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ORIGINAL RESEARCH ARTICLE

Trends in beekeeping and honey bee colony losses in Latin America

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Over the past decade, several countries have carried out monitoring programs of managed honey bee colonies, which suggest beekeeping difficulties, with high colony loss rates all over the world. Although Latin America plays a major role in the global honey supply, information about trends in beekeeping activities and honey bee colony losses are lacking. Using the Food and Agriculture Organization of the United Nations (FAO) dataset and a synthesis of unpublished data of colony losses survey carried out over the last 7 years, we reveal a worrying situation of the beekeeping in this region. The Latin American trends in honey production and beehive numbers are drifting from the global pattern, and several high colony loss rates were registered in this region. These results reveal the presence of beekeeping difficulties in Latin America. However, the variability in methods of colony loss survey across initiatives prevent proper conclusion on loss rates. Efforts are needed to adapt, centralize and standardize methods to monitor honey bee health and colony losses across countries in Latin America, the main objective of the "colony losses" working group at the Latin-American Society for Bee Research, SOLATINA, a large-scale platform created in 2017 to coordinate bee research programs in Latin America.

Tendencias en la apicultura y pérdida de colonias de abejas melíferas en América Latina

Durante la última década, varios países han llevado a cabo programas de monitoreo de colmenas de abejas melíferas, que sugieren dificultades en la apicultura relacionadas con altas tasas de pérdida de colonias al rededor del mundo. Aunque América Latina juega un papel importante en la producción mundial de miel, hay un vacío de información sobre la actividad apícola y las pérdidas de colonias en la región. Utilizando el conjunto de datos de la FAO y una síntesis de datos inéditos de encuestas sobre pérdidas de colonias realizada en los últimos siete años, revelamos una preocupante situación para la apicultura en esta región. Las tendencias latinoamericanas en la producción de miel y el número de colonias se desvían del patrón global, y se registran altas tasas de pérdidas de colonias en la región. Estos resultados revelan dificultades en el desarrollo apícola latinoamericano. Sin embargo, la variabilidad en los métodos de valoración de la pérdida de colonias en las diferentes iniciativas impide llegar a conclusiones definitivas sobre las tasas de pérdidas. Se necesitan esfuerzos para adaptar, centralizar y estandarizar los métodos de monitoreo de la salud de las abejas melíferas y las pérdidas de colonias en todos los países de América Latina. Esto constituye el principal objetivo del grupo de trabajo "Pérdida de colonias" de la Sociedad Latinoamericana de Investigación en Abejas, SOLATINA, una plataforma a gran escala creada en 2017 para coordinar los programas de investigación apícola en América Latina.

Keywords: Apis mellifera; beekeeping; citizen science; colony losses; honey; monitoring; SOLATINA; South America

Introduction

Global concerns about beekeeping difficulties and the loss of managed honey bee (*Apis mellifera*) colonies have motivated monitoring programs of colony losses over the past 10 years. Among the most renowned ones, the Bee Informed Partnership has developed a national monitoring program in USA carried out annually since 2007 (Kulhanek et al., 2017), while the honey bee research association COLOSS (Brodschneider et al., 2016) and the EPILOBEE consortium (Jacques et al.,

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2017) have developed theirs in Europe (with additional non-European countries for the COLOSS monitoring). However, several countries of the world are missing from these efficient programs, although some of them have critical roles in the global honey supply.

