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Supplementary information: Monitoring of the development of honeybee colonies placed near apple orchards in South Tyrol during spring

Zusatzinformationen: Beobachtungen zur Volksentwicklung von Honigbienenvölkern im Einzugsgebiet des Südtiroler Obstanbaus während des Frühjahrs

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Materials and method

The number of observed apiaries and colonies varied over the three years of monitoring and are summarized in Table S1. 2014 in total, 74 colonies were involved in the monitoring (on site number 12 only four colonies were available instead of five). As a consequence of the reduced number of apiaries in 2015 and 2016, also the number of bee colonies decreased in to 65 resp. 64 (in 2016 only four colonies were present on site number 9 instead of five)

Bee colonies

The bee colonies were kept in different beehive-types like Zander, Deutsch-Normal-Maß (DNM), and Dadant. Some beehives of the monitored colonies were made by local producers and the frames used within differed slightly from general standards. This was taken into consideration when the surface area of the frames had to be calculated for the evaluation of colony size. On two sites and even within the five colonies from one site, different beehive-types were used (in the years 2015 and 2016 at site 1 and at site 13 in 2015). No information on the ages of the queens and their genetics were available. Some beekeepers migrated with their colonies during the monitored period to another site (as is marked for site 9 in Fig. S1 and noted in Table S2).

Table S1. Overview of the number of observed colonies in each year within the monitoring.

year	number of colonies	number of apiaries
2014	74	15
2015	65	13
2016	64	13

Monitored apiaries

The apiaries positioned southern from Bozen/Bolzano (sites no. 5, 9, 10, and 11) were in the "non-AP-area" whereas colonies on sites north of Bozen/Bolzano (site no. 1, 2, 3, 4, 6, 7, 8, 12, 13, 14, and 15) were within the AP-area (see Fig. S1).

For some reason, it was not possible to observe the same apiaries for all three years. For instance, the beekeeper of site 6 preferred to switch the position of his apiary from 2014 to 2015 by around 1 km, whereas in another case (site no. 11 in 2014) the apiary was difficult to reach by vehicle and there-

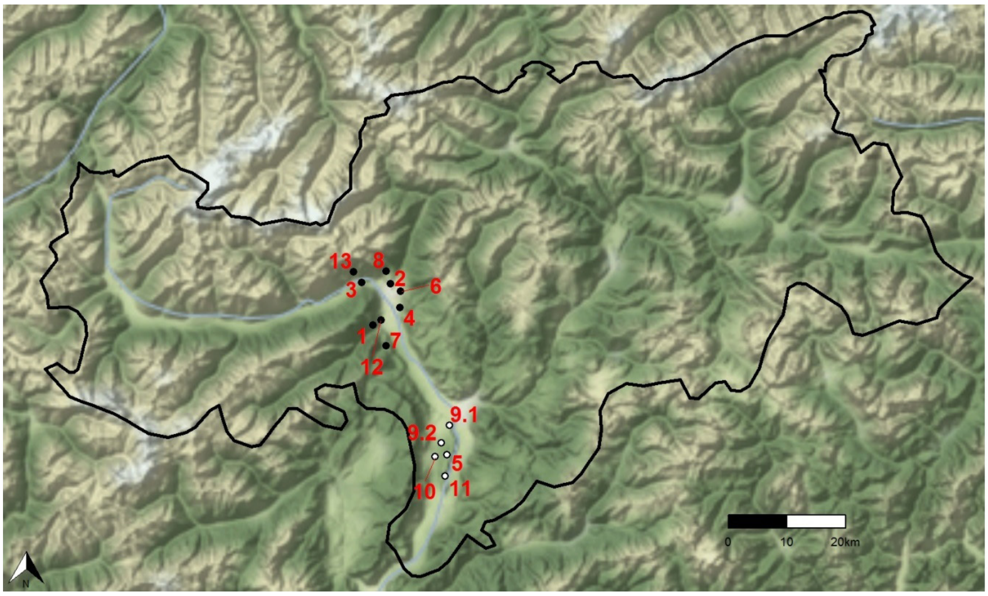

Fig. S1. Positions of the observed apiaries in 2015 on a map of South Tyrol (province of Italy). The spots indicate the positions of the monitored apiaries in the "AP-area" (black) and in the "non-AP-area" (white). The numbers were given to the 13 different apiaries for identification (more details in Table S2). Apiary 9 was at the beginning of the monitoring on position 9.1 and migrated during the monitoring to position 9.2.

fore had to be changed. In Table S2, the exact positions of all apiaries in each year are given. Most of the apiaries over 600 m were present in the AP-area (exception site no. 5 in 2015 in Mölten (Verschneid)).

An overview of the distribution of the positions of the apiaries over different altitudes is given in Fig. S2. The altitudes ranged from 222 m a.s.l. (in Pfatten) up to 1,181 m a.s.l. (in Mölten (Verschneid)).

Table S2. Summarizes some information from the different apiaries monitored from 2014-2016 in the project Apistox I. For apiaries where the beekeepers migrated with the colonies (for example apiary 5 in 2014) two different positions are listed: the first one corresponds to the position at the start of the monitoring and the second one is the one to which he migrated.

apiary number	Year	Township	Coordinates	m a.s.l.	"AP" or "non-AP"
1	2014	Lana (Pawigl)	46°37'05.8"N 11°08'01.9"E	504	AP
	2015	Lana (Pawigl)	46°36'42.0"N 11°07'33.6"E	520	AP
	2016	Lana (Pawigl)	46°36'42.0"N 11°07'33.6"E	520	AP
2	2014	Tisens	46°34'41.4"N 11°09'04.0"E	753	AP
	2015	Dorf Tirol (Putzengütl)	46°40'29.0"N 11°09'55.7"E	487	AP
	2016	Dorf Tirol (Putzengütl)	46°40'29.0"N 11°09'55.7"E	487	AP
3	2014	Algund	46°40'35.6"N 11°06'09.4"E	488	AP
	2015	Algund	46°40'35.6"N 11°06'09.4"E	488	AP
	2016	Algund	46°40'35.6"N 11°06'09.4"E	488	AP
4	2014	Plaus	46°38'42.5"N 11°02'10.4"E	560	AP
	2015	Meran	46°38'18.4"N 11°11'11.8"E	540	AP
	2016	Meran	46°38'18.4"N 11°11'11.8"E	540	AP
5	2014	Terlan and Mölten (Verschneid)	46°32'01.8"N 11°15'26.6"E and 46°33'52.2"N 11°15'56.9"E	286 and 1181	non-AP
	2015	Eppan	46°24'46.1"N 11°17'32.3"E	530	non-AP
	2016	Eppan	46°24'46.1"N 11°17'32.3"E	530	non-AP
6	2014	Schenna	46°40'23.7"N 11°11'50.9"E	562	AP
	2015	Meran	46°39'48.7"N 11°11'17.3"E	367	AP
	2016	Schenna	46°41'47.6"N 11°11'33.7"E	615	AP
7	2014	Tisens	46°34'47.8"N 11°09'19.3"E	715	AP
	2015	Tisens	46°34'47.8"N 11°09'19.3"E	715	AP
	2016	Tisens	46°34'47.8"N 11°09'19.3"E	715	AP
8	2014	Dorf Tirol	46°41'38.7"N 11°09'21.0"E	646	AP
	2015	Dorf Tirol	46°41'38.7"N 11°09'21.0"E	646	AP
	2016	Dorf Tirol	46°41'38.7"N 11°09'21.0"E	646	AP
9	2014	Eppan 1 and Eppan 2	46°27'28.3"N 11°17'47.3"E and 46°25'58.6"N 11°16'44.0"E	449 and 511	non-AP
	2015	Eppan 1 and Eppan 2	46°27'28.3"N 11°17'47.3"E and 46°25'58.6"N 11°16'44.0"E	449 and 511	non-AP
	2016	Eppan 1 and Eppan 2	46°27'28.3"N 11°17'47.3"E and 46°25'58.6"N 11°16'44.0"E	449 and 511	non-AP
10	2014	Kaltern 1 and Kaltern 2	46°24'43.7"N 11°13'47.8"E and 46°24'29.7"N 11°15'53.2"E	576 and 378	non-AP
	2015	Kaltern 2	46°24'29.7"N 11°15'53.2"E	378	non-AP
	2016	Kaltern 2	46°24'29.7"N 11°15'53.2"E	378	non-AP
11	2014	Nals and Grissian	46°32'41.4"N 11°11'43.4"E and 46°32'20.5"N 11°10'50.1"E	407 and 860	non-AP
	2015	Pfatten	46°22'46.7"N 11°17'11.7"E	222	non-AP
	2016	Pfatten	46°22'46.7"N 11°17'11.7"E	222	non-AP

Table S2. Continued

apiary number	Year	Township	Coordinates	m a.s.l.	"AP" or "non-AP"
10	2014	Kaltern 1 and Kaltern 2	46°24'43.7"N 11°13'47.8"E and 46°24'29.7"N 11°15'53.2"E	576 and 378	non-AP
	2015	Kaltern 2	46°24'29.7"N 11°15'53.2"E	378	non-AP
	2016	Kaltern 2	46°24'29.7"N 11°15'53.2"E	378	non-AP
11	2014	Nals and Grissian	46°32'41.4"N 11°11'43.4"E and 46°32'20.5"N 11°10'50.1"E	407 and 860	non-AP
	2015	Pfatten	46°22'46.7"N 11°17'11.7"E	222	non-AP
	2016	Pfatten	46°22'46.7"N 11°17'11.7"E	222	non-AP
12	2014	Dorf Tirol	46°41'49.7"N 11°08'46.8"E	662	AP
	2015	Lana	46°37'09.3"N 11°08'39.3"E	300	AP
	2016	Lana	46°37'09.3"N 11°08'39.3"E	300	AP
13	2014	Lana	46°37'09.3"N 11°08'39.3"E	300	AP
	2015	Partschins	46°41'38.3"N 11°05'02.2"E	873	AP
	2016	Partschins (Rabland)	46°40'26.0"N 11°03'17.7"E	530	AP
14	2014	Eppan 3 and Eppan 4	46°27'28.1"N 11°17'15.9"E and 46°26'02.9"N 11°17'38.3"E	398 and 520	non-AP
	2015	-	-	-	
	2016	-	-	-	
15	2014	Algund (Ried)	46°39'13.4"N 11°03'14.1"E	553	AP
	2015	-	-	-	
	2016	-	-	-	

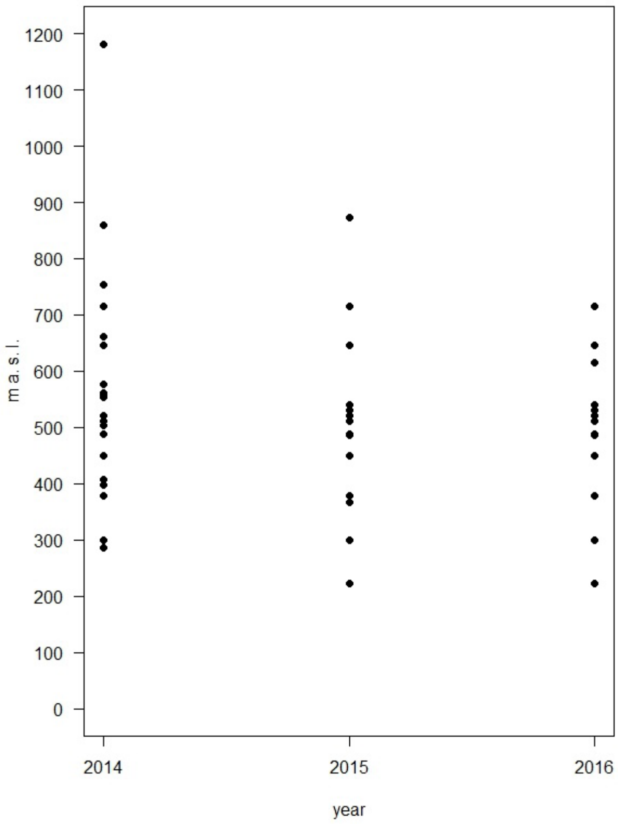

Fig. S2. Distribution of the apiaries disaggregated by altitude.

Observation period

In 2014, there were some organizational problems to fix the last two sites which participated at the monitoring and therefore the first evaluation at site 10 and site 15 was made 6 resp. 13 days later than the first evaluation on the other sites, where the monitoring could start in time as planned. In the years 2014 and 2016, the evaluation of colony size started on all apiaries in cw 12, whereas in 2015, it started in cw 11.

Evaluating colony size

Every 21 days, a scientific assistant of the Research Centre Laimburg estimated the adult bee population and the number of brood cells present in the colonies using the Liebefeld Method; in doing so, he was accompanied by another collaborator of the research centre or the owner of the colonies. The 21-day-interval could have had a deviation of one or two days in case of bad weather conditions or some organizational issues, but in most of the cases, there were intervals of 21 days between two inspections. Most of them were made in the early hours of the morning, before the colonies started with their normal flight activity (as described in (Imdorf et al., 2008; Liebig, 1993a)). In a few cases, estimations were made in the evening (due to heavy rain in the morning or organizational issues with beekeepers). To get the real raw numbers of adult bees, sealed and open brood cells out of the estimated covered frame-areas were used with the following parameters: 1.25 bees/cm² and 4 brood cells/cm² (Wallner, 1995). In Table S3 are listed the exact dates of evaluation of colony size for each apiary and year.

Observed mortality

The simplest way to observe mortality was to position a tarp in front of the hives with a width of around 1.5 m and to use it to catch the accumulating dead bees. At some apiaries (only for 2015 and 2016, see Table S4), it was possible to work with underbaskets (see Fig. S3 first picture left). They allowed catching dead bees per single colony. In addition, dead bees were protected there and could not easily be transported away by wind or rain.

Climatic conditions

For the analysis of the climatic conditions, only those time spans in which data on the bee colonies of the different apiaries had been collected were considered. If the investigations started in mid-March, only those days from that moment

Table S3. Lists the dates (first row) when colony-size over the different sites (here expressed as numbers; explanation of them in Table S2) was evaluated. In the first column the date from the 1st of March – 30th June is shown. From the other six columns two columns per year are always shown: in the column "apiary" the apiary which was evaluated is shown, and in the column "calendar week" the calendar weeks of the year are shown.

Date	2014		2015		2016	
	apiary	calendar week	apiary	calendar week	apiary	calendar week
1. March						
2. March						
3. March						*9*
4. March						
5. March				*10*		
6. March		*10*				
7. March						
8. March						
9. March			11			
10. March			8; 3; 2			*10*
11. March			10; 9; 7; 5			
12. March			13; 12; 4; 1	*11*		
13. March		*11*				
14. March						
15. March						
16. March						
17. March						*11*
18. March	7; 3; 2; 1					
19. March	12; 8; 6; 4			*12*		
20. March	13; 11; 5	*12*				
21. March	14; 9				9; 5; 12	
22. March					10; 4; 3	
23. March					11; 8; 2	
24. March	10				1; 13	*12*
25. March					7	
26. March				*13*	6	
27. March		*13*				
28. March						
29. March						
30. March			11; 9; 5			
31. March	15		8; 6; 4; 2			*13*
1. April			13; 10			
2. April			12; 7; 3; 1	*14*		
3. April		*14*				
4. April						
5. April						

Table S3. Continued

Date	2014		2015		2016	
	apiary	calendar week	apiary	calendar week	apiary	calendar week
6. April						
7. April	9; 5					*14*
8. April	4; 3; 1					
9. April	13; 7; 2			*15*		
10. April	12; 11; 8; 6	*15*				
11. April	10				9; 5; 12	
12. April	14				4; 3; 13	
13. April					10; 8; 2	
14. April					7	*15*
15. April					11; 1	
16. April				*16*	6	
17. April		*16*				
18. April						
19. April						
20. April			9; 5			
21. April			8; 6; 2			*16*
22. April	15		11; 10; 7			
23. April			13; 4	*17*		
24. April		*17*	3; 1			
25. April						
26. April						
27. April						
28. April	14; 9; 5					*17*
29. April	4; 3					
30. April	11; 2			*18*		
1. May	12; 8; 6	*18*				
2. May	13; 7; 1				9; 5; 12	
3. May					10; 4; 3	
4. May					13	
5. May	10				11; 8; 2	*18*
6. May					7; 1	
7. May				*19*	6	
8. May		*19*				
9. May						
10. May						
11. May			9; 5			
12. May			8; 6; 4; 2			*19*
13. May	15		11; 10			
14. May			13; 7	*20*		
15. May		*20*				
16. May			12; 3; 1			
17. May						
18. May	5					
19. May	14; 9					*20*
20. May	4; 3					
21. May	11; 2			*21*		
22. May	12; 8; 6	*21*				
23. May	13; 7; 1				9; 5; 4	
24. May					10; 3; 12	
25. May					8; 2	

Table S3. Continued

Date	2014		2015		2016	
	apiary	calendar week	apiary	calendar week	apiary	calendar week
26. May	10				11; 7; 13	*21*
27. May					6	
28. May				*22*	1	
29. May		*22*				
30. May						
31. May						
1. June			9; 5			
2. June			8; 6; 4; 2			*22*
3. June			11; 10; 7; 3			
4. June	15		13	*23*		
5. June		*23*	12; 1			
6. June						
7. June						
8. June	9					
9. June	14; 5					*23*
10. June	13; 7					
11. June	4; 3			*24*		
12. June	12; 11; 8; 6; 2	*24*				
13. June	1				9; 5; 12	
14. June					10; 4; 3	
15. June					8; 1; 2	
16. June	10				11; 7; 13	*24*
17. June						
18. June				*25*	6	
19. June		*25*				
20. June						
21. June						
22. June						
23. June						*25*
24. June						
25. June				*26*		
. June	15	*26*				
27. June						
28. June						
29. June						
30. June						

on were considered. The same applies also for June: not the whole month was analysed but only those days until the end of the investigations (mostly in mid-June). In 2015, the last two days of February for site 11 were also observed, but they were not considered for the analysis of the climatic conditions. Data for the weather data analysis were taken from the weather stations closest to the apiaries from the South Tyrolean Consulting organization for fruit and viticulture.

Statistical analysis

Parametric data, i.e., bees/colony, brood cells/colony, brood/bee, open brood/bee, mean lifespan and production, losses and balance of bees per colony/day, were analysed by the following steps: (i) Linear and Nonlinear Mixed Effects Models (package nlme) (Pinheiro et al., 2016) and (ii) one-way ANOVA with subsequent Tukey-test at $\alpha = 0.05$, for multiple comparisons (multcomp package) (Hothorn et al., 2008). Colony ID and exact date of the evaluation of colony-size were considered as a random effect.

Results

Not all colonies could be considered for a final analysis. For example, if a colony was swarming or if beekeepers intervened with measurements which had a strong impact on

Table S4. Lists on which apiaries for 2015 and 2016 a tarp or underbaskets (or even both) were used for the collection of dead bees accumulating in front of the honeybee colonies.

apiary	tarp	underbasket for each colony	underbasket for 3 of 5 colonies
1			x
2		x	
3	x		
4		x	
5			x
6	x		
7			x
8	x		
9	x		
10	x		
11		x	
12			x
13			x

colony development (for example: removing brood frames to build up new colonies) they were not considered.

Observed days per month

In April and May, the observations were always made for the whole month, whereas in March and June, when the observations started resp. ended, only a part of the month was always monitored (see Fig. S4). In March 2014, fewer days were observed than in March 2015 or March 2016 (median: 13 resp. 28 and 27 days). This must be taken into consideration especially when comparing climatic parameters for this month of the different years in the next graphs (Fig. S5, Fig. S6, Fig. S7, Fig. S8).

Temperature

With the ongoing season in each of the three years from 2014-2016, a decreasing no. of days per month with mean temperature < 10°C was observed. In March-May of 2015, most days displayed mean temperature < 10°C in comparison to 2014 and 2016 (see Fig. S5). For April, the lowest number of days with mean daily temperature < 10°C was observed in 2014. For March 2014, is to consider that only around half as many days were observed as in 2015 and 2016 (see Fig. S4). In none of the three years were days with mean daily temperature < 10°C observed in June.

Looking at the mean temperatures in Table S6, we see that the coolest March and April were in 2015 (mean temperature 7.5 resp. 10.9°C). The coolest May was in 2014 (13.9°C), whereas the coolest June in 2016 (16.7°C); it was also in June 2016 that the most days of rain were observed (see Fig. S7). The warmest March and April were registered in 2016 (8.3°C resp. 12°C) and the warmest May and June in 2015 (15.1°C resp. 19.6°C). In 2015, it was warmer in May and June than in the other two years but slightly colder in March and April.

Wind

In Fig. 7S we see the days where the mean wind speed during the hours 8:00-17:00 of a day were above 3 m/s. In total, the lowest number of days in which the mean wind speed exceeded 3 m/s was observed in 2016. The highest number of days with a mean daily wind speed above 3 m/s was observed

Fig. S3. On the left is a picture of apiary 11 from 2015 with an underbasket in front of each hive. In the middle is shown an open underbasket and on the right, a picture of apiary 3 from 2016 with only a tarp in front of the hives without underbasket is shown.

