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NOTES AND COMMENTS

Multi-country loss rates of honey bee colonies during winter 2016/2017 from the COLOSS survey

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In this short note we present comparable loss rates of honey bee colonies during winter 2016/2017 from 27 European countries plus Algeria, Israel and Mexico, obtained with the COLOSS questionnaire. The 14,813 beekeepers providing valid loss data collectively wintered 425,762 colonies, and reported 21,887 (5.1%, 95% confidence interval 5.0–5.3%) colonies with unsolvable queen problems and 60,227 (14.1%, 95% CI 13.8–14.4%) dead colonies after winter. Additionally we asked for colonies lost due to natural disaster, which made up another 6,903 colonies (1.6%, 95% CI 1.5–1.7%). This results in an overall loss rate of 20.9% (95% CI 20.6–21.3%) of honey bee colonies during winter 2016/2017, with marked differences among countries. The overall analysis showed that small operations suffered higher losses than larger ones ($p < 0.001$). Overall migratory beekeeping had no significant effect on the risk of winter loss, though there was an effect in several countries. A table is presented giving detailed results from 30 countries. A map is also included, showing relative risk of colony winter loss at regional level.

Tasas de pérdida de colonias de abejas melíferas en varios países durante el invierno 2016/17, según el estudio de COLOSS

En esta breve nota presentamos tasas de pérdida comparables de colonias de abejas melíferas durante el invierno 2016/17 de 27 países europeos más Argelia, Israel y México, obtenidas con el cuestionario COLOSS. Los 14.813 apicultores que proporcionaron datos válidos de pérdidas en conjunto hibernaron 425.762 colonias, y reportaron 21.887 colonias (5.1%, intervalo de confianza del 95% 5.0–5.3%) con problemas irresolubles de reinas y 60.227 colonias (14.1%, IC del 95% 13.8–14.4%) muertas después del invierno. Además, se solicitaron las pérdidas de colonias debido a desastres naturales, que constituyeron otras 6.903 colonias (1.6%; IC del 95%: 1.5 a 1.7%). Esto da como resultado una tasa global de pérdida del 20,9% (IC del 95%: 20.6 a 21.3%) de las colonias de abejas melíferas durante el invierno 2016/17, con marcadas diferencias entre los países. El análisis general mostró que las operaciones pequeñas sufrieron pérdidas más altas que las grandes ($p<0.001$). La apicultura migratoria en general no tuvo un efecto significativo en el riesgo de pérdida invernal, aunque hubo un efecto en varios países. Se presenta una tabla con resultados detallados de 30 países. También se incluye un mapa que muestra el riesgo relativo de pérdida de colonias de invierno al nivel regional.

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[†]Did data processing and editing, all statistical analysis for the results in the table and text, produced the relative risks map, and contributed to the text of the article.

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The non-profit honey bee research association COLOSS has established the monitoring of winter losses of managed honey bee colonies in many European and some additional countries. As well as thorough modelling of risk factors (van der Zee et al., 2012, 2014), we have started a series of rapid publications of loss rates (Brodschneider et al., 2016). Making use of standardized methods for surveys on colony losses, our investigation, based on a large number of responses giving self-reported data from beekeepers, provides a quick, but well accepted, measure of honey bee colony loss rates (van der Zee et al., 2013). Moreover these surveys, which have now been running for a number of years in some of the countries, provide information on trends in honey bee winter colony losses both in time and space.

In the most recent COLOSS survey starting in March 2017, we asked beekeepers for the number of colonies wintered, and how many of these colonies after winter: (a) were alive but had unsolvable queen problems (like a missing queen, laying workers, or a drone egg laying queen); (b) were dead or reduced to a few hundred bees; and (c) were lost through natural disaster. To calculate the overall proportion of colonies lost, for this article, the sum of a + b + c was calculated and the result was divided by the number of colonies going into winter. Beekeepers were allowed to answer anonymously. Data files were checked for consistency of loss data (i.e. number of colonies at the start of winter should not be missing and should be greater than zero, number of colonies lost due to each of a, b and c should not be missing and should be greater than or equal to zero, and the sum a + b + c should not be greater than the number of colonies at the start of winter). Responses with insufficient or illogical answers were excluded. For most participating countries this amounted to a relatively small number of responses. However, in the case of Germany, which provided by far the highest number of responses, this year an exceptionally large proportion of the loss data returned by the beekeepers was incomplete. Results for Germany are therefore presented twice, one set of results derived from a limited data-set that contains all requested information required for calculating a + b + c, and a second set derived from the full data-set by treating missing values in a or b or c as zero, so as to include also incomplete responses. The true values of the loss rates for Germany are expected to lie between those given for these two cases. By the end of June 2017, 30 countries contributed data to our study. These data were collected centrally, processed and used for calculation of loss rates for this short note.