Latin America (LA) includes developing countries with high interest in beekeeping and honey production. Seven LA countries are within the 20 leading countries of the world honey market (Supplementary Figure S1), revealing a critical role of LA for the global honey supply and an economical importance of honey production in this region. Moreover, LA countries are within the top 20 countries for production (Figure 1a) and livestock (Figure 1b) with, respectively, a total of 14% of the global honey production (i.e., more than 200 million tons) and 9.7% of the global livestock [i.e., 7.8 million managed honey bee colonies; data for 2016 obtained from the Food and Agriculture Organization of the United Nations (FAOSTAT, 2018)]. Nevertheless, such values do not inform on the situations of beekeeping and loss rates of honey bee colonies, for which LA lacks crucial surveys, estimates, and published data (Figure 1a, b; Requier, Garcia, Andersson, Oddi, & Garibaldi, 2017). In this article, we examine (1) the trends of beekeeping (i.e., production and livestock) in LA over the last 30 years (from 1986 to 2016) using the FAO dataset (FAOSTAT, 2018), and (2) the rates of colony loss in LA over the last seven years using a synthesis of unpublished data. For full details of methods used see Supplementary data.

Results and discussion

Honey production in LA did not increase in the period since 1986, showing a stagnation trend, while in other countries it increased by 84% (Figure 1c). Conversely, Argentina showed a decline in honey production since 2000 (Supplementary Figure S2). Thus, LA showed a deficit in honey productivity of about 460,000 tons in 2016, compared to global pattern. Overall, the number of beehives increased in LA over the last 30 years, as well as in the rest of the world (Figure 1d). However, livestock increases of about 9% in LA were seven times smaller than increases of about 64% in the rest of the world. Consequently, LA has currently a deficit of about 210,000 beehives compared to global pattern. These trends and drifts of LA are robust, regardless of inclusion of China in the global trend, that is, the current most important honey producer with recent rapid increase in beekeeping activity (see Supplementary Figure S2). Such results show that beekeeping productivity and livestock in LA countries are growing slower than the global trend, suggesting potential professional difficulties for beekeepers in such developing economies.

What about honey bee colony losses? Although slow increases in livestock and the stagnation of productivity in LA might be partly explained by colony losses, among other factors (see Aizen & Harder, 2009), these trends do not provide by itself information on the rate of colony losses at the country or region scale. Large-scale monitoring programs to estimate colony loss rates have been launched in many countries (Requier et al., 2017); however, LA is not involved in such programs, leading to incertitude on loss range. For instance, Vandame and Palacio (2010) performed a global review and concluded that "there are no reports of massive colony losses in Latin America". More recently, Maggi et al. (2016) stated that "several cases of colony losses and colony depopulation were reported by beekeepers throughout the continent, yet no accurate data has been published to date". Although Giacobino et al. (2016) reported validated estimates (i.e., published in an international scientific journal with a peer-review process) of 11.4% of winter colony losses at regional scale in Argentina, only recently Antúnez, Invernizzi, Mendoza, van Engelsdorp, and Zunino (2017) published estimates at national scale for Uruguay, with 19.8 and 18.3% of summer and winter colony losses, respectively. However, Uruguay's results may not necessarily represent the situation of the whole LA, as this country only accounts for 7.5% of the beehives, 9.3% of the honey production, and 0.9% of the territory of LA (data for 2016 from FAOSTAT, 2018).

To attempt to provide insights about honey bee colony losses, we summarize the (mainly unpublished) data from monitoring programs of colony losses in LA (Table 1). These data come from individual research initiatives at regional or national scales based on questionnaires using a citizen science approach (Supplementary Table S1). Among the 1768 responses collected (about 1.1 million managed honey bee colonies) across five countries and over the last 7 years, annual loss rates varied between 0.1% [95% confidence interval (CI) 0–0.3%] for Northern Patagonia (Argentina) in 2012–2013 and 62% (95% CI 57.9–66.1%) for the multi-annual Brazilian survey (Table 1 and Supplementary Table S1). Overall, estimates of honey bee colony losses in LA were lower than standardized estimates of USA (Kulhanek et al., 2017; Lee et al., 2015; Seitz et al., 2015; Steinhauer et al., 2014; van Engelsdorp et al., 2012), for respective years (Table 1, Supplementary Table S2). However, several of these LA estimates came from small sample sizes (between 10 and 354 respondents) and various methods of survey (Supplementary Table S1), preventing further comparisons and proper conclusions on loss rates. To illustrate the hazard of error related to a low sampling size, the estimated loss rate of 0.1% showed in Northern Patagonia during the 2012–2013 survey with a sampling size of 10 respondents increases by 214% [i.e., 21.4% (0–43.5%), a value fairly more similar to those reported in other regions of this country; Table 1] with the addition of three personal communications from

