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ORIGINAL RESEARCH ARTICLE

A survey of managed honey bee colony losses in the Republic of South Africa - 2009 to 2011

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Summary

This study reports honey bee, *Apis mellifera* L., colony losses that occurred in South Africa over two consecutive years. The total losses were 29.6% (95% CI: 22.8-37.5) in 2009-2010 and 46.2% (95% CI: 37.3-55.0) in 2010-2011. Furthermore, the study shows that the *capensis* worker social parasite, a problem unique to southern Africa, is the main perceived cause, and could explain the significant differences in the number of losses between beekeepers using the subspecies *A. m. scutellata* and those using the subspecies *A. m. capensis*. In contrast to previous studies in North America and Europe, we find a significant negative effect of migratory beekeeping practices on the extent of colony losses. Migratory beekeepers lost on average more colonies (35.5% (95% CI 29.7-47.2)) than did stationary beekeepers (17.2% (95% CI 11.2-22.3)). This was especially pronounced when the beekeepers were migrating for the pollination of apples/cherries, eucalyptus, onions and/or sunflowers. The major beekeeper-perceived causes of mortality were small hive beetles, varroa mites, absconding (non-reproductive swarming), and chalkbrood disease. Those listing chalkbrood disease lost significantly fewer colonies than those who did not list chalkbrood. The exact mechanism for this difference is unknown, and may be related to other beekeeping practices that correlate with finding chalkbrood infections – namely more intensive inspection and management.

Estudio de pérdidas de colonias de abejas manejadas en la República de Sudáfrica - de 2009 a 2011

Resumen

Este estudio informa sobre las pérdidas de colonias de abeja de la miel, *Apis mellifera* L., que tuvieron lugar en Sudáfrica durante dos años consecutivos. Las pérdidas totales fueron del 29.6% (IC 95%: 22.8-37.5) en el período 2009-2010 y el 46.2% (IC 95%: 37.3-55.0) durante el mismo periodo de 2010 a 2011. Además, el estudio muestra que el parásito social *capensis*, un problema exclusivo de África del sur, es la principal causa percibida que podría explicar las diferencias significativas en el número de pérdidas entre los apicultores que utilizan la subespecie *A. m. scutellata* y los que usan la subespecie *A. m. capensis*. En contraste con estudios anteriores en los Estados Unidos, hemos encontrado un efecto de las prácticas de la apicultura migratoria en la magnitud de las pérdidas de colonias. Los apicultores trashumantes perdieron en promedio más colonias 35.5% (IC del 95%: 29.7 a 47.2) que los apicultores estacionarios 17.2% (IC 95%: 11.2-22.3). Esto fue especialmente pronunciado cuando los apicultores estaban migrando para la polinización de manzanas/cerezas, eucalipto, cebolla y/o girasol. Las principales causas de mortalidad percibidas por los apicultores fueron el pequeño escarabajo de la colmena, el ácaro Varroa, la fuga de enjambres (enjambrazón no reproductiva), y la enfermedad ascosferosis. Aquellos que reportaron ascosferosis perdieron significativamente menos colonias que aquellos que no la enumeraron. El mecanismo exacto de esta diferencia no se conoce, y puede estar relacionado con otras prácticas de apicultura relacionadas con las infecciones de ascosferosis encontradas como pueden ser la inspección y el manejo más intensivos.

Keywords: honey bee, migratory, mortality, South Africa, colony losses

Introduction

Over recent decades the decreasing numbers of not only managed honey bee (*Apis mellifera* L.) colonies, but also feral and wild colonies have become a matter of great concern (Moritz *et al.*, 2010; vanEngelsdorp and Meixner, 2010). Honey bees produce not only honey and wax and collect pollen, but they also play a critical role as pollinators of agricultural crops and natural vegetation (Delaplane, 2000; Aizen *et al.*, 2009; Moritz *et al.*, 2010; Potts *et al.*, 2010a). The economic value of honey bee pollination has been estimated to be around €153 billion annually. Considering honey bees' important role as pollinators, it is not surprising that understanding the apparent increased rate of losses, especially overwintering colony losses, has received considerable attention (Gallai *et al.*, 2009; Brodschneider *et al.*, 2010; Currie *et al.*, 2010; Genersch *et al.*, 2010; Topolska *et al.*, 2010; vanEngelsdorp and Meixner, 2010; van der Zee *et al.*, 2012).

