compared to Limburg, these provinces exhibited a statistically significant lower prevalence of mortality. When comparing regions, Brussels has the highest mortality rate (43.3%, 95% CI:14.9%-71.8%), closely followed by Flanders (41.7%, 95% CI:32.5%-51.0%). In contrast, Wallonia showed a substantially lower mortality rate, nearly half that of the other regions (22.4%, 95% CI:16.2%-28.6%). The difference in mortality is statistically significant between Wallonia and Flanders but not between Wallonia and Brussels, due to larger confidence intervals.

Table V Yearly honeybee weighted colony mortality from Fall 2023 until Summer 2024

Geographical entity	Number of sampled colonies (mi)	**Estimate mortality (%)**	95% CI Lower Limit	95% CI Upper Limit
Belgium	703	**31.2**	25.7	36.6
Brussels-Capital region	30	**43.3**	14.9	71.8
Flanders region	323	**41.7**	32.5	51.0
Walloon region	350	**22.4**	16.2	28.6
Hainaut	101	**22.3**	11.5	33.1
Liege	32	**15.4**	1.0	29.8
Luxembourg	76	**22.2**	6.9	37.5
Namur	55	**23.9**	9.3	38.5
Walloon Brabant	86	**27.3**	10.2	44.3
Antwerp	90	**36.9**	20.1	53.6

East Flanders	58	**33.0**	6.4	59.6
Flemish Brabant	54	**33.0**	12.1	53.9
Limburg	53	**60.0**	43.3	76.6
West Flanders	68	**47.1**	26.5	67.6

95% CI: 95% Confidence Interval

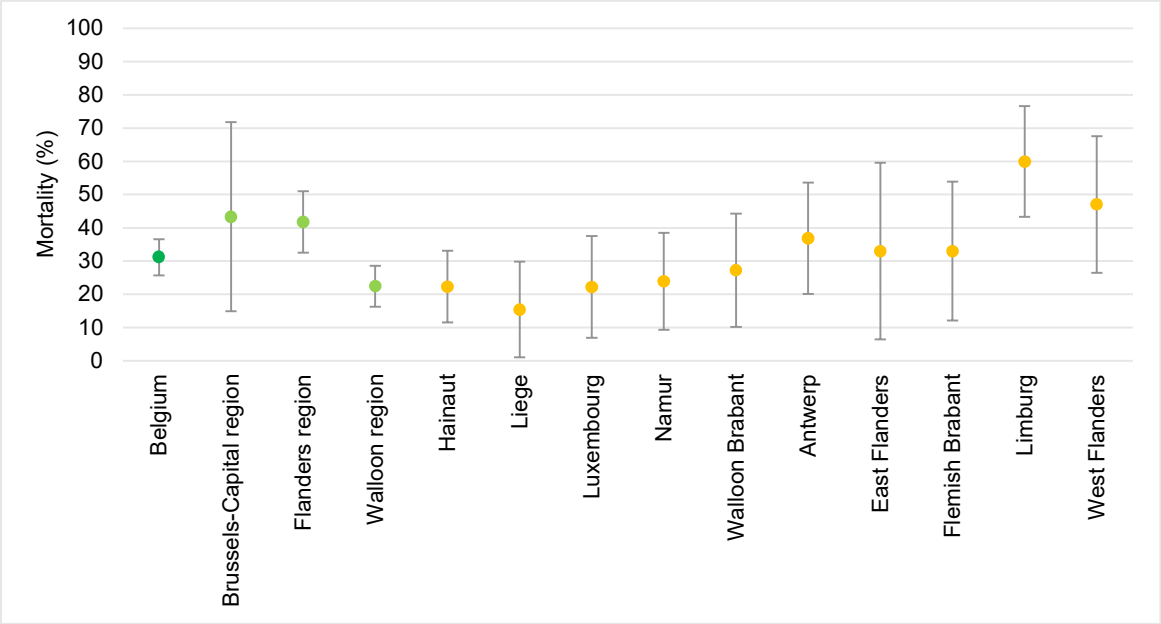

Figure 4 Yearly honeybee weighted colony mortality (with 95% CI) from Fall 2023 until Summer 2024

2. Evolution of honeybee winter colony mortality between 2016-2024

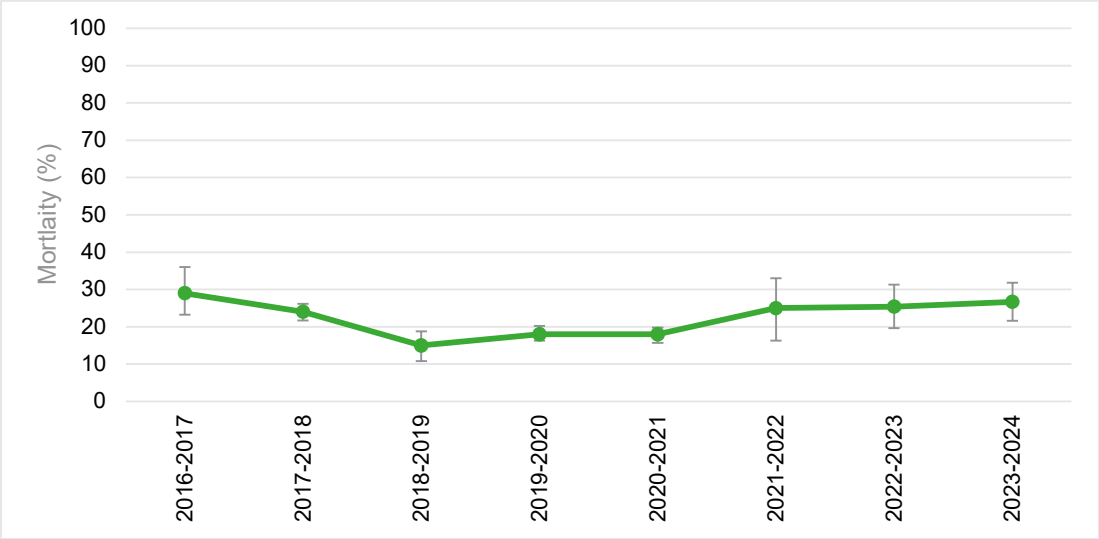

Figure 5: Evolution of winter weighted colony sample mortality (%) in Belgium between 2016-2024

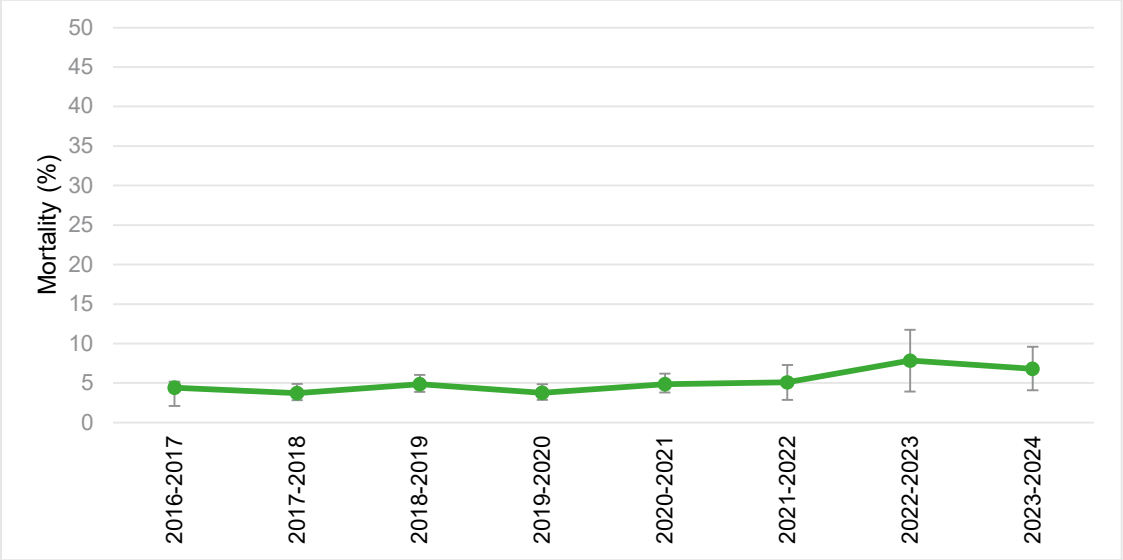

Figure 6: Evolution of summer weighted colony sample mortality (%) in Belgium between 2016-2024 (spring-summer)