Altogether, we received over 25,000 responses. Of these, 14,813 beekeepers provided complete and consistent loss data. These 14,813 beekeepers collectively wintered 425,762 colonies and reported 21,887 colonies with unsolvable queen problems, 60,227 dead colonies and 6,903 colonies lost due to natural disaster during winter. This gives an overall loss rate of 20.9% (95% confidence interval 20.6–21.3%) during winter 2016/2017, with marked differences among countries (Table 1). The highest winter loss rate was found in Germany, irrespective of whether the limited or full data-set from Germany is used for calculation. High overall losses were also reported from Spain, Mexico, Malta and Serbia. At the other end of the spectrum, loss rates were lowest in Norway, Northern Ireland and Algeria. Figure 1 shows the lower risk across most of North-Western and Northern Europe, with higher risk areas across the whole of Germany, parts of Spain and France, the north of Italy and certain regions of most other countries.

For comparison, over winter 2015/2016 the highest loss rates were in Ireland, Northern Ireland, Wales and Spain, and the lowest were in the Czech Republic and central Europe generally, so the pattern differs between years. The large increase in overall loss rate of honey bee colonies during winter 2016/2017 compared to the previous winter (12.0%, Brodschneider et al., 2016) should be considered with caution, as the group of participating countries differs slightly between the two years. More conclusive is the comparison of loss rates of the 26 countries from which we have results for the last two wintering periods. This shows that twelve countries had, based on 95% confidence intervals, significantly higher losses than in 2015/2016, eleven remained stable and three experienced lower losses.

The loss rates presented in previous publications likewise included all three categories of lost colonies as reported in this article, but as the sum of these cases of loss (Brodschneider et al., 2016; van der Zee et al., 2012, 2014). Here we present for the first time a separate number for colonies lost due to natural disaster. This was rather loosely defined, as the causes can be very different in participating countries, including fire, storm, flooding, vandalism, bears, martens, woodpeckers, falling trees, suffocation from snow and many more. However it may be interpreted differently in different countries. Beekeepers in our study experienced between none (of 459 colonies in Northern Ireland) and 10.6% of colonies (in Malta) lost due to natural disaster; overall it was only 1.6% (Table 1). The highest rates for colony losses due to natural disaster were reported from Malta, Mexico and Israel. In the USA's annual colony loss survey, beekeepers reported natural disaster as a negligible cause, with a relative frequency of below 2.5%, and it is not considered as a factor significantly

Table 1. Number of respondents with valid loss data, corresponding number of colonies going into winter, mortality rate (including 95% confidence interval, CI), loss rate of colonies due to queen problems, loss of colonies due to natural disaster, overall loss rate, response rate per country (expressed as percentage of responses per estimated number of beekeepers), and effect of migratory beekeeping. Mortality and loss rates were calculated as colonies lost as a percentage of colonies wintered, CIs were calculated using the quasi-binomial generalized linear modelling (GzLM) approach in van der Zee et al. (2013), and effect of migratory beekeeping was tested using a single factor quasi-binomial GzLM to model probability of loss.