Reports of exceptional colony losses are not unusual and there are multiple records of repeated honey bee colony losses (Moritz *et al.*, 2010; vanEngelsdorp and Meixner, 2010) along with evidence of a general decline in pollinators (Potts *et al.*, 2010a; Potts *et al.*, 2010b). Unambiguous identification of the cause/s for the extensive losses of colonies at a national level remains elusive (vanEngelsdorp and Meixner, 2010). Several factors, including pesticides, poor nutrition, beekeeping management practices, pests and diseases, could play a role, both alone and in combination (Neumann and Carreck, 2010; vanEngelsdorp and Meixner, 2010; Di Pasquale *et al.*, 2013).

Research into factors driving the decline shows a geographic bias towards Europe and North America (Archer *et al.*, 2013). In addition, beekeeping is unique in much of Africa (and, in particular, South Africa) because this region represents the only place on earth where large populations of native honey bees still exist in the wild. Africa is thought to have some 310 million honey bee colonies (Dietemann *et al.*, 2009), but only a small proportion are managed by beekeepers (Johannsmeier, 2001; reviewed in Dietemann *et al.*, 2009). The wild population is exposed to all the major honey bee diseases and parasites that plague much of the rest of the world including *Varroa* mites and American foulbrood (reviewed in Human *et al.*, 2011). Moreover, South Africa is the home to two subspecies of honey bees, the Cape honey bee, *A. m. capensis*, and the African or Savannah bee, *A. m. scutellata* (Hepburn and Radloff, 1998). The Cape honey bee is unique in that its workers are thelytokous, that is, they can produce female offspring without mating. Outside of their native range, Cape worker bees parasitise nests of other honey bee subspecies by producing pseudo queens which eventually achieve reproductive dominance and cause the demise of colonies (Neumann and Hepburn, 2002; Neuman and Moritz, 2002; Neumann *et al.*, 2003; Dietemann *et al.*, 2007; Phiancharoen *et al.*, 2010; Zheng *et al.*, 2010). The Savannah honey bee, *Apis mellifera scutellata*, achieved unwanted fame when they were accidentally released into the Americas in the 1950s (Kerr, 2006) and hybridized with bees of European lineages to give rise to what became the "Africanised bees".

South Africa has a well-developed beekeeping industry and infrastructure that includes a strong pollination component. The apiaries have many of the pathogens and pests common to domestic beekeeping, and are based on a large genetically diverse population (Hepburn and Radloff, 1998; Johannsmeier, 2001; Human *et al.*, 2011; Strauss *et al.*, 2013). However, knowledge about colony losses is limited. Therefore, it was the objective of the questionnaires described in this report, to quantify colony losses in South Africa for 2009-2010 and 2010-2011, and to identify potential causes and threats to the local bee population. We report on average and total colony losses for the country by sub-species and we compare losses by operation size and activity (migratory *vs.* non migratory). We also aimed to identify possible reasons for colony losses as self-reported by respondent beekeepers.

Material and methods

Survey

This survey was a survey of convenience with snowballing recruitment and it was based on the standard survey methods (Van Der Zee *et al.*, 2013) modified for the southern hemisphere. Survey questionnaires were published in the local *South African Bee Journal*, on the SABIO (South African Bee Industry Organisation) website and through emails requesting responses sent to beekeeping organisations (all provincial branches and associations, n = 9) as well as to individual beekeepers (n = 40 respondents). The beekeepers were encouraged to forward these questionnaires to other beekeepers. In addition questionnaires were handed out during several association meetings (n = 5) and local conferences (n = 2). Participation was anonymous and on a voluntary basis.

The questions asked included:

1. Do you keep bees as a hobby or profession?
2. How many living colonies did you have on 1 September 2009/2010?
3. How many living colonies did you have on 1 April 2010/2011?
4. Which type of bees did you keep? [Information about the subspecies, *A.m. scutellata* or *A. m. capensis*]
5. Did you migrate with your bees? If yes, to which crops?
6. Did you feed your colonies? [only added to the questionnaire in 2010]
7. Did you practice queen replacement? [only added to the questionnaire in 2010]
8. Did you practice comb replacement? [only added to the questionnaire in 2010]
9. Did you treat against any diseases?
10. Which pests/diseases/parasites did you find in your colonies during the last 12 months?
11. Additional information was requested on other pests/diseases/parasites found in their hives.
12. How many colonies were lost during the last 12 months?

13. In your opinion, which factor(s) was the main cause(s) of colony death in your operation between 1 September (2010) and 1 April the following year (2011)?

For question 10, respondents were given the option to choose between commonly known pests/diseases/parasites (small hive beetles, American and European foulbroods, varroa mites, chalkbrood, wax moth and viruses). Although the average beekeeper does not have the laboratory capacity to identify viruses, some of them sent in samples on their own account and even more acquired the knowledge to identify secondary symptoms. Therefore the reason for including it was to identify apiaries of interest for viruses and bacteria. For question 13, respondents could give their own reasons for colony death and add comments. Although the period in questions 2, 3 & 13 corresponds to northern hemisphere autumn and winter, it actually covers the spring and summer period in the southern hemisphere. Since beekeeping can be practiced throughout the year (Hepburn and Radloff, 1998; Johannsmeier, 2001) we focused on the time window of spring and summer which is the main period of beekeeping and bee activity (Johannsmeier, 2001), including migrating, swarming and absconding, as the period of interest.

Questionnaire responses were collected after the spring/summer period during late winter and the following spring (August to January) each year. The data was entered into a database for analysis using spreadsheet software (Excel Microsoft and Numbers Apple).

Calculations and statistical analysis

For calculations of total and average colony losses the approach and standard outlined by vanEngelsdorp *et al.* (2012, 2013) were used. For the calculations of 95% Confidence Intervals (CI) for total losses, R (R Development Core Team, 2009), code (Y Brostaux and B K Nguyen, *pers. comm.*), was used. In order to determine average loss among all respondents and subgroups, the mean percent loss was calculated of individual operations. The statistical program SAS JMP (SAS, 2007) was used to calculate the average loss and 95% Confidence Intervals (95% CI).

Potential differences between sub-groups (type of bee, type of business, type of crop pollinated or not etc.) of the responding beekeepers were explored by calculating and comparing average operational losses using the Kruskal-Wallis rank sum test (vanEngelsdorp *et al.*, 2010) when assumptions of normality were not met, and student's t test/ANNOVA when assumptions of normality were met (Pirk *et al.*, 2013). These comparisons were made on a data set resulting from combining the response data from both survey years. In case of respondents answering the survey in both years the individual averages were used for the pooled data set. In case of non-significant results only the sample sizes are given. The 95% Confidence Interval is given in parentheses following the total or an average unless stated otherwise.

Results

Average and total losses

Total number of respondents was 47 in 2009 and 48 in 2010, which is around 4% of the SABIO registered beekeepers. However, in 2009, 10 and in 2010, 16 of the 82 registered professional beekeepers (SABIO Chair, *pers. comm.*, 2012) replied to the survey. Beekeepers responding to our 2009 survey reported that they started with 5,034 colonies in September and ended with 3,540 colonies on 1 April. This represents a total loss of 29.6% (95% CI: 22.8-37.5) and an average loss of 20.6% (13.4-27.7). Beekeepers responding to the 2010 survey reported having started with 18,321 colonies and came out of winter with 9,851 colonies. This represents a total loss of 46.2% (37.3-55.0) and an average loss of 28.6% (20.1-37.2). The surveys covered between 5% in 2009 and 18% in 2010 of the estimated 100,000 colonies kept by beekeepers (SABIO Chair, *pers. comm.*, 2012).

Operations managing colonies in more than one province - migratory

Thirty-two percent of respondents from the combined 2-year data set were migratory (n = 30). These beekeepers managed, on average, 639 colonies ± 233.9 (SE) compared to stationary beekeepers who managed fewer colonies 69 ± 21.7 (n = 63). Migratory beekeepers lost, on average, more colonies 35.5% (29.7-47.2) than did stationary beekeepers 17.2% (11.2-22.3).

Colony losses according to the crops and plants pollinated

With respect to crop pollination, 52 of 93 beekeepers indicated that they pollinated at least one crop. Beekeepers who pollinated aloes (Yes, pollinated: n = 8, average = 40.5% (19.0-61.9%); No, did not pollinate: n = 44, average = 27.9% (17.4-28.9%)), avocado/mango/nuts (Yes: n = 3, 43.3% (0-100%); No: n = 49, 29.1% (18.9-30.3%)), canola (Yes: n = 2, 47.5% (0-100%); No: n = 50; 29.9% (18.6-29.7%)), citrus (Yes: n = 4, 38.5% (10.1-66.9%); No: n = 48, 29.2% (18.3-29.8%)), lucerne (Yes: n = 3, 26.6% (0-91%); No: n = 49, 30.1% (18.9-30.3%)), or wildflowers (Yes: n = 45, 27.8% (19.3-36.2%); No: n = 7, 43.5% (14.3-29.3%)) did not have significant more average losses than the beekeepers who did not pollinate these crops (Fig. 1). Note that plants were included that are non-crop plants however, colonies are actively moved to these plants by beekeepers to build up or maintain their colonies.

Beekeepers pollinating apples/cherries (Yes: n = 8, 54.5% (32.7-76.4%); No: n = 44, 21.8% (95% CI 16.3-27.4%); F = 8.32, df 1,50, $p < 0.0058$)), Eucalyptus (Yes: n = 11, 50.7% (29.3-72.0%); No: n = 41, 21.2% (15.3-26.6%); F = 8.86, df 1,50, $p < 0.0045$)), onions (Yes:

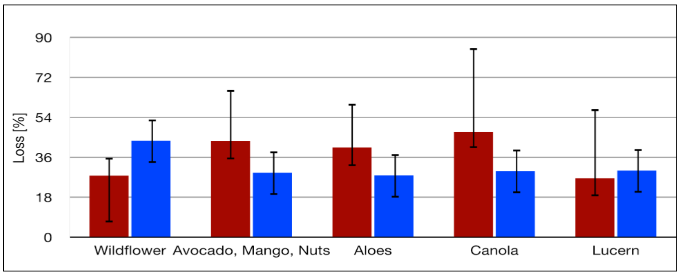

Fig. 1. The comparison of pollinating wildflowers, aloes, avocado/ mango/nuts, canola, or lucerne and the respective losses. Means and 95% CI are shown. For all crops the differences between pollinated (red bar) or not (blue bar) are not significant ($p > 0.05$).

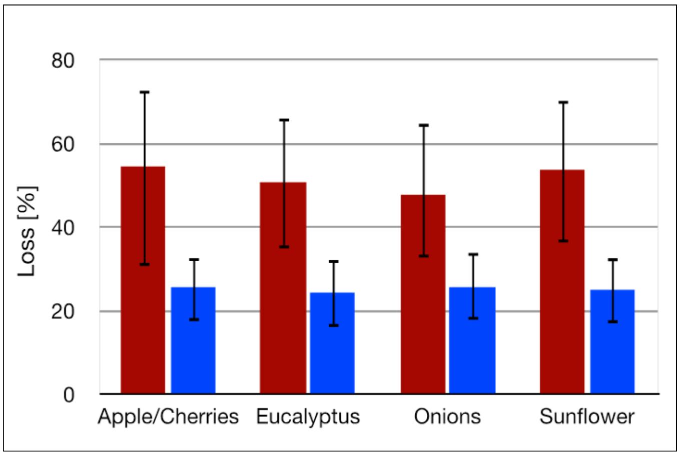

Fig. 2. The comparison of pollinating apples/cherries, eucalyptus, onions, or sunflower and the respective losses. Means and 95% CI are shown. For all crops the differences between pollinated (red bar) or not (blue bar) are significant ($p < 0.05$).

n = 10 47.7% (27.6-67.8%); No: n = 42 25.6% (16.3-27.5%); F = 5.46, df 1,50, p < 0.023)), or sunflowers (Yes: n = 9, 53.7% (29.2-77.5%); No: n = 43, 21.6% (16.2-27.0%); F = 8.8, df 1,50, p < 0.0045)) lost significantly more colonies than the beekeepers not pollinating these crops (Fig. 2).

Losses by race of bees

Beekeepers who used only *A. m. scutellata* colonies managed on average 307 ± 54.9 colonies (n = 58) while those who used only Cape bees kept on average 162 ± 49.1 colonies (n = 34). Beekeepers who maintained only the *A.m. scutellata* subspecies lost more colonies, on average 29.1% (22.1 - 36.2), than those who managed Cape bees 17.9% (8.2-26.6) (p = 0.047).

Table 1. Losses by race and beekeeping management: Sample size (n) and average losses in percentage with 95% CI are shown.