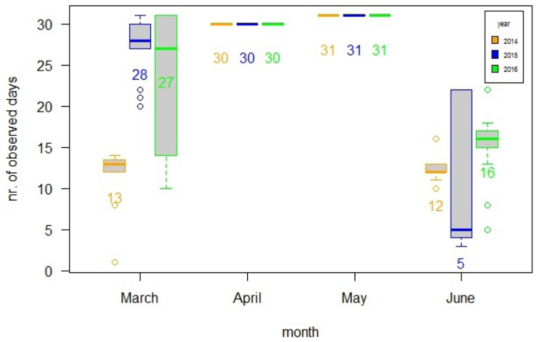

Fig. S4. Distribution of the observed days per month during monitoring. Medians of observed days for each month are displayed.

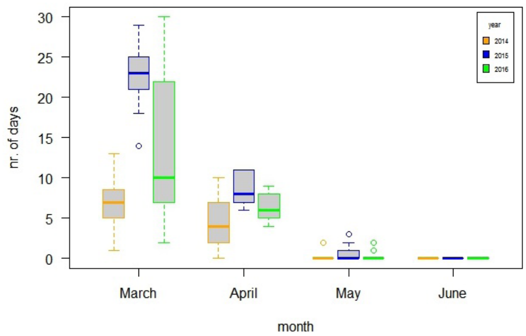

Fig. S5. Distribution of days over March-June during which the mean daily temperature did not exceed 10°C.

Table S5. Shows colonies and the reasons why they were not considered for further analysis.

site	colony	reason
	2014	
1	I and II	not in normal conditions (very weak adult population after winter)
	III, IV, V	removing brood frames to build up new colonies
2	II, III, IV, V	removing brood frames to build up new colonies
6	I, IV, V	removing brood frames to build up new colonies
7	V	introduction of replacement queen
8	II	introduction of replacement queen
9	III, IV	queen cells present during monitoring
11	II, V	queen cells present during monitoring
12	no colony V	beekeeper could offer only four instead of five colonies
13	II	swarmed during the monitoring
14	III	removing brood frames to build up new colonies
15	II	queen cells present during monitoring
	2015	
1	I, II, III	removing brood frames to build up new colonies
2	I, II, IV	swarmed during the monitoring
3	I	queen cells present during monitoring
3	II	removing brood frames to build up new colonies
4	I	swarmed during the monitoring
	V	queen cells present during monitoring
6	all 5 colonies	removing brood frames to build up new colonies
7	I and V	queen cells present during monitoring
8	V	no 1st evaluation of colony size; was present as from the 2nd
9	III	queen cells present during monitoring
	V	removing brood frames to build up new colonies
10	I	introduction of replacement queen
	II	removing brood frames to build up new colonies
11	I, II, IV	swarmed during the monitoring
12	II	queen cells present during monitoring
	IV	removing brood frames to build up new colonies
13	I	removing brood frames to build up new colonies
	2016	
1	V	swarmed during the monitoring
2	II, IV	swarmed during the monitoring
	V	introduction of replacement queen
3	II, V	swarmed during the monitoring
4	I	swarmed during the monitoring
5	I, V	swarmed during the monitoring
6	II	removing brood frames to build up new colonies
8	I, II, III	introduction of replacement queen
9	I	introduction of replacement queen
	no colony III	beekeeper could offer only four instead of five colonies
10	IV	swarmed during the monitoring
11	III	swarmed during the monitoring
12	II, V	swarmed during the monitoring
13	IV	not in normal conditions (very weak adult population after winter)
13	III and V	no 5th evaluation was made because due to a heavy thunderstorm after colony II the evaluation had to be stopped before the beekeeper than migrated to another apiary.

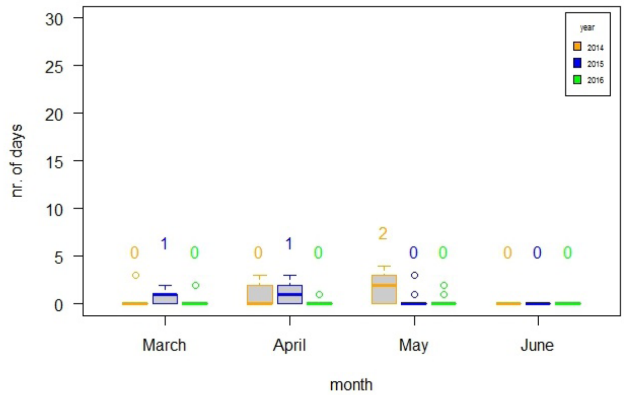

Fig. S6. Distribution of days in which the mean wind speed exceeded 3 m/sec in the observed months (displayed numbers show the median).

in the months of March and April of 2015 (in both months median 1 day) and in May 2014 (median 2 days).

Rain

Most days with rain were registered in 2016 (especially during the months of April and June – see Fig. S7). In the years 2014 and 2015, the most days with rain were observed in May (median 12 and 13 days), whereas in 2016, it was in June (median 16 days).

Potential of days for normal flight activity

To get an idea of the available potential of conditions for normal flight activity, we considered only days when no precipitation was registered, mean daily wind speed was < 3 m/sec, and mean daily temperature remained >10°C. Unfortunately, through this analysis it is not possible to consider that a day with a storm in the evening could have had also good conditions for normal flight activity during the day. Nevertheless, this parameter should make it easier to analyse the observed period regarding their favourableness of the weather conditions to bees' outdoor activities. The potentially available days to fly were very similar for the years 2015 and 2016 in March. For April and May in 2014 and 2016, the median remained constant at 19 resp. 18 days, whereas in 2015, 21 days were

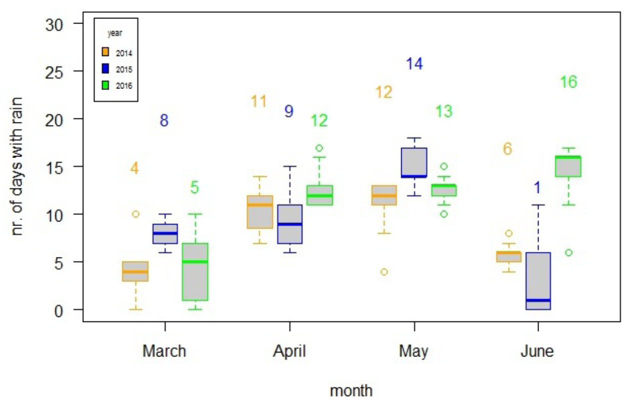

Fig. S7. Distribution of days per month during which it rained (displayed numbers show the median).

Table S6. Mean temperatures from March-June.

	mean temperature		
	2014	2015	2016
March	8	7,5	8,3
April	11,4	10,9	12
May	13,9	15,1	14,3
June	18,3	19,6	16,7

available in April and 16 days in May. Since the most days with rain were registered in June 2016 (see Fig. S7), the potential of available days for a normal flight activity were the lowest.

Chemical residue analysis of dead bees

In total, 347 analyses were made, and 16 of them were zero samples where we didn't expect any residues of plant protection products. In 210 of the 347 (60.5 %) analysed samples, products harmful to bees were found. Every year, more than 50 % of the samples were contaminated with products harmful to bees. Some samples were contaminated with more than one product harmful to bees: 51 samples with two and 17 samples with three or more (see Table S7). In general, between 4 to 16 analyses per apiary in one season were made.

Production, losses, and balance

Figure S9 shows the daily rates of production, losses, and balance in bees/colony for the four intervals between the five evaluations of colony-size over the three monitored years. Production is represented in green and increased significantly from the 1st to the 2nd (from + 549 bees/day to + 1,140 bees/day; p-value <0.01) and from the 2nd to the 3rd evaluation (from + 1,140 bees/day to + 1,652 bees/day; p-value <0.01). In the last interval (from the third to the fourth evaluation), the median of production increased from + 1,652 to + 1,702 bees/day but this difference is not significant. The red boxes in Figure 10 represent the daily losses of bees/colony and in general show an increasing tendency from the 1st until the 4th interval.

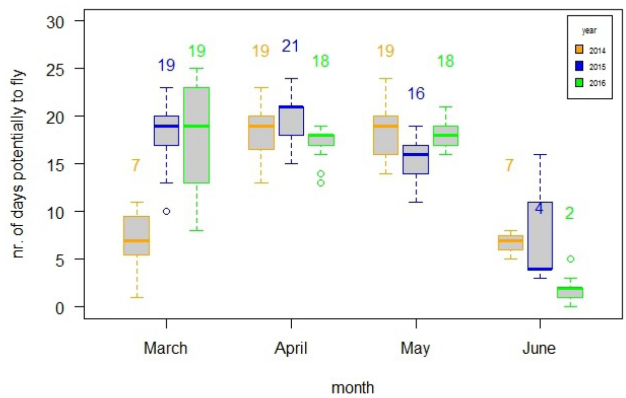

Fig. S8. Shows the number of days per month which potentially showed good conditions for normal flight activity (displayed numbers show the median).

Table S7: Shows the number of analysed samples per year and apiary and how often products harmful to bees were detected on them.

year	apiary	number of analysed samples	Samples with products harmful to bees	Samples with 1 product harmful to bees	Samples with 2 products harmful to bees	Samples with 3 or more products harmful to bees
2014	1	6	6	4	2	
	2	6	5	3	1	1
	3	9	6	5	1	
	4	7	5	4	1	
	5	6	3	1	2	
	6	4	2	1	1	
	7	8	7	5	2	
	8	12	11	6	5	
	9	5	3	1	2	
	10	7	6	4	1	1
	11	7	5	4		1
	12	4	4	2	2	
	13	10	7	5	1	1
	14	6	3	1	2	
	15	5	4	2	2	
Total 2014		102	77	48	25	4
2015	1	12	7	7		
	2	14	6	4		2
	3	8	4	3	1	
	4	9	5	3	1	1
	5	10	4	3		1
	6	7	4	3	1	
	7	10	4	4		
	8	9	5	5		
	9	7	2	1	1	
	10	8	5	4	1	
	11	16	11	6	3	2
	12	9	7	5		2
	13	9	5	4		1
Total 2015		128	69	52	8	9
2016	1	8	3	3		
	2	15	7	5	2	
	3	5	4	4		
	4	15	7	5	2	
	5	8	6	2	1	3
	6	9	5	2	3	
	7	9	5	3	1	1
	8	4	2	1	1	
	9	7	3	3		
	10	5	2	1	1	
	11	12	7	4	2	
	12	11	8	5	3	
	13	9	5	3	2	
Total 2016		117	64	41	18	4
TOTAL		347	210	142	51	17

As it has already been observed for production, for the losses, too, the highest increase was registered in the 1st (from -393 bees/day to -844 bees/day; p-value <0.01) and the 2nd interval (from -844 bees/day to -1,335 bees/day; p-value <0.01). The rate continued to increase significant also from the 3rd to the 4th evaluation (from -1,335 to -1,501 bees/day; p-value < 0.01).