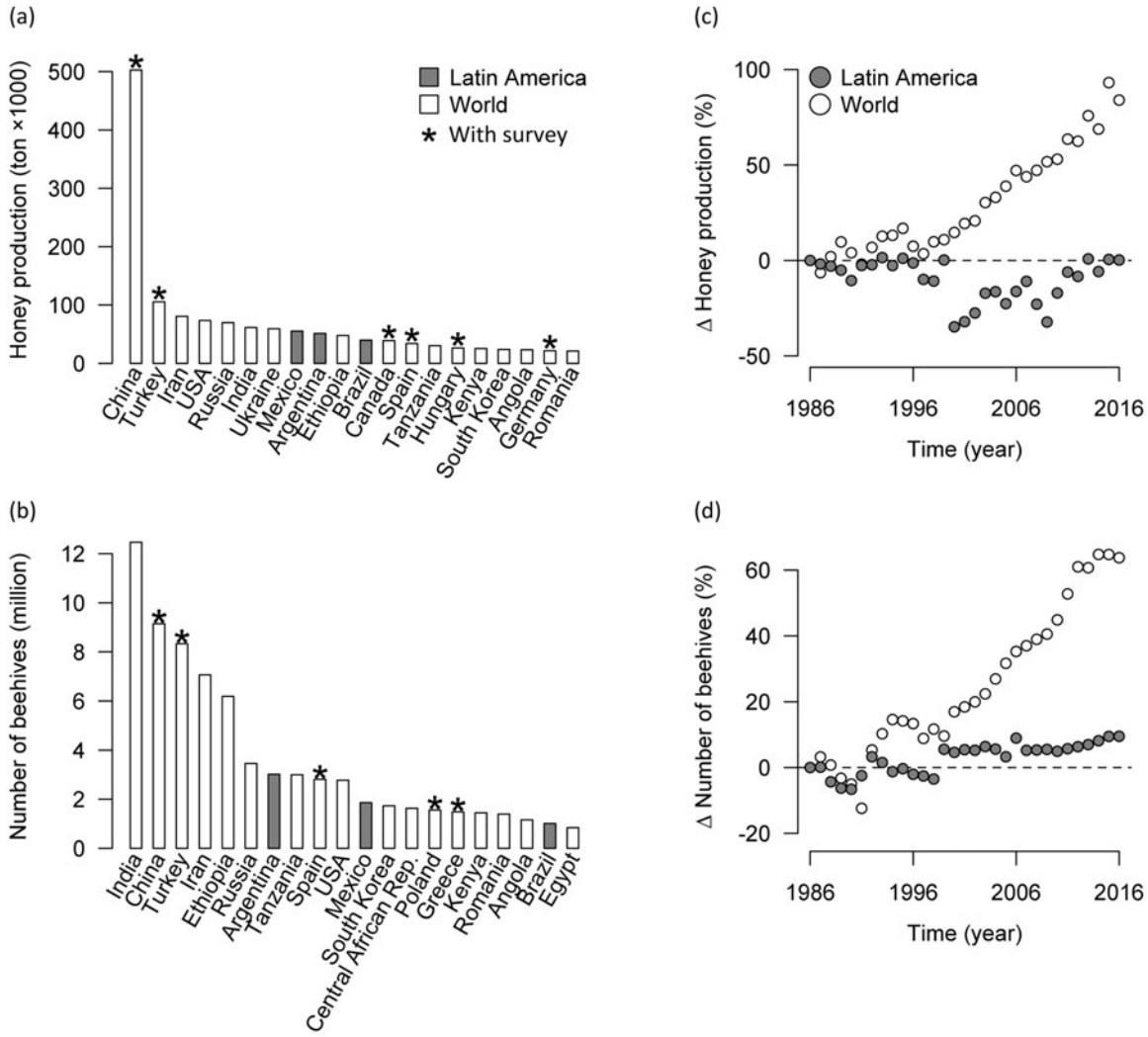

Figure 1. Using the FAO dataset (FAOSTAT, 2018) we examined the ranking of Latin American countries (in grey) within the top 20 countries in their contribution to (a) honey production, and (b) number of beehives in 2016 (the last year of the FAO data available). *Countries with survey and published data on the loss rates of honey bee colonies (complete list in Requier et al., 2017). We also showed the recent drift of Latin America (in grey) of the global trend (in white) in (c) honey production, and (d) number of beehives, from 1986 to 2016 and following methods of Aizen and Harder (2009). Values were corrected per region area (in ha) for better spatial comparisons, while absolute values are shown in Supplementary Figure S2. World trend includes China (see Supplementary Figure S2 for this distinction), and all the world countries excluding Latin America.

beekeepers (for the same low livestock size, i.e., 37 colonies on average for 10 participants versus 34 colonies on average for three additional beekeepers) not originally included in the survey.

The low participation rates from beekeepers across initiatives (Table 1) confirms the difficulty in carrying out monitoring programs of colony losses in LA (Maggi et al., 2016). Furthermore, most of these monitoring initiatives have been developed independently from each other, which can further reduce participation rates because of the potential overload and discouragement of the beekeepers to answer the same questions for various surveys. We also found a wide range of methods across surveys (more details in Supplementary Table S1), probably because of little communication among initiatives and the adaptation of the questions to study-specific goals. For example, the Brazilian survey used a multi-annual approach to record honey bee mass death and CCD (colony collapse disorder), while the Colombian survey used a multi-annual questionnaire to assess the link between colony losses and pesticides exposures (Supplementary Table S1). These oriented-based methods imply a non-random sampling of respondents with potential bias, and differ from traditional non-oriented surveys applied in other countries (Supplementary Table S1). Moreover, such methodological diversity prevents proper spatial and temporal comparisons (van der Zee et al., 2013; van Engelsdorp et al., 2013), and limits the understanding of the causes of colony losses in LA.

Our study reveals a worrying situation of the beekeeping in LA, associated with some estimates of high loss rates of honey bee colonies in various countries. This article also highlights the need to (1) coordinate

Table 1. A synthesis of unpublished data of honey bee colony losses in Argentina, Brazil, Chile, Colombia, and Uruguay.