					Kruskal Wallis Rank Sum Test	
Sub species used	**Non-Migratory Ave (95% CI)**	**n**	**Migratory Ave (95% CI)**	**n**	χ^2	**P- Value**
A. m. capensis	15.8 (6.0-25.7)	27	23.4 (4.0-47.8)	7	1.6	n.s.
A. m. scutellata	20.0 (12.0-27.9)	39	42.9 (31.4-54.2)	20	10.9	0.0016

While there was no difference between migratory and stationary beekeepers who used Cape bees, migratory beekeepers who indicated they managed *scutellata* bees lost more than twice the number of colonies than their stationary counterparts (F = 10.95, df 1, 61, p = 0.0016; Table 1).We did not make comparisons between beekeepers that treated against varroa mites and the ones that did not treat because only two beekeepers commented on this and the question was only asked in the 2010 survey. However, in the case of supplementary feeding, those who fed (n = 12) lost significantly more colonies 51.2% (35.8-66.8) than those who did not (n = 36; 21.1% (12.1-30.0) F = 11.15, df = 1,46, p = 0.004). In the case of practicing queen replacement, only 3 beekeepers indicated that they practiced this and their losses (average = 25.7% (0-56.7%)) were not significantly different from the group not practicing queen replacement (did not: n = 45, average = 28.8% (19.9-37.8)). The same is true for practicing comb replacement. The ones who did (n = 17) lost on average 29.1% (14.5-43.6) of their colonies compared to those who did not (n = 31) and who lost 28.4% (17.6-39.2) of their colonies (p = 0.94). Beekeepers who use *A. m. scutellata* bees (n = 58) have problems with *A. m. capensis* worker parasitism and of these only 15 of the 58 indicated that *capensis* bees were a problem. Those indicating that *capensis* is a problem lost 47.3% (44.4-50.4) versus those who did not have a problem with *capensis* 20.6% (19.1-22).

As a response to question 13, the four main causes put forward for the losses were small hive beetles, absconding, varroa mites and chalkbrood disease. Interestingly, for those beekeepers who did not mention chalkbrood as a cause of losses, lost significantly more colonies than their observant counterparts who did identify chalkbrood (Table 2). Whereas the comparison in colonies lost if a perceived cause was identified or not, was not significantly different between the two groups (Table 2).

Table 2. Perceived causes of loss, average colony loss and 95% CI are shown

		Cause Listed		***Cause not Listed****	***Kruskal Wallis Rank Sum Test***	
Cause	**n**	**Avg Loss % (95%CI)**	**n**	**Avg Loss % (95%CI)**	χ^2	**P**
Small hive beetle	68	24.6 (19.6-32.7)	25	19.6 (9.3-29.8)	0.42	n.s.
***Varroa* mites**	31	23.8 (14.5-33.12)	61	24.4 (17.7-31)	0.09	n.s.
Absconding	19	17.8 (6-29.7)	73	29.8 (18.6-30.7)	0.11	n.s.
Chalkbrood	16	22.4 (9.5-35.4)	76	54.4 (52.8-56.0)	37.5	0.0001

Discussion

This first survey of potential causes of colony losses in an African honey bee population reveals that this population is both affected by the same factors as bee populations elsewhere and by Africa-specific ones. The total losses in both years were higher than what is seen as acceptable elsewhere (vanEngelsdorp *et al.*, 2010). However, in the comment section of the questionnaire, none of the participants commented on the fact that the losses were threatening their businesses or were above the acceptable threshold.

The four causes put forward for the losses were small hive beetles, absconding, varroa mites and chalkbrood disease. Small hive beetles and absconding are more southern Africa specific causes, while varroa mites and chalkbrood disease are universal causes of honey bee colony loss (Table 2). Strauss *et al.* (2013) also confirmed the presence of varroa mites in migratory and non-migratory colonies, but they were not implicated as being causative factors for the loss of honey bee colonies. Surprisingly, beekeepers who indicated chalkbrood as a cause of loss, lost significantly fewer colonies than the beekeepers who did not mention it (Table 1). This could be a result of differences in the management practices of those who identified chalkbrood disease or the result of more "intensive care" for the colonies and apiaries after detection of chalkbrood, thereby reducing the overall losses.

The small hive beetle is omnipresent in sub-Saharan Africa (Schmolke, 1974; Neumann and Elzen, 2004), however, it seems that these beetles take over when brood and resources are left behind, for example, after an absconding event (Neumann *et al.*, 2001b). Therefore, its permanent presence could be easily linked to colonies which absconded, but the reasons for absconding are related to disturbance (predation or manipulation) or resource related (Winston *et al.*, 1979; Neumann *et al.*, 2001a; Neumann and Hepburn, 2011) rather than to small hive beetles themselves.