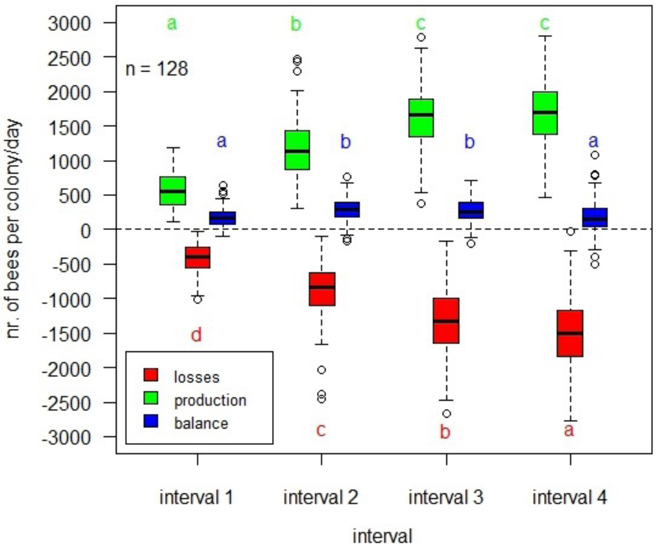

Fig. S9: Shows the production, losses, and balance of bees/day in the colonies between the five evaluations of colony-size from March-June in the years from 2014 until 2016.

The difference between the daily production and daily losses of bees/colony are represented as daily balance by the blue boxes in Figure 10. The balance increased significantly from the 1st to the 2nd interval (from 158 bees/day to 287 bees/day) and tended to decrease from the 2nd to the 3rd evaluation (from 287 bees/day to 251 bees/day). From the 3rd to the 4th evaluation, the rate continued to decrease, and this difference was significantly different from the previous rate (from 251 bees/day to 153 bees/day; p-value < 0.01). This means that the adult population of colonies increased mostly over all intervals and particularly in the 2nd and the 3rd interval.

Figure S10 shows the parameters analysed in Fig. S9 for the three different years 2014-2016 in the four intervals. In interval 1 (first graph from the left in Fig. S10), the lowest numbers were observed for all the three analysed parameters. In the same interval in 2015, the production was with + 371 bees/day significantly lower than in 2014 and 2016 (+593 resp. + 610 bees/day; p-value < 0.01). The same trend was observed in the 2nd interval: in 2014 and 2016, the production of bees/day was with + 1,235 and + 1,320 significantly higher as in 2015 with + 863 (p-value in both cases < 0.01). In the 3rd interval, no significant differences between the production rates of the three years were found, whereas in the 4th interval in 2015, the production was with + 1,942 bees/day significantly higher than in 2016 with + 1,644 (p-value < 0.01); 2014 did not differ significantly from the other two years. In the 1st interval, losses between 2015 and 2016 differed significantly (-332 resp. -429; p-value = 0.04). In the 2nd, significant differences between all the three years were found (2014: -1,036, 2015: -639, 2016: -852; p-value always < 0.01 except 2016 vs. 2014: p-value = 0.03). In the 3rd interval, significant differences were found between 2014 and 2016 (-1,466 resp. -1,210; p-value =0.01) and the last interval 2016 showed significantly lower bee losses/colony than the other two years (2016: -1,251 resp. 2014: -1,643 and 2015: -1,802; p-value in both cases < 0.01). Regarding the balance bees/day in the 1st interval, significant differences were found (2014: + 226, 2015: + 68 and 2016: + 171; p-value always < 0.01 except 2016 vs. 2014: p-value = 0.02); whereas for the other three intervals in 2016, the balance resulted always significantly higher than in 2014 and 2015: 2nd interval: 2014: + 243, 2015: + 237 and 2016: + 381; 3rd interval: 2014: + 213, 2015: + 213, and 2016: + 445; and 4th interval: 2014: + 77, 2015: + 131 and 2016: + 368 (p-value in all cases < 0.01).

The adult population of the bee colonies

From 2014 -2016, the first evaluation of colony-size was made roughly in the second half of March (earliest first determination on March 9, 2015 and latest first determination on March 31, 2014; for details, see Table S3). The median for the adult population at this point in time in 2014 was 3,312; in 2015, it was 4,856; and in 2016, it was 6,004 (first graph on the left in Fig. S11). These populations were all significantly different

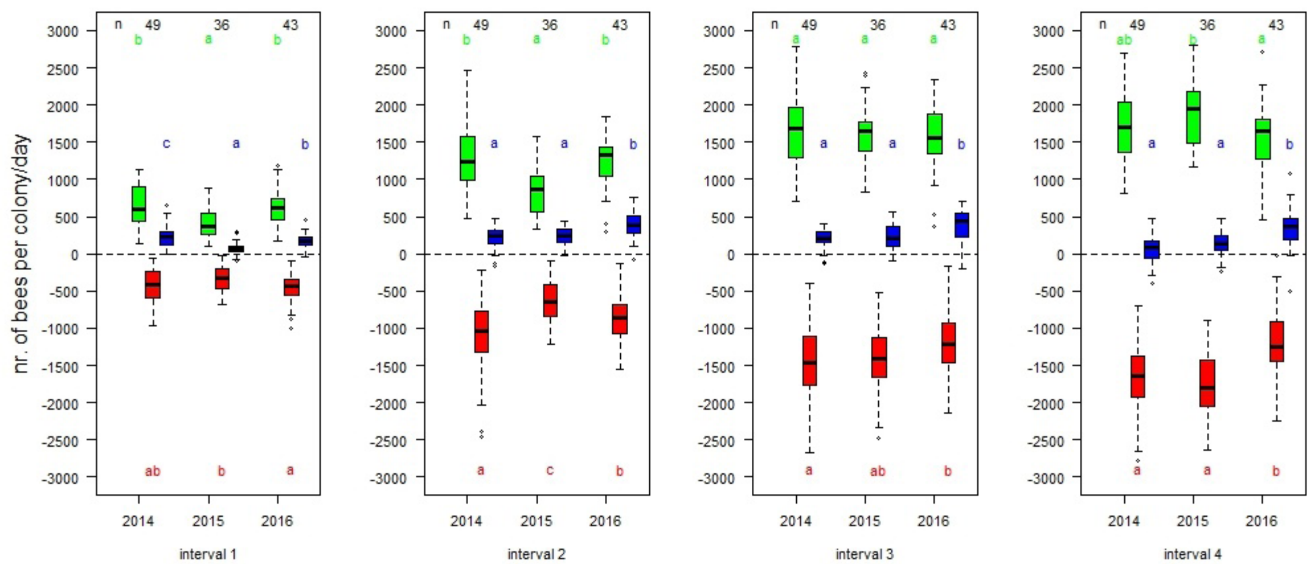

Fig. S10. Shows the production, losses, and balance of bees/day in the colonies in the three years 2014, 2015 and 2016 for four intervals from March-June.

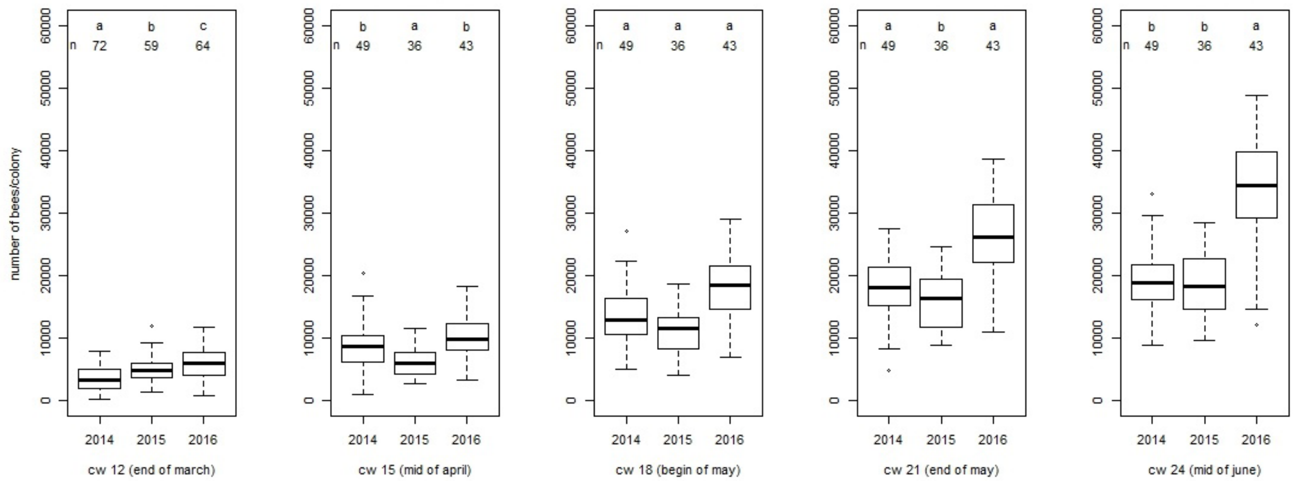

Fig. S11. The graphs show the number of adult bees present in the colonies at the five points in time of colony-size evaluation.

from each other (p-value always < 0.01). At the moment of the 2nd determination of colony strength, colonies from the years 2014 and 2016 were composed of significantly more bees than the colonies from 2015, whereas at the third determination in cw 18 (begin of May), no differences between the three years were found. In cw 21 (end of May), significant differences between the colonies of 2015 (median: 16,367 bees) and those of the other two years (2014 median: 18,091 bees; 2016 median: 26,268 bees) were found. The differences regarding the fifth evaluation (cw 24 = beginning/mid of June) are represented in the last graph on the right of Figure 12. In 2014 and 2015, the median of the adult population was below 19,000 bees (18,956 and 18,283), whereas in 2016, it was approximately 15,000 bees higher at 34,430. At the end of the monitoring in 2016, the colonies were composed of significantly more bees than in 2014 and 2015 (p-value for both years < 0.01).

Analysing the number of adult bees in the colonies at the 1st evaluation, the distribution over six different classes is shown in Fig. S12. Most of the colonies were in the two classes of 2,500-5,000 (51 colonies) and 5,000-7,500 (44 colonies) adult bees, which corresponds to 74.2 % (95 of 128) of the whole colonies. 19 colonies were in the group of < 2,500 bees, 11 in the group of 7,500-10.000 bees, and only 3 in the group of more than 10,000 bees.