Country	No. of respon-dents	No. of colonies going into winter	% Mortality Rate (95% CI)	% Rate of loss of colonies due to queen problems (95% CI)	% Rate of loss of colonies due to natural disaster (95% CI)	Overall winter loss rate (95% CI)	Estimated % of beekeepers represented	Effect of migrating colonies
Algeria	106	10,473	7.2 (6.3–8.2)	1.8 (1.4–2.3)	1.8 (1.0–3.4)	10.8 (9.5–12.3)	<1	ns, DK > m*
Austria	1656	43,852	18.6 (17.7–19.6)	4.4 (4.1–4.7)	0.4 (0.2–0.6)	23.4 (22.4–24.4)	6	ns
Belarus	36	1081	11.5 (7.2–17.7)	2.8 (1.7–4.5)	0.5 (0.2–1.0)	14.7 (10.0–21.1)	na	ns
Belgium	695	6152	19.2 (17.3–21.3)	3.9 (3.2–4.8)	0.3 (0.1–0.5)	23.4 (21.4–25.6)	7	s > m**
Croatia	238	16,508	20.4 (17.6–23.6)	2.2 (1.8–2.7)	0.5 (0.3–0.9)	23.1 (20.2–26.3)	2	ns
Czech Republic	1191	24,688	10.9 (10.0–12.0)	3.0 (2.7–3.3)	1.1 (0.9–1.4)	15.0 (14.0–16.2)	2	ns
Denmark	1161	12,849	13.9 (12.7–15.2)	5.1 (4.6–5.7)	0.3 (0.2–0.5)	19.3 (18.0–20.7)	18	s < m*
Estonia	151	6039	6.7 (4.8–9.1)	4.2 (3.1–5.6)	2.5 (1.7–3.8)	13.4 (10.8–16.5)	3	s > m**
Finland	269	9652	9.4 (8.1–10.8)	4.0 (3.4–4.7)	1.2 (0.8–1.7)	14.6 (13.2–16.1)	9	ns
France	459	24,943	14.7 (13.0–16.6)	4.1 (3.5–4.7)	0.7 (0.5–1.0)	19.5 (17.6–21.5)	<1	ns
Germany[1]	780	19,588	30.2 (28.5–31.9)	11.5 (10.7–12.4)	2.8 (2.4–3.1)	44.5 (42.7–46.3)	<1	s > m*
Germany[2]	11,322	149,417	19.3 (18.9–19.7)	12.5 (12.2–12.7)	0.5 (0.4–0.5)	32.2 (31.7–32.7)	10	ns
Ireland	395	3415	5.0 (4.1–6.1)	8.0 (6.9–9.2)	0.3 (0.1–0.8)	13.3 (11.7–15.1)	11	ns
Israel	47	27,150	8.0 (5.9–10.7)	1.7 (1.0–2.9)	4.9 (3.1–7.6)	14.6 (12.3–17.3)	9	ns
Italy	395	13,392	10.9 (9.6–12.3)	6.8 (6.0–7.8)	1.5 (1.1–1.9)	19.2 (17.5–20.9)	<1	ns
Latvia	375	12,322	13.2 (11.5–15.1)	4.0 (3.5–4.6)	1.3 (0.9–2.0)	18.5 (16.6–20.6)	9	s > m, DK > m***
Macedonia	320	18,400	14.2 (12.6–16.1)	4.9 (4.1–5.7)	3.3 (2.5–4.4)	22.5 (20.3–24.7)	11	ns
Malta	36	1130	2.6 (0.8–7.8)	11.0 (7.3–16.1)	10.6 (6.8–16.2)	24.2 (18.1–31.4)	17	ns
Mexico	90	14,357	7.7 (5.8–10.1)	11.6 (8.5–15.7)	6.0 (4.2–8.6)	25.3 (20.2–31.3)	<1	s < m*

(Continued)

Table 1. (*Continued*).