Year	Questionnaire*	Scale*	Method*	No. of respondents (beekeepers)	No. of colonies	% of colonies	% summer losses (95% CI)	% winter losses (95% CI)	% annual losses (95% CI)	Reference
ARGENTINA										
2015–2016	BIP/COLOSS adapted	National	Face-to-face interview and self-reported	92	28,204	1	4.5 (3.1–5.9) ↓	13.5 (11.1–16) ↓	17.3 (14–20.6) ↓	Requier et al. (unpublished data)
2014–2015	Independent	Regional	Face-to-face interview	69	2882	<1†	4.4 (1.8–6.9) ↓	7.6 (4.2–11) ↓	11.3 (7.1–15.4) ↓	Giacobino, Molineri and Pacini (unpublished data)
2013–2014	COLOSS adapted	National	Face-to-face interview and self-reported	23	5805	<1	–	14.3 (8.5–20) ↓	–	Garrido and Porrini (unpublished data)
2012–2013	Independent	Regional	Face-to-face interview	46	276	<1†	–	11.4 (8.8–14.1) ↓	–	Giacobino et al. (2016)
2012–2013	Independent	Regional	Face-to-face interview	10	375	2.6†	–	–	0.1 (0–0.3) ↓	Morales et al. (unpublished data)
2010–2011	Independent	Regional	Face-to-face interview	354	129,342	39.4†	–	–	21.9 (6.8–37) ↓	Reynaldi et al. (unpublished data)
BRAZIL										
2013–2016	Independent	National	Self-reported	247	27,858	–	–	–	62 (57.9–66.1)	Castilhos et al. (unpublished data)
CHILE										
2015–2016	Independent	National	Face-to-face interview	179	70,764	17.5	–	–	5.9 (2.9–8.8) ↓	Aldea et al. (unpublished data)
2014–2015	Independent	National	Face-to-face interview	179	49,285	15.6	–	–	19.7 (15.6–23.9) ↓	Aldea et al. (unpublished data)
COLOMBIA										
2014–2016	Independent	National	Self-reported	139	7506	–	–	–	10.8 (8–13.5)	Colectivo Abejas Vivas (unpublished data)
URUGUAY										
2015–2016	BIP/COLOSS adapted	National	Self-reported	31	10,088	1.7	14.2 (9.9–18.5) ↓	11.9 (5–18.8) ↓	19.1 (12–26.2) ↓	Antúnez et al. (unpublished data)
2013–2014	BIP/COLOSS adapted	National	Self-reported	78	25,527	5.1	19.8 (14–25.5) ↑	18.3 (13.1–23.6) ↓	28.6 (22.5–34.6) ↓	Antúnez et al. (2017)
2012–2013	Independent	National	Phone interview	321	50,503	10.1	–	–	21.2 (19.3–23.2) ↓	CHDA, Santos et al. (unpublished data)

The loss rates are calculated as the average value per beekeeper (95% Confidence Interval) following van Engelsdorp et al. (2013).
The % of colonies is computed at the national scale from FAOSTAT (2018) only for annual surveys (excluding Brazil and Colombia).
*More details on the surveys' methods are available in Supporting Information (Table S1).
†Data obtained at province scale from RENAPA (2017). We show whether Latin American estimates of loss were lower (↓) or higher (↑) than standardized estimates of United States (van Engelsdorp et al., 2012; Steinhauer et al., 2014; Lee et al., 2015; Seitz et al., 2016; Kulhanek et al., 2017), for respective years of survey and every annual estimate (excluding multi-annual surveys of Brazil and Colombia).
Differential values of loss rates between Latin American countries and United States are shown in Supporting Information (Supplementary Table S2).

among individual survey initiatives (Maggi et al., 2016) and (2) standardize methods (van der Zee et al., 2013; van Engelsdorp et al., 2013) to improve the effectiveness of monitoring programs and the understanding of the honey bee health in LA. For this purpose, the Latin-American Society for Bee Research, SOLATINA, was created in 2017 as a large-scale platform to coordinate bee research programs in LA (Supplementary Figure S3). SOLATINA comprises a consortium of researchers from 11 LA countries (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Mexico, Peru and Uruguay, see Supplementary Figure S2), representing 90% of its territory, 91% of the beehives and 90% of the honey production in 2016 (Supplementary Figure S2, FAOSTAT, 2018).

The "colony losses" working group (complete list in the authorship plus acknowledgements) of the SOLATINA consortium has developed an unified questionnaire of colony losses based on surveys that have proved to be effective in other regions, specifically, those developed by the Bee Informed Partnership (Kulhanek et al., 2017), COLOSS (Brodschneider et al., 2016) and EPILOBEE (Jacques et al., 2017). Our questionnaire was adapted to LA climatic conditions, for example, by considering determinants of the season of honey bee low activity other than thermic winter, more representative of tropical and subtropical regions (e.g., dry or rainy season). Moreover, we included other types of beekeeping activities, like meliponiculture, an activity well established and developed in LA (Jaffé et al., 2015). The LA survey of colony losses has been launch in October 2017 using such a unified questionnaire. More researchers who wish to contribute and exchange ideas about collaborative studies in LA are very welcome and needed.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Supplementary material

Supplementary data for this article can be accessed at here. https://doi.org/10.1080/00218839.2018.1494919.

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