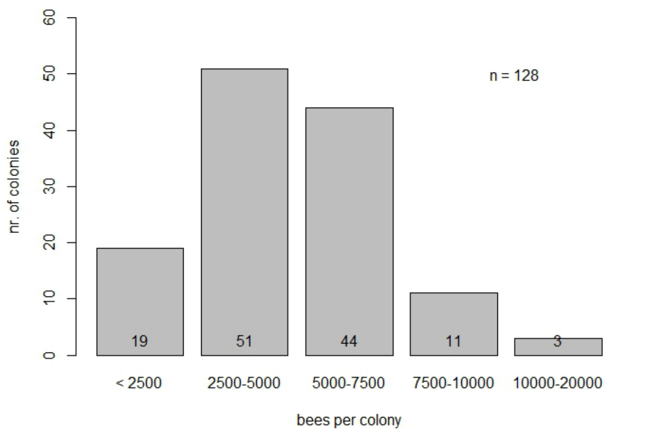

Fig. S12. The bars represent the number of colonies according to their adult population at the point in time of the 1st evaluation of colony-size. Numbers at the bottom of the bars show the exact number of colonies within each class.

The number of brood cells

The number of brood cells at the 1st evaluation of colony-size resulted in significantly smaller amounts in colonies from 2015 (median of brood cells: 7,520) compared with those in 2014 and 2016 (2014: 12,808 and in 2016: 12,757) (first graph on the left in Fig. S13). The same situation has been observed at the 2nd evaluation in cw 15: 2014 with a median for brood cells of 27,832, 2015 with 18,765 and 2016 with 27,520. At cw 18, no significant differences between 2014 (median: 35,399), 2015 (median: 35,096), and 2016 (median: 31,824) were found. Interesting at this moment is the dispersion of the data around the median: from 2014 to 2016, the variance tended more and more to decrease. At the 4th determination (cw 21) in 2015 (median: 41,244), significantly more brood cells were present than in 2016 (median: 34,880, p-value < 0.01) and 2014 (median: 35,880, p-value = 0.04). At the last determination (cw 24), colonies from 2016 (median: 30,800) had significantly smaller amounts of brood cells than those in 2014 (median: 35,875, p-value < 0.01) and those in 2015 (median: 36,720, p-value = 0.02).

Ratio of brood cells/bee

The number of total brood cells/bee within the colonies over all the three years is represented in Fig. S14. The median of this ratio started at the end of March with 2.3 total brood cells per bee and increased until mid-April up to 3.0; then it started to decrease until the end of the observations (begin of May 2.5, end of May 1.8, and mid-June 1.7). From March until June, colonies got more and more homogeneous with regards to this parameter (fewer outliers and smaller boxes at the end of May and mid-June in comparison with those at the end of March and mid-April). Between all the medians of the five different points in time, significant differences were found except between the median for the 1st evaluation of

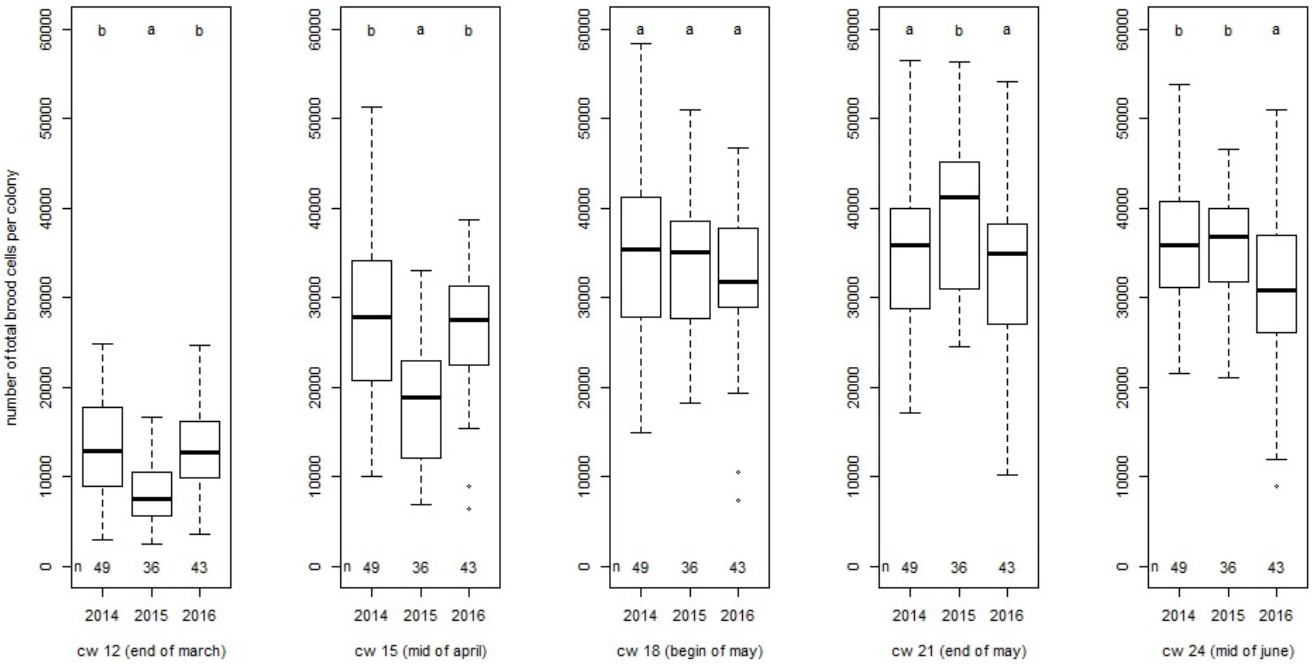

Fig. S13. The graphs show the amount of brood cells (open and sealed) per colony at the five points in time of colony size evaluation.

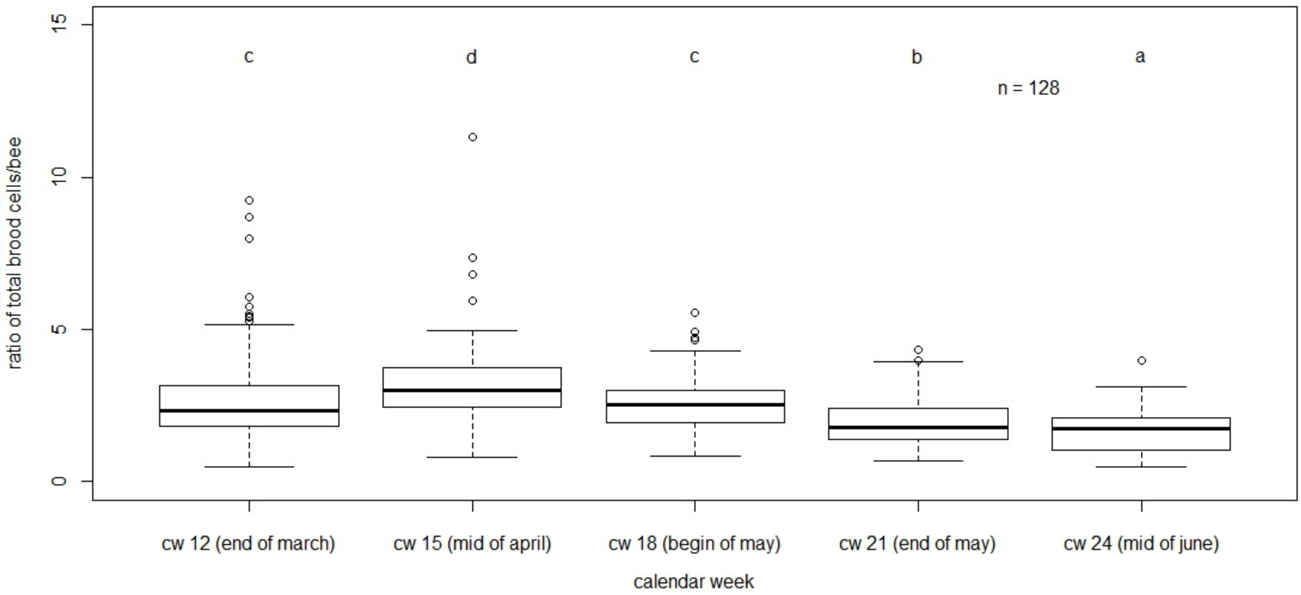

Fig. S14. The boxes represent the ratio number of total brood cells/bee at the five moments of colony size evaluation.

colony-size (cw 12: 2.3) and the one for the 3rd determination (cw 18: 2.5).

For the ratio open brood cells/bee, the same trend was observable as for the ratio total brood cells/bee. The median for cw 12 with 1.0 was slightly lower than the 1.3 in cw 15. Then the ratio tended to decrease (cw 18: 0.95; cw 21: 0.72) until attaining 0.54 in cw 24 in mid-June. Significant differences were found between all the medians except between the one at the 1st and the 3rd evaluation of colony-size.

Figure S16 displays the different ratios of total brood cells/bee between the single years from 2014 until 2016 at the five moments of colony size-evaluation. At cw 12, there was a significant higher total brood cell/bee ratio in 2014 (median = 3.4) than in 2015 (1.9; p-value < 0.01) and 2016 (2.2; p-value = 0.014). At cw 15, only between the years 2014 and 2016 were significant differences found (2014: 3.4; 2015: 3 and 2016: 2.7), whereas 2015, with a median of 3.0, did not differ from the other two years. At the third determination (cw 18), the highest median for total brood cell/bee ratio 3.0 was measured in the year 2015 (2014: 2.7 and 2016: 1.9; p-value always < 0.01) and in cw 21, the ratio remained highest in 2015, with a median of 2.5 total brood cells/bee (2014: 1.9 and 2016: 1.3; p-value always < 0.01). In mid-June (cw 24), the ratio, with 0.9, was below 1 only in 2016, and was thus the lowest observed in the whole monitoring period, differing significantly from the other two years (2014: 2 and 2015: 1.9 p-value in both cases < 0.01).