One could speculate that the reason for the observed effect of pollinating cherries/apples, sunflower, onions and eucalyptus are due to the agricultural practice of pesticides usage on these crops, since pesticide usage can affect honey bees (Fiedler, 1987; Long and Morandin, 2011). Although that would have to be verified since other factors might play a role as well, such as reduced attractiveness in case of onions (Soto *et al.*, 2013 and reference therein). However eucalyptus is attractive to bees (Johannsmeier, 2001) and pesticides do not play a major role in this plant, therefore other factors, that have to be verified, such as management practices or the sequence of crops pollinated during migration.

The lower numbers of colonies kept by stationary beekeepers compared to the migratory ones can be easily explained by the inherently larger operations of the professional and migratory beekeepers. However, in contrast to findings in the USA and Europe (vanEngelsdorp *et al.*, 2008; van der Zee, 2010; vanEngelsdorp *et al.*, 2010; vanEngelsdorp and Meixner, 2010; vanEngelsdorp *et al.*, 2011; Dainat *et al.*, 2012; van der Zee *et al.*, 2012) the migratory beekeepers suffered significantly more losses than their stationary counterparts (Table 1). Nevertheless, this difference was only significant for beekeepers using *A. m. scutellata*, but not *A. m. capensis*, in their operations. Indeed one of the ongoing threats to beekeeping in the northern parts of South Africa is still the parasitic *capensis* clone workers (Hepburn and Allsopp, 1994; Baudry *et al.*, 2004; Dietemann *et al.*, 2009), which are able to invade and take over the reproduction in *A. m. scutellata* host colonies after which the host colony slowly dwindles (Neumann and Hepburn, 2002; Neumann and Moritz, 2002). It seems that this parasite relies on human facilitated transmission (Dietemann *et al.*, 2006) that would explain why the migratory beekeepers using *A. m. scutellata* experience higher losses than migratory beekeepers using *A. m. capensis* in their operation (Table 1). The persistence of the social parasite over almost two decades (Hepburn and Allsopp, 1994) and the reproductive dominance compared to other subspecies and pre-adaptations to be a social parasite (Ruttner and Hesse, 1981; Verma and Ruttner, 1983; Jarosch *et al.*, 2011; Moritz *et al.*, 2011; Pirk *et al.*, 2012) makes the Cape honey bee a threat to any subspecies if introduced to their native range.

Although this survey represents 4% of all registered beekeepers in South Africa, it is representative of nearly 20% of the professional beekeepers in the country making it the first robust survey regarding colony losses. It highlights the problems, which are experienced, and provides the first empirical and systematical basis for comparisons in the future. One aim is to improve the return rate and thereby cover more of the beekeepers and their colonies in South Africa. One result of the survey is that the level of losses that are experienced in South Africa are higher than the international average, suggesting that a threshold might soon be reached, where beekeeping might become unsustainable and therefore threating to the bee industry in South Africa. However this will be only conclusively answered by the subsequent surveys and a constant re-evaluation of the present situation.

This study provides the first information regarding the extent, and probable causes of colony losses in South Africa setting a baseline for future studies. Although the diseases and parasites that are present in South African colonies are the same as those found elsewhere, the impact of these on colony health appears to be less threatening. A cause of colony loss that is unique to South Africa, is that occasioned by the presence of the *capensis* worker social parasites which infect *scutellata* colonies and impact most heavily on migratory beekeepers. In contrast to the numerous studies in the northern hemisphere that found none, weak and positive effects, (vanEngelsdorp *et al.*, 2008; Aston, 2010; Brodschneider *et al.*, 2010; Currie *et al.*, 2010; Nguyen *et al.*, 2010; van der Zee *et al.*, 2012), we found that colony losses of migrating beekeepers were significantly increased both as a consequence of the *capensis* social parasites and the tendency of southern African colonies to abscond when disturbed (Hepburn and Radloff, 1998; Hepburn *et al.*, 1999; Neumann and Hepburn, 2011).

Although these southern hemisphere colony losses are higher when compared with their northern hemisphere counterparts, nevertheless none of the respondents mentioned that the losses were threatening their businesses. The high losses, which appear to be acceptable to beekeepers, may be a result of the apicultural techniques used in South Africa, where colony numbers are increased by catching wild swarms rather than by breeding queens (reviewed in Hepburn and Radloff, 1998; Johannsmeier, 2001; Dietemann *et al.*, 2009). The observed high losses and the methods used to compensate for those losses may not be sustainable over time.

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