Country	No. of respon-dents	No. of colonies going into winter	% Mortality Rate (95% CI)	% Rate of loss of colonies due to queen problems (95% CI)	% Rate of loss of colonies due to natural disaster (95% CI)	Overall winter loss rate (95% CI)	Estimated % of beekeepers represented	Effect of migrating colonies
Northern Ireland	85	459	3.7 (2.2–6.1)	6.3 (4.4–9.0)	0.0 (na)	10.0 (7.5–13.3)	9	ns
Norway	602	11,056	3.5 (3.0–4.2)	3.7 (3.3–4.2)	0.5 (0.3–0.8)	7.7 (6.9–8.5)	15	ns
Poland	491	23,193	14.9 (13.2–16.8)	6.1 (5.4–6.9)	0.9 (0.5–1.4)	21.8 (19.9–23.9)	<1	ns
Scotland	336	1609	9.3 (7.4–11.5)	9.7 (8.1–11.5)	1.5 (0.9–2.4)	20.4 (17.7–23.5)	21	ns
Serbia	84	5084	14.6 (10.7–19.6)	6.6 (4.5–9.5)	2.9 (1.1–7.3)	24.1 (18.7–30.3)	<1	ns
Slovakia	401	9331	11.1 (9.6–12.9)	4.4 (3.5–5.3)	0.7 (0.5–1.0)	16.2 (14.3–18.3)	2	ns
Slovenia	106	3336	19.2 (14.5–24.9)	0.3 (0.0–2.3)	0.1 (0.0–0.5)	19.6 (14.9–25.4)	1	ns
Spain	224	43,960	18.1 (16.1–20.3)	8.6 (7.7–9.7)	0.9 (0.5–1.5)	27.6 (25.1–30.2)	<1	ns overall, but *s* < *m*
Sweden	2186	20,353	9.6 (8.9–10.4)	3.3 (2.9–3.6)	2.3 (2.1–2.7)	15.2 (14.4–16.1)	15	DK > *m** , *s* = *m*
Switzerland	1348	20,433	13.7 (12.7–14.8)	6.8 (6.3–7.3)	0.3 (0.2–0.5)	20.8 (19.7–22.0)	8	na
Ukraine	536	20,846	14.0 (12.3–15.9)	1.8 (1.4–2.2)	2.1 (1.7–2.7)	17.9 (16.0–19.9)	<1	*s* > *m***
Wales	14	111	5.4 (1.4–18.7)	9.9 (5.4–17.6)	4.5 (0.6–27.5)	19.8 (10.0–35.4)	<1	ns
Overall[3]	14,813	425,762	14.1 (13.8–14.4)	5.1 (5.0–5.3)	1.6 (1.5–1.7)	20.9 (20.6–21.3)	na	DK < *m*** , or ns if DK excluded

Notes: Significance codes for *p*-values: ns = non-significant ($p > 0.05$); na: data not available, DK = Don't Know; *s* = stationary, *m* = migratory.
*$0.01 < p \leq 0.05$.
**$0.001 < p \leq 0.01$.
*** $p <= 0.001$.
[1]Result for Germany using only the beekeepers with complete loss data.
[2]Result for Germany replacing missing numbers lost by 0.
[3]Overall result using the smaller data-set for Germany, for consistency with the treatment of other countries.

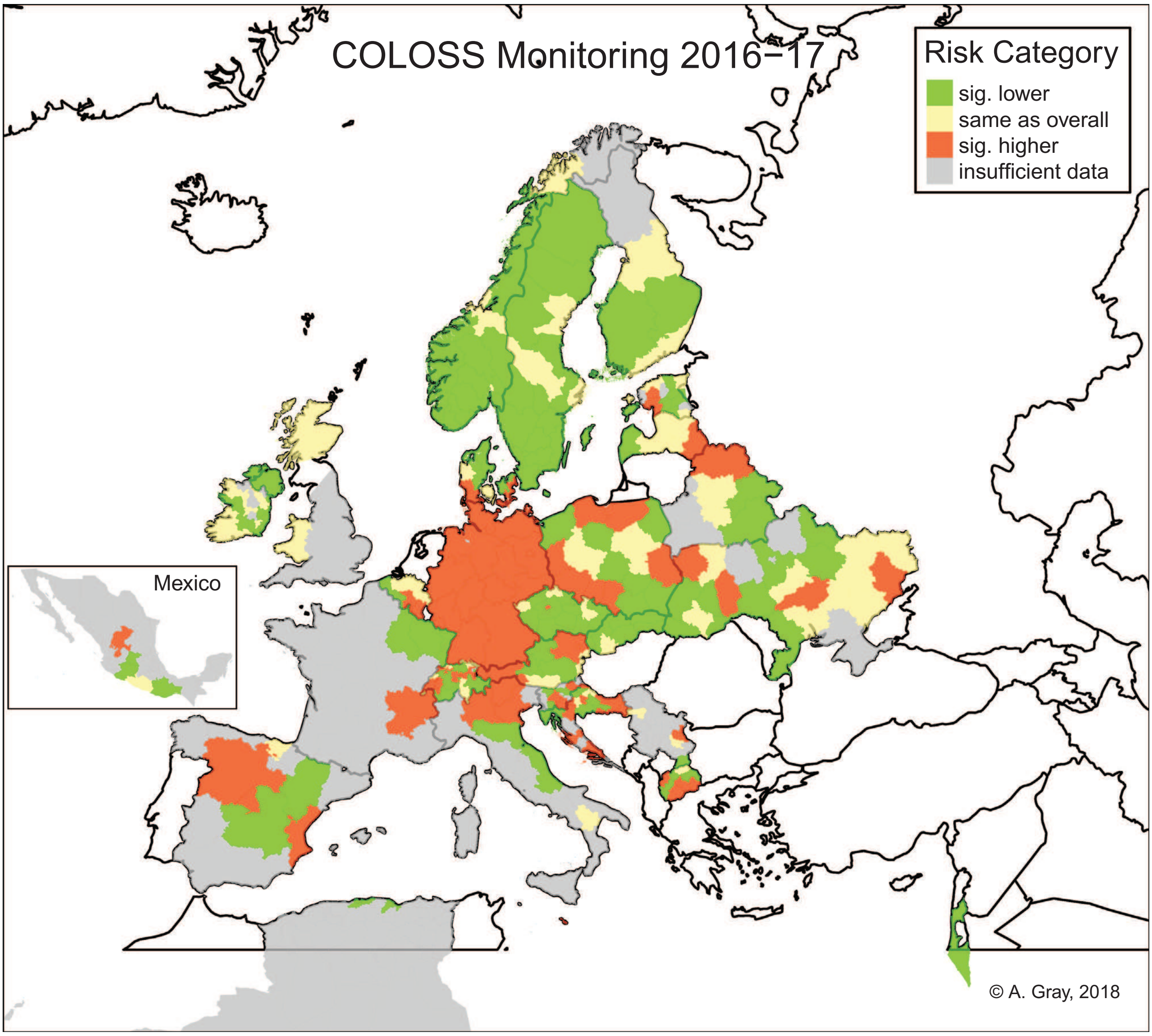

Figure 1. Color-coded map showing relative risk of overwinter colony loss at regional level for participating countries.
Notes: Regions with a relative risk of loss (loss rate relative to the loss rate over all regions) that is significantly higher/lower than 1 are shown in red/green respectively. Regions with a relative risk not significantly different from 1 are shown in yellow. Where no data were available or data were available from fewer than 6 beekeepers in a region, this was treated as insufficient for reliable calculation and the region is shown in grey. The smaller limited data-set satisfying the data checks was used for Germany, for consistency with other countries.

contributing to colony losses (Kulhanek et al., 2017; Seitz et al., 2016).

Although the losses due to natural disaster are important for individual operations or even for the honey bee population in a given region, colonies lost by natural disaster do not admit an epidemiological analysis of biological causes for colony losses and may therefore be left out or treated separately in further risk analysis. Winter losses related to queen problems varied between 0.3% in Slovenia and more than 10% in Germany. The overall loss rate due to queen problems was 5.1%, which was slightly higher than that recorded in the previous winter (4.4%, Brodschneider et al., 2016).

Operation size has been identified as a risk factor for winter losses before (e.g. Seitz et al., 2016). We were able to verify our findings from last year, that beekeeping operations with 50 or fewer colonies experience higher total winter losses in the overall analysis ($p < 0.001$; Brodschneider et al., 2016). This year we focused on another often discussed risk factor for colony losses, migratory beekeeping. The proportion of beekeepers migrating bee colonies varied greatly from 3% of those answering this question in the Czech Republic to 50% in Mexico. The results indicate a significant effect only in a minority of countries (Table 1), and the direction of the effect of migration on the risk of winter loss varies. In many countries some beekeepers replied "don't know" to whether or not they migrated. Overall the "don't knows" had lower losses than those migrating, though in 3 countries (see Table 1) they had higher losses. Omitting "don't know", overall there was no effect of migration. Our results are broadly in accordance with reports from the USA, where migratory beekeeping was not found to increase colony loss rates (Kulhanek et al., 2017; Seitz et al., 2016).

Achieving representativeness of the beekeeper population is an important issue in estimation of loss rates (van der Zee et al., 2013). One strategy, which we also followed in this study, is to aim for as many answers from beekeepers as possible, but the response rate (estimate of beekeepers represented, Table 1) reveals high differences between countries. Whereas in 14 countries between 6% and 21% of the respective beekeeper population participated in our study, in other countries only a low number of responses, sometimes from certain regions only, was available this year. Although based on few answers only, here we present winter loss rates for the first time from Belarus, Malta, Mexico and Serbia. Routine surveys on colony losses are widely accepted by beekeepers and authorities in many countries, and the network is planning to further expand with respect to the number of countries participating and especially to try to improve the response rates in countries with few answers this year, to further facilitate understanding of honey bee health.

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