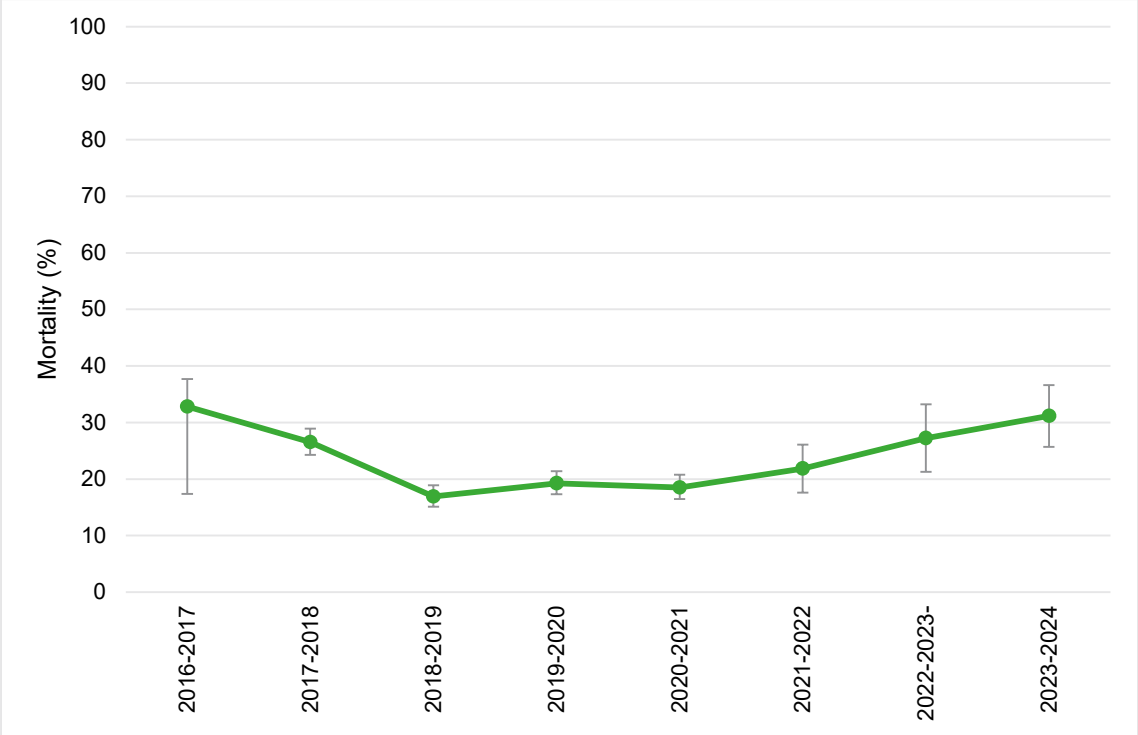

Figure 7: Evolution of yearly weighted colony sample mortality (%) in Belgium between 2016-2024 (fall 2023-summer 2024)

DISCUSSION

The estimated **winter weighted colony mortality** for 2023-2024 in Belgium was 28.2% (95% CI: 23.4%-33.0%); it is higher than the previous year's estimate of 25.4% (95% CI: 19.6%-31.3%). This increase is statistically significant when compared to the mortality rates observed in previous years (2018-2019 to 2021-2022). Moreover the time trend shows a steady increase since 2018-2019 when the observed mortality was at the lowest since the beginning of the monitoring program (14.7% - 95% CI 10.8 %-18.7%)The rise in mortality is observed both at provincial and regional levels. For example. Limburg showed significantly higher winter colony mortality compared to provinces with the lowest mortality rates. such as Liège and Hainaut. At the regional level. Flanders experienced a significantly higher mortality prevalence than Wallonia.

The **summer weighted colony mortality** (spring-summer 2024) was estimated at 7.1% (95% CI: 4.9%-9.4%). slightly lower than the 2022-2023 estimate of 7.8% (95% CI: 3.9%-11.7%). Mortality differences between provinces during this period were less pronounced. although West Flanders recorded the highest summer mortality.

Considering both winter and summer mortality, the **overall yearly weighted colony mortality** for 2023-2024 was 33.3% (95% CI: 29.8%-36.8%). representing a significant increase from the previous year's estimate of 21.9% (95% CI: 17.6%-26.1%). Limburg recorded the highest yearly mortality at 60.4% (95% CI: 38.7%-82.0%). while Wallonia exhibited the lowest mortality among the regions. However. the provincial-level analysis was constrained by a limited number of samples from Brussels. resulting in wide confidence intervals.

Analyzing **trends** from 2016 to 2024 (Figures 5. 6. and 7) offers valuable insights into the evolution of honeybee colony mortality in Belgium. While winter mortality fluctuates annually, summer mortality (spring-summer) remains relatively stable at lower levels. However. when combining both periods. the overall yearly mortality trends show significant variability. with a clear increasing statistically significant trend in recent years.

The reason(s) for this increasing bee mortality in Belgium has not been investigated in this study. It would be interesting to analyse more in details the data registered by FASFC agents during field sampling of apiaries (treatments. diseases. hornets attacks. …). This could help to find potential correlations and risk factors between observed mortality and registered variables to provide possible explanations for mortality.

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