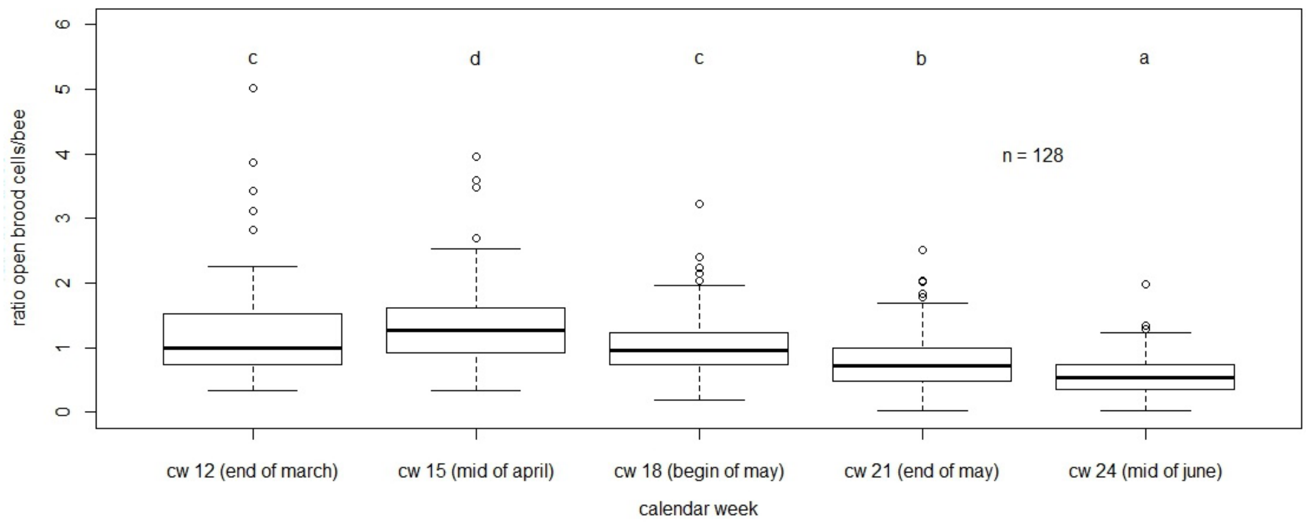

Fig. S15. The boxes represent the ratio open brood cells/bee to the five points in time at which the evaluation of colony-size was conducted.

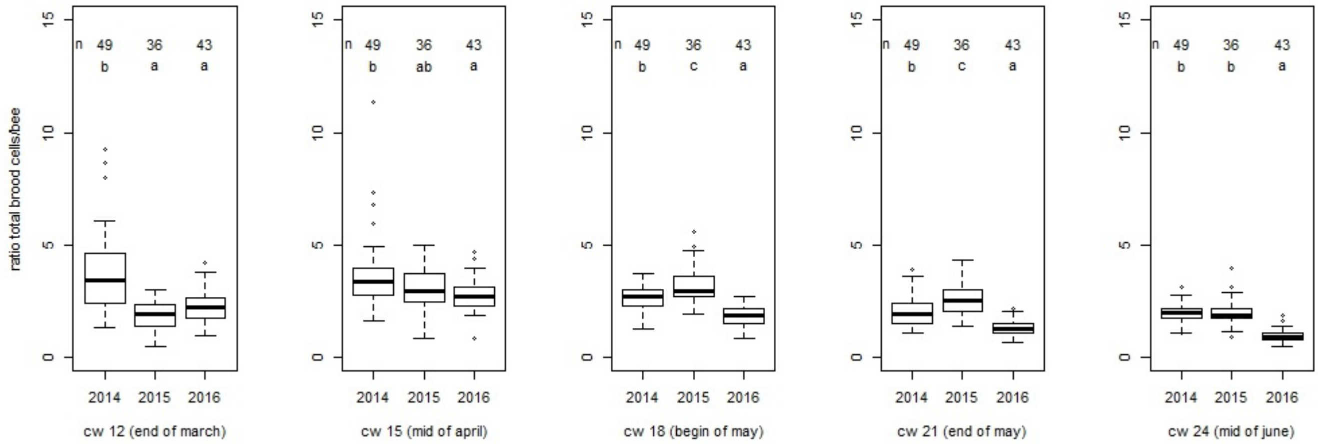

Fig. S16. The plots represent the total brood cell/bee ratios between the three different years at the five points in time of colony evaluation.

Mean lifespan

Mean lifespan of the bees in the monitored bee colonies was calculated for the four intervals between the five colony size-evaluations and is represented in Fig. S17. At the beginning of spring (interval 1), the median was 12.2 days and therefore higher than in the succeeding two intervals (9.7 resp. 10.2). In the last interval, the median was again above 12, at 12.4 days.

Analysing the different mean life spans between the three years from 2014 until 2016 were found significant differences in the 1st interval between 2014 and the other two years (2014: 9.6 resp. 2015: 14.3 and 2016: 13.5 days; p-value < 0.01). In the 2nd interval, again, significant differences between 2014 and the other two years (2014: 8.4 resp. 2015: 9.7 and 2016: 10.9 days; p-value < 0.01 resp. < 0.02) were found. In the 3rd and 4th interval, significantly different mean life spans always between 2016 and the other two years (3rd interval: 2016= 14.1 2015: 8.5 and 2014: 9.1; p-value in both cases < 0.01 and in the 4th interval: 2016: 19.1 2015: 9.3 and 2014: 11; p-value in both cases < 0.01) were found.

Discussion

The weather conditions for the development of bee colonies in spring of the three monitored years can be described as bad in 2014, very good in 2015, and moderate in 2016. Regarding the analysed parameters, the best colony developments were observed in 2016. In the spring of 2014, when the monitoring started, it wasn't possible to immediately get the right fifteen sites (criteria: distributed over different altitudes, optimal suited to monitor also the number of dead bees/day in front of the hives, easy accessible with a car) and so the first evaluation of colony-size for some sites was delayed in comparison with the earliest first determination of other apiaries within the same year (for example site 13, where it were already thirteen days). In addition, the fact that in 2015 the first evaluation of colony-size was done mostly in cw 11 and in 2014 and 2016 mostly in cw 12 was at least one reason for the significant higher amount of brood cells at the beginning of the monitoring (cw 12 and 15) in the colonies from 2014 and 2016 in comparison to those from 2015 (Fig. S13). The reason for the higher brood/bee ratio in early spring is a consequence of the fact that the bee colonies must mul-

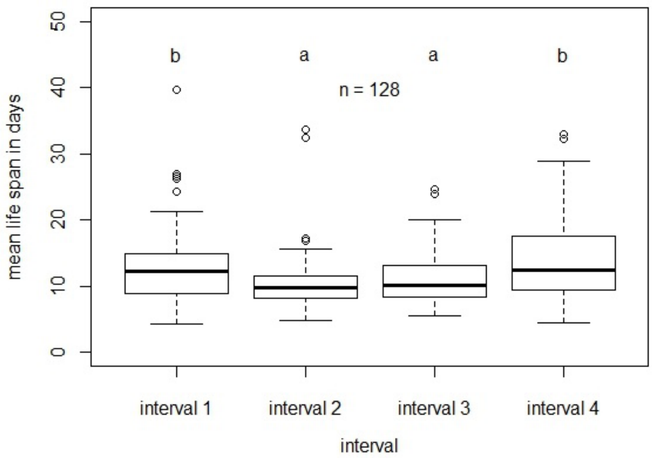

Fig. S17. Shows the mean lifespan in days over three years in the four intervals between the five colony size-evaluations.

tiply their adult population in a short time. A ratio of 2.3 brood cells/bee in early spring seems to be comparable with observations in Germany. In Hohenheim a ratio of about 1.6-1.9 brood cells/bee was observed in smaller colonies (with 5,000 bees) in mid-March of 1990-1992. For the same period, in colonies with around 10,000 bees, the ratio resulted in 1-1.5 brood cells/bee (Liebig, 1993b). Harbo (1986) also observed that bee colonies with a lower number of bees (4,500 bees) were able to rear more brood/bee than colonies with a higher number of bees (35,000 bees). Considering that, in 2014 and 2015, the median for the adult population at the start of the monitoring was always below 5,000 bees, it could be explainable why in this monitoring a slightly higher brood cells/bee ratio was observed (1.9 in Germany vs. 2.3 brood cells/bee in South Tyrol). The observation of colonies with more than 2 brood cells/bee in late May or the beginning of June (Fig. S16) is comparable with results in other regions. Brood per bee ratios of more than 2 in June were for example observed frequently in honeybee colonies in Louisiana (Harbo, 1986) and in Germany (Wallner, 1995). The main reason for the significant higher brood/bee ratio in 2014 at the point in time of the first evaluation of colony-size (cw 12) in comparison to the other two years (first graph in Fig. S16) could be that, in 2014, one site was estimated in cw 13 and another even in cw 14 (see Table S3). Therefore, their development was probably already further ahead than that one of the other colonies, mostly evaluated in cw 12 and so they shifted the ratio to a higher level because in all years, an increasing tendency for this parameter with the ongoing season was shown in this moment. The lower brood/bee-ratio in the year 2016 than in the other two years at the points in time of cw 18, 21, and 24 (3rd, 4th and 5th graph of Fig. S16) could be related to the fact that, in 2016, colonies had a higher adult bee population and stronger colonies were rearing fewer brood/bee than smaller ones (Harbo, 1986). The significantly higher brood/bee ratio in 2015 in cw 18 and 21 (Fig. S16) is not totally clear but could be explained at least partially for cw 21 with the fact that, at this point in time, significantly fewer bees (Fig. S11) and significantly more brood cells (Fig. S13) were present in these colonies in comparison to the other two years. The development of the open brood/bee ratio during the monitoring showed the same trend as it was for the brood/bee ratio (see Figure 15: brood/bee and Fig. S15: open brood/bee). The fact that, in spring (mostly between mid-April and mid-May), this ratio is often above 1 was also described by authors from Switzerland (Imdorf et al., 2008). Regarding the open brood, it is important to consider that this is to some authors the most difficult parameter to estimate/analyse. Liebig wrote that to determine the open brood, good light conditions are necessary, especially in older frames early in the morning. Sometimes it is necessary to shake off all the bees covering the frame, and it has to be checked precisely if recently laid eggs are really deposited in each cell (Liebig, 1993a). According to Bühlmann (1997), the open brood is also a parameter difficult to analyse because bees can influence their own colony development by removing eggs or young larvae. The lowest mean lifespan (9.7 days in cw 15) was observed in interval 2 (Fig. S17) – at the same

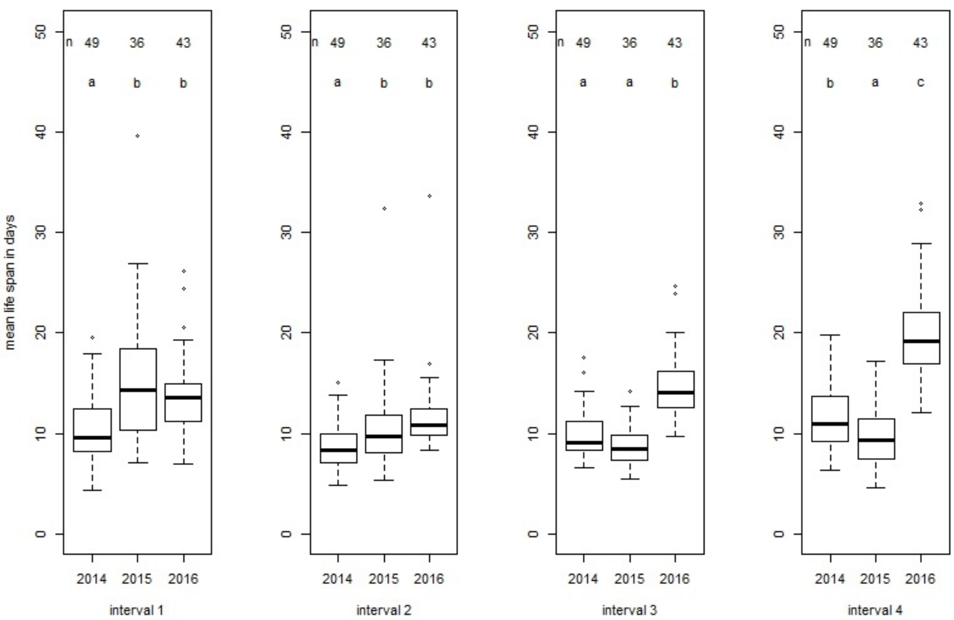

Fig. S18. The plots show the different mean life spans in days for each single year from 2014-2016 in the four intervals between the five colony size evaluations.

time when the brood/bee ratio was the highest (Fig. S14). Literature shows that hatching bees have a lifespan-reducing effect on the worker bee population of a colony (Fluri, 2012; Imdorf et al., 2008) but it seems not to be the brood rearing process itself which causes the lifespan-reducing effect (Fluri, 2012; Kratky, 1931). For Ligustica, colonies values of mean lifespan frequently below 10 days were also observed (Wille, 1984). Extreme values of mean lifespan observed in Switzerland by Bühlmann ranged from 12.9-29.5 days (Bühlmann, 1986) which is similar to the expectations of Wille: 15-25 days (Wille, 1984). Bühlmann observed in June a median life expectancy below 17 days which is true in our observations for 2014 and 2015 (9.3 and 11 days) but is not congruent with 19.1 days in 2016 (4th graph in Fig. S18). There is no clear reason why mean lifespan in 2016 in May/June was higher than in 2014 and 2015, but it was one factor which explains the higher mean adult population at the end of the observations of 2016 as compared to the previous years (5th graph Fig. S11). One reason for the higher mean lifespan in interval four of 2016 (Fig. S18) could be related to the fact that colonies at this point in time had significant smaller amounts of brood. Moreover, it should be considered whether this high discrepancy might not be only explainable by one single factor like weather conditions, pollen-supply, or measurements of beekeepers but will be influenced also by some inner-factors of the bee colonies which are difficult to analyse (Wille, 1984). The production-rates of bees increased significantly in the first two intervals (Fig. S9) and tended to then remain constant for interval three and four (Fig. S9). This stagnation seems also logical and normal in view of the fact that the colonies reach their maximum population in May/June (the time of the last determination of colony strength). At least for the first interval, the slightly lower production in bees/day in 2015 can be explained by the fact that the first evaluation of colony-size was conducted one calendar week earlier than in the other two years (same also for the losses). Losses of around 1500 bees/day (median in the 4th interval = 1501) were also comparable with data of other studies: Wallner thought that 1600 bees/day could be a maximum of normal losses, Bühlmann published examples where the losses ranged from 1200 up to more than 1600 bees/day (Bühlmann, 1985). Wille showed in exemplary colonies losses between ca. 1500-1900 bees/day (Wille, 1984). Higher bee losses like in the second interval for 2014 or in the fourth interval for 2015 (see Fig. S10) could be related to the fact that these colonies had a higher brood production at these times (Fig. S13). Liebig observed in his investigations that the more brood colonies are rearing the higher their losses of bees are (Liebig, 1993c; 1993d). The low number of bee losses in the 4th interval of 2016 (4th graph Fig. S10) was very likely an important factor which induced the significant higher balance in the same interval which consequently resulted in a high bee population. The balances of the 2nd and 3rd interval were higher than those in the 1st and the 4th which means that at these times was the highest increment in adult population in the colonies. The high balance in interval one for 2014 in Figure 11 was probably due to the fact that some colonies (site 10 and 15 in 2014) for the 1st evaluation of colony-size were evaluated later, on March 24 resp. March 31 (which corresponds to cw 13 resp. 14, whereas all other colonies mostly were evaluated in cw 12 or even cw 11). This was probably also the reason for the lowest balance for the colonies in 2015 in the first interval in Figure 11 (+67.5 bees/colony per day whereas in 2014 + 226 and 2016 + 171). The fact that the balance from interval two to four was always significant higher in the year 2016 compared to the other two years is not easy to explain (production and losses were not always significantly higher in comparison to 2014 and 2015, see Fig. S10) although at least in interval four the low number of losses compared to the other years was probably a leading factor.

Annex

Table S8: Calculated number of dead bees per apiary and day (mostly two collection's each week).

Date	Lana	Partschins	Laimburg	Kaltern	Eppan 1/ Eppan 2	D. Tirol	Tisens	Meran	Eppan	Sallmann	Marling	D. Tirol	Pawigl
01.03.15			14										5.75
02.03.15			14										5.75
03.03.15		1.67	9			3.33		1.5			20.67		3.67
04.03.15		1.67	9	4.9	6	3.33		1.5	2		20.67		3.67
05.03.15		1.67	10	4.9	4.5	3.33		2.67	2		20.67		3.67
06.03.15		9.4	10	4.9	4.5	2.2	21.4	2.67	2		48.8	53	14.5
07.03.15		9.4	10	4.9	4.5	2.2	21.4	2.67	2		48.8	53	14.5
08.03.15		9.4	10	4.9	4.5	2.2	21.4	2.67	2		48.8	53	14.5
09.03.15		9.4	10	4.9	4.5	2.2	21.4	2.67	2		48.8	53	14.5
10.03.15		9.4	29	4.9	4.5	2.2	21.4	2.67	2		48.8	53	17.25
11.03.15	21	15	29	3	45	8.5	46	11.33	2	28.71	30.33	25	17.25
12.03.15	21	15	29	3	3.2	8.5	18.6	11.33	16	28.71	30.33	25	17.25
13.03.15	21	15	19	1	3.2	3	18.6	11.33	3.5	28.71	30.33	25	17.25
14.03.15	43	14	19	1	3.2	3	18.6	6.67	3.5	12.54	16.33	21	6.33

Table S8: Continued

Date	Lana	Partschins	Laimburg	Kaltern	Eppan 1/ Eppan 2	D. Tirol	Tisens	Meran	Eppan	Sallmann	Marling	D. Tirol	Pawigl
15.03.15	43	14	19	1	3.2	3	18.6	6.67	3.5	12.54	16.33	21	6.33
16.03.15	43	14	19	3.33	3.2	3	18.6	6.67	3.5	12.54	16.33	21	6.33
17.03.15	20	14.33	33	3.33	13.67	14.67	26	13.25	26.33	64	22.75	15	30.5
18.03.15	20	14.33	33	3.33	13.67	14.67	26	13.25	26.33	64	22.75	15	30.5
19.03.15	20	14.33	33	2	13.67	14.67	26	13.25	26.33	64	22.75	15	30.5
20.03.15	20	6.5	39	2	15.4	15.25	33.8	13.25	11.6	64	22.75	15	30.5
21.03.15	32	6.5	39	2	15.4	15.25	33.8	9.33	11.6	109.89	10.67	19	26.67
22.03.15	32	6.5	39	2	15.4	15.25	33.8	9.33	11.6	48.51	10.67	19	26.67
23.03.15	32	6.5	39	2	15.4	15.25	33.8	9.33	11.6	46.53	10.67	19	26.67
24.03.15	29	7.33	39	3	15.4	16.25	33.8	7.5	11.6	48.51	11.67	21	20.75
25.03.15	29	7.33	34	3	15	16.25	33	7.5	12.5	48.51	11.67	21	20.75
26.03.15	29	7.33	34	2.5	15	16.25	33	7.5	12.5	48.51	11.67	21	20.75
27.03.15	29	24	23	2.5	26.5	16.25	19.8	7.5	21.5	28.2	10.2	21	20.75
28.03.15	19	24	23	2.5	26.5	72.67	19.8	13.75	21.5	28.2	10.2	30	13.5
29.03.15	19	24	23	2.5	26.5	72.67	19.8	13.75	21.5	28.2	10.2	30	13.5
30.03.15	19	24	23	6.75	26.5	72.67	19.8	13.75	21.5	28.2	10.2	30	13.5
31.03.15	19	24	46	6.75	40.5	76.67	19.8	13.75	26.33	28.2	10.2	30	13.5
01.04.15	22	14.5	89	6.75	40.5	76.67	20	70.33	26.33	21.45	13	45	19.67
02.04.15	22	14.5	134	6.75	5.5	76.67	33.5	70.33	26.33	21.45	13	45	19.67
03.04.15	22	13	271	7.8	5.5	43.5	33.5	70.33	40.6	21.45	13	45	19.67
04.04.15	56	13	101	7.8	5.5	43.5	37	58	40.6	37.5	32	60	57
05.04.15	19	22	101	7.8	5.5	27	15.25	7.5	40.6	37.5	18.25	60	19.75
06.04.15	19	22	101	7.8	5.5	27	15.25	7.5	40.6	8.58	18.25	25	19.75
07.04.15	19	22	101	7.8	5.5	27	15.25	7.5	40.6	8.58	18.25	25	19.75
08.04.15	43	22	69	4	25.5	41.33	15.25	7.5	49.5	8.58	18.25	25	19.75
09.04.15	43	15	69	4	25.5	41.33	28.5	109	49.5	23	23.5	93	33
10.04.15	18	15	52	8.75	23.75	41.33	28.5	68.5	18.5	23	23.5	93	33
11.04.15	18	50.25	52	8.75	23.75	45.33	27.67	68.5	18.5	21.75	15	74	23.75
12.04.15	18	50.25	52	8.75	23.75	45.33	27.67	68.5	18.5	21.75	15	74	23.75
13.04.15	18	50.25	52	8.75	23.75	45.33	27.67	68.5	18.5	21.75	15	74	23.75
14.04.15	20	50.25	106	17.5	28.5	43.5	33.5	50	18.5	21.75	15	74	23.75
15.04.15	20	18	106	17.5	28.5	43.5	33.5	50	18.5	47	19	53	9
16.04.15	48	18	52	11.83	243.2	18	37	50	24	47	6.5	53	9
17.04.15	23	16	52	11.83	243.2	18	16	115	24	46	6.5	86	20
18.04.15	23	12	52	11.83	243.2	48	16	109	24	20.43	21	71	41
19.04.15	23	12	52	11.83	243.2	48	16	109	24	20.43	21	71	41
20.04.15	23	12	52	11.83	243.2	48	16	109	24	20.43	21	71	41
21.04.15	23	12	90	11.83	572	33.25	16	82.75	63.67	20.43	21	71	41
22.04.15	49	60	90	93	23	33.25	16.33	82.75	63.67	20.43	26.67	71	117.33
23.04.15	49	60	485	93	23	33.25	16.33	82.75	63.67	20.43	26.67	71	117.33
24.04.15	73	60	68	20.8		33.25	16.33	82.75	38.4	20.43	26.67	71	117.33
25.04.15	73	17.67	68	20.8		55.33	49.33	75.67	38.4	41.58	45	124	27
26.04.15	73	17.67	68	20.8		55.33	49.33	75.67	38.4	41.58	45	124	27
27.04.15	28	17.67	68	20.8		55.33	49.33	75.67	38.4	41.58	45	124	27
28.04.15	28	26.5	68	20.8		86	18	116	38.4	34	22.5	135	20.5
29.04.15	28	26.5	318	82.5	45.5	36.5	39.5	103.33	58.5	90.42	22.5	135	20.5
30.04.15	62	22	318	82.5	45.5	36.5	39.5	103.33	58.5	90.42	38	182	28.5
01.05.15	62	22	127	38	19	36.5	49	103.33	280	90.42	38	182	28.5

Table S8: Continued

Date	Lana	Partschins	Laimburg	Kaltern	Eppan 1/ Eppan 2	D. Tirol	Tisens	Meran	Eppan	Sallmann	Marling	D. Tirol	Pawigl
02.05.15	62	22	127	38	19	36.5	25.67	103.33	21	527	43	182	40.33
03.05.15	45	47.5	129	115	140	84	25.67	103.33	21	153.5	43	302	40.33
04.05.15	45	47.5	129	22	2.5	84	25.67	103.33	21	153.5	43	302	40.33
05.05.15	45	200	43	22	2.5	230	194	176	124	131.5	86	230	218
06.05.15	45	102.33	43	22	2.5	230	53.5	90	32	131.5	37.33	230	36
07.05.15	444	102.33	43	22	2.5	124.5	53.5	90	32	153.5	37.33	164	36
08.05.15	102	102.33	43	34.8	129.5	124.5	40.25	90	90.75	153.5	37.33	164	27.5
09.05.15	102	64	43	34.8	129.5	81	40.25	111.5	90.75	105.27	38	137	27.5
10.05.15	102	64	43	34.8	129.5	81	40.25	111.5	90.75	105.27	38	137	27.5
11.05.15	102	39.67	43	34.8	129.5	56.33	40.25	157	90.75	105.27	14.33	137	27.5
12.05.15	171	39.67	79	34.8	34.5	56.33	119	157	46	300.5	14.33	327	69
13.05.15	84	39.67	79	216	34.5	56.33	92	157	46	300.5	14.33	327	37
14.05.15	84	217	79	40	28.6	66	92	204	27.8	138	139	197	37
15.05.15	165	67.75	79	40	28.6	37.75	93.5	161	27.8	138	25.25	197	127.8
16.05.15	165	67.75	50	40	28.6	37.75	93.5	161	27.8	136	25.25	177	127.8
17.05.15	165	67.75	50	40	28.6	37.75	93.5	161	27.8	136	25.25	177	127.8
18.05.15	165	67.75	50	40	28.6	37.75	93.5	161	27.8	136	25.25	177	127.8
19.05.15	165	88	51	21.67	25	51.5	57.33	161	69.33	136	33.5	177	127.8
20.05.15	74	88	51	21.67	25	51.5	57.33	135.5	69.33	115.83	33.5	293	80.33
21.05.15	74	88	51	21.67	25	165.33	57.33	135.5	69.33	115.83	33.5	293	80.33
22.05.15	136	88	98	49.4	75	165.33	96.6	109.2	148.4	115.83	33.5	133	80.33
23.05.15	136	112	98	49.4	75	165.33	96.6	109.2	148.4	72.4	34	133	105.8
24.05.15	136	112	98	49.4	75	165.33	96.6	109.2	148.4	72.4	34	133	105.8
25.05.15	136	112	98	49.4	75	165.33	96.6	109.2	148.4	72.4	34	133	105.8
26.05.15	136	112	98	49.4	75	165.33	96.6	109.2	148.4	72.4	34	133	105.8
27.05.15	136	112	69	69.5	48.5	261.5	57	170	123.5	72.4	34	133	105.8
28.05.15	221	169	69	69.5	48.5	261.5	57	151	123.5	171	182	135	247
29.05.15	50	68	212	73.25	30.25	162	139	42.25	180.33	171	50	135	51
30.05.15	50	68	212	73.25	30.25	162	139	42.25	180.33	101.5	50	182	51
31.05.15	50	68	212	73.25	30.25	162	139	42.25	180.33	101.5	50	182	51
01.06.15	50	68	212	73.25	30.25	162	139	42.25	129.5	101.5	50	182	51
02.06.15	50	70	445	104	46	202.5	114.33	409	129.5	101.5	105	221	175
03.06.15	189	70	445	104	46	202.5	114.33	52.67	129.5	223	105	221	154
04.06.15	189	236	445		46	192	114.33	52.67	129.5	68.5		147	154
05.06.15	189		183					52.67		68.5		147	154
06.06.15	106		183							87		147	
07.06.15	106		183							87		147	
08.06.15	106		183							87		147	
09.06.15	106		183							87		147	

References

Bühlmann, G., 1985: Assessing population dynamics in a honeybee colony. Kiel (4), 312–316.

Bühlmann, G., 1986: Bienentage – Ausdruck des Leistungspotentials des Bienenvolkes. Ein Schlüsselbegriff zur Erfassung wichtiger Eigenschaften eines Bienenvolkes. Schweizerische Bienen-Zeitung (2), 50–62.

Bühlmann, G., 1997: Jahrblatt – Standardtabelle und Berechnungen zum Entwicklungsverlauf von Bienenvölkern. Version dBASE IV. Mitteilung Schweizerisches Zentrum für Bienenforschung (22), 1–46.

Fluri, P., 2012: Regulation der Lebensdauer bei Arbeiterinnen der Honigbienen: Bedeutung der Brutpfl ege, des Nachwuchses und der Volksgrösse. Unter Mitarbeit von Luzio Gerig, Anton Imdorf, Charles Maquelin, Charrière Jean-Daniel, Georges Bühlmann, Bogdanov Stefan et al. Hg. v. Forschungsanstalt Agroscope Liebefeld-Posieux ALP. Agroscope. Bern. URL: http://www.imker-ostbelgien.be/media/files/Lebensdauer-der-Biene.pdf, zuletzt geprüft am 06.12.19.

Harbo, J.R., 1986: Effect of Population Size on Brood Production. Journal of Apicultural Research 25, 1986 (1), 22–29, DOI: 10.1080/00218839.1986.11100687.

Hothorn, H., F. Bretz, P. Westfall, R.M. Heiberger, 2008: multcomp: Simultaneous Inference in General Parametric Models, URL: http://CRAN.R-project.org. R package version 1.0-0.

Imdorf, A., K. Ruoff, P. Fluri, 2008: Volksentwicklung bei der Honigbiene. Hg. v. Forschungsanstalt Agroscope Liebefeld-Posieux ALP. Agroscope (68). Zugriff: 13.11.2019, URL: https://www.agroscope.admin.ch/agroscope/de/home/themen/nutztiere/bienen/biologie/volksentwicklung/_jcr_content/par/columncontrols/items/0/column/externalcontent.external.exturl.html/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoL2RlLUNIL0FqYXgvUH/VibGlrYXRpb24_ZWluemVscHVibGlrYXRpb25JZD0yMDQ4MyZw/YXJlbnRVcmw9JTJGZGUtQ0glMkZQdWJsaWthdGlvbnNsaXN0ZS/UyRkVpbnplbG4lM0Zwb3NpdGlvbiUzRG1pZGRsZSUyNnB1Ymxp/a2F0aW9uSWQlM0QxODgzNw==.html.

Kratky, E., 1931: Morphologie und Physiologie der Drüsen in Kopf und Thorax der Honigbiene (Apis mellifica L.). Zeitschrift für wissenschaftliche Zoologie **139** (1), 120–200. Zugriff: 06.12.2019, URL: https://w3.avignon.inra.fr/dspace/bitstream/2174/310/1/AD_2009_B1075_1.pdf.

Liebig, G., 1993a: Die biologischen Grundlagen der Volksentwicklung. Einführung in die Methode der Populationschätzung (I). Deutsches Bienen Journal (1), 14–15.

Liebig, G., 1993b: Die biologischen Grundlagen der Volksentwicklung (III) – Die Bruttätigkeit während der Saalweidenblüte. Deutsches Bienen Journal (3), 10–11.

Liebig, G.,1993c: Die biologischen Grundlagen der Volksentwicklung (VIII). Die Entwicklung im Spätsommer und im Herbst. Deutsches Bienen Journal (8), 10–11.

Liebig, G., 1993d: Die biologischen Grundlagen der Volksentwicklung (XI). Schlußbetrachtung. Deutsches Bienen Journal (11), 14.

Pinheiro, J., D. Bates, S. DebRoy, D. Sarkar, R.C. Team, 2016: Nlme: Linear and Nonlinear Mixed Effects Models. R Package Version 3.1-128. URL: http://CRAN. R-project.org/package=nlme.

Wallner, K., 1995: Bienenschäden im Weinbau. Versuche und Beobachtungen zu den Ursachen der Bienenschäden in Weinbaugebieten der Ortenau vor und während der Rebblüte. Stuttgart: Dr. Neinhaus Verlag AG.

Wille, H. 1984: Überlebensstrategien des Bienenvolkes. Liebefeld, S. 169–182. Zugriff: 10.12.2019, URL: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwik08b326rmAhXO26QKHf-GB9EQFjAAegQIBRAC&url=https%3A%2F%2Fwww.summ-summ.ch%2Fapp%2Fdownload%2F10847897595%2FWille_Ueberlebensstrategien.pdf%3Ft%3D1488210726&usg=AOvVaw03U6C3CBUR-8JlbTvIBl0wT.