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Beehive fences as effective deterrents for crop-raiding elephants: field trials in northern Kenya

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Abstract

Increasing elephant populations in Kenya since 1989 have been widely praised as a conservation success story. However, where elephants and agricultural land overlap, incidents of human–elephant conflict are on the increase. Wildlife managers and farmers are now trying different farm-based deterrents to keep elephants out of crops. Here, we present data on the effectiveness of a novel beehive fence deployed in a Turkana community of 62 communally run farms in Kenya. Specifically, 1700 m of beehive fences semi-surrounded the outer boundaries of seventeen farms, and we compared elephant farm invasion events with these and to seventeen neighbouring farms whose boundaries were 'protected' only by thorn bush barriers. We present data from 45 farm invasions, or attempted invasions, recorded over 2 years. Thirteen groups of elephants approached the beehive fences and turned away. Of the 32 successful farm invasions, only one bull elephant broke through the beehive fences. These results demonstrate that beehive fences are more effective than thorn bush barriers at deterring elephants and may have a role to play in alleviating farmer–elephant conflict. Additionally, the harvesting of 106 kg of honey during the trial period suggests that beehive fences may also improve crop production and enhance rural livelihoods through honey sales.

Key words: African elephants, beehive fences, beekeeping, crop-raiding, farm-based deterrents, human–elephant conflict

Résumé

L'accroissement des populations d'éléphants au Kenya depuis 1989 a été largement salué comme une victoire de la conservation. Cependant, là où éléphants et terrains agricoles se rencontrent, les incidences de conflits hommes-éléphants sont de plus en plus nombreuses. Les gestionnaires de faune et les exploitants agricoles essaient aujourd'hui différents moyens dissuasifs pour garder les éléphants loin des cultures. Nous présentons ici les données sur l'efficacité d'une clôture originale intégrant des ruches déployée dans une communauté turkana comptant 62 exploitations gérées collectivement au Kenya. Très précisément, 1 700 mètres de clôtures avec ruches entouraient à moitié les limites extérieures de 17 exploitations, et nous avons comparé les incidences totales d'invasions par les éléphants par rapport à ces dernières et aussi à 17 exploitations voisines qui ne sont protégées que par des barrières de buissons épineux. Nous présentons des données portant sur 45 invasions, réelles ou tentées, enregistrées en deux ans. Treize groupes d'éléphants se sont approchés des barrières avec ruches et se sont éloignés. Sur les 32 invasions réussies, seul un mâle a traversé les barrières avec les ruches. Ces résultats montrent que ces clôtures sont plus efficaces que celles qui sont composées de buissons épineux pour dissuader les éléphants et qu'elles ont donc un rôle à jouer pour réduire les conflits entre exploitants agricoles et éléphants. De plus, la récolte de 106 kilos de miel pendant la période d'essai suggère que les clôtures avec ruches pourraient aussi augmenter la production des cultures et améliorer les moyens de subsistance ruraux grâce à la vente de miel.

Introduction

Conflict between farmers and elephants *Loxodonta africana africana* in Africa is becoming a notoriously complex problem to solve (Newmark *et al.*, 1994; Hoare, 2000; Balfour *et al.*, 2007). Both are competing for finite land and water resources (Sitati, 2003; Okello, 2005) in a

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continent going through unprecedented human population growth. In Kenya, the government is keen to protect all wildlife as a national asset that also attracts much needed foreign exchange through tourism activities (Okello, Wishitemi & Lagat, 2005). However, there is intense media interest and political pressure to tackle the issue of human–elephant conflict (HEC) (Adams & Hulme, 2001; Omondi, Bitok & Kagiri, 2004; Balfour *et al.*, 2007).

Electric fences have proved to be successful in barring elephants from some human-designated areas (Hoare, 2003; Kioko *et al.*, 2008), but in Kenya, electrification projects have often failed because of poor maintenance, spiralling costs and/or a lack of community buy in (Thouless & Sakwa, 1995; Thouless, Georgiadis & Olwero, 2002; Okello & D'Amour, 2008). Much attention has been focused recently on the effectiveness of different farmer-based deterrents such as the use of buffer zones, fire crackers, dogs, watch towers or drums (Hoare, 1995; Osborn & Parker, 2003; Sitati & Walpole, 2006; Graham & Ochieng, 2008). Concentrated chilli extract burnt in dung brickets, sprayed or pasted onto string fences has also been tested as an elephant deterrent (Osborn, 2002; Sitati & Walpole, 2006). There has been considerable variation in the success and failure of these different mitigation methods across Kenya, and most HEC studies described here support each other by concluding that there is no one perfect deterrent, rather it is healthy to train and equip farmers with a 'toolbox' of various deterrents that, either combined or rotated, may have a greater effect than relying on any one method alone (Walpole *et al.*, 2006; Hedges & Gunaryadi, 2009).

In this toolbox of deterrents, the African honey bee *Apis mellifera scutellata* could well be an important, and novel, component. First, it was shown that elephants avoid feeding on acacia trees with beehives (Vollrath & Douglas-Hamilton, 2002). This was followed by behavioural experiments demonstrating that not only do elephants run from bee sounds (King, Douglas-Hamilton & Vollrath, 2007) but also that elephants have an alarm 'call' that alerts family members to retreat from a possible bee threat (King *et al.*, 2010). A pilot study using a beehive fence was found to be an effective elephant deterrent (King *et al.*, 2009), but the scope of the study was small and the beehives remained empty during the trial. The concept of applying elephants' natural bee avoidance behaviour to benefit rural farmers is an attractive one, not only could farmers benefit from reduced crop-raiding but such beehives could offer an additional income through the sale of honey and wax products.

Although a beehive does not 'sleep' at night, individual bees are less active as they can rest for several hours (Kaiser, 1988) and will spend time cleaning the hive and feeding the brood, behaviour also seen during cold days (Hooper, 1997). Although such bee behaviour could be a limiting factor in the use of a beehive fence, as most elephant crop-raids occur at night, most elephant–man interfaces in Kenya tend not to be in cold/high-altitude zones. Additionally, there is a constant buzzing sound of bees fanning their wings from fully occupied *A.m. scutellata* hives, which may give elephants enough warning to stay away (King, Douglas-Hamilton & Vollrath, 2007). Furthermore, species of both Asian and African bees, *Apis dorsata* and *A. m. adansonii*, have been observed foraging successfully on moonlit nights (Fletcher, 1978; Dyer, 1985).

Here, we present evidence that beehive fences have a role to play as a novel farmer-managed elephant deterrent. Our data come from a 2-year participatory study (King, 2010) involving a Turkana community of 62 farms in northern Kenya.

Materials and methods

The farm-based trials were conducted in two small Turkana farming communities that have built up within the elephants' range over the last 40 years (King, 2010). The communities are located 2 kms apart, within the greater Ngare Mara community, Meru North District in Northern Kenya (N 0.44529 : E 37.67353). Both communities have chosen to practice communal farming on either side of a rocky plateau on the lower flattened banks of two rivers that are less rocky and more suitable for agriculture.

The settlement neighbours three unfenced reserves, and communal farming strengthens the farmers' ability to protect the crops from wild animals. Elephants in particular migrate between Shaba, Samburu and Buffalo Springs National Reserves and Meru National Park to the south (Douglas-Hamilton, Krink & Vollrath, 2005). Save the Elephants (STE) has recorded approximately 1200 elephants that use the three neighbouring northern game reserves, but the number of elephants utilizing the Ngare Mara area is unknown. Before our study, the area was identified by STE's Monitoring of Illegal Killing of Elephants program (MIKE) as a hot spot for illegal killing of elephants (Douglas-Hamilton, Wittemyer & Ihwagi, 2010). Between

2002 and 2006, and prior to these beehive fence trials, nine illegally killed elephants were classified as 'poached' within an 8-km radius around this farming study site.

Multiple participatory community meetings were used to identify the layout of 62 farms and houses in the area. Each farm boundary and their positions were recorded and the GPS data uploaded into ARC GIS 9.2 (ESRI, Redlands, CA, U.S.A.) to create an accurate map. Using these maps, and participation from a focal group of ten men and nine women farmers, we identified the general routes most dominantly used by crop-raiding elephants. These historical routes revealed elephants coming to both rivers to drink and then walking up the opposite banks into the farms to crop-raid (Fig. 1). Although we could not verify this anecdotal evidence prior to the study's commencement, this local knowledge helped us select all 34 farms that were 'on the front line' of these historical elephant raids. Beehive fences were constructed along 50% of the 34 most raided front line farms leaving the remaining 50% as control farms protected only by traditional thorn bush barriers. Each farm varied in size and therefore comparable lengths of farm boundaries were used to select bee (n = 17) and control (n = 17) farms rather than a purely random design (Fig. 1).

The beehive fences were constructed on the template of an earlier pilot design (King *et al.*, 2009) but improved to include the more productive Kenyan top-bar hives (KTBH). Additional improvements came in the invention of a simpler, flat-thatched roofing system designed by a group of participating farmers during the construction phase (see Fig. 2). Three 80-cm-long beehives were constructed out of each 2.4 × 1.8 m, 9-mm industrial plywood sheet. The design of the KTBH hive (adapted from Jones, 1999) incorporates a queen excluder to keep the brood separate from the honey chamber, and this increases both the ease of harvesting and the value of the honey. Of these, 149

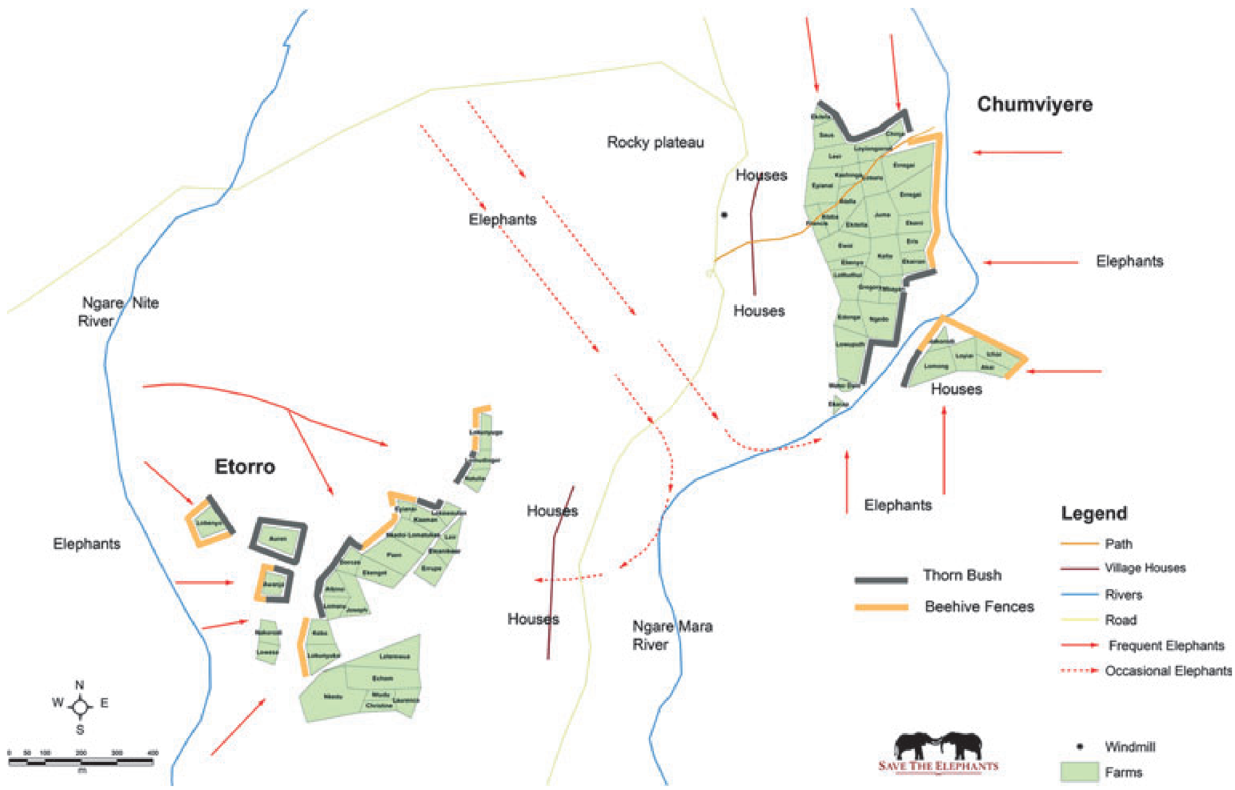

Fig 1 Map of the two focal farming communities Chumviyere and Etorro lying between the Ngare Mara and the Ngare Nite Rivers. All 62 farms in the two study farming communities were mapped with common routes used by crop-raiding elephants marked on as red arrows. Beehive fences were built along the boundaries of seventeen farms, and a further seventeen farms were classified as control farms where thorn bush barriers were left as the only defence between elephants and the field of crops

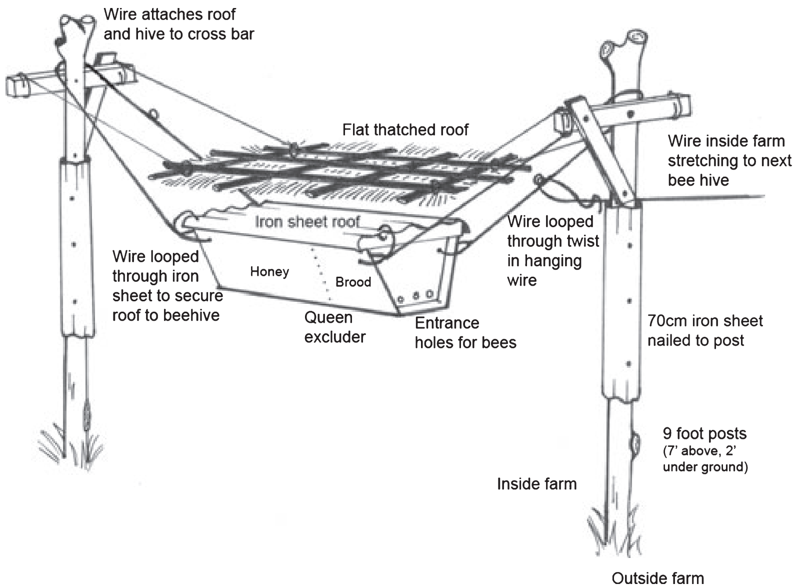

Fig 2 Beehut design – the key element of the beehive fence. The beehive fence is comprised of two elements, the 'beehut', as seen in the diagram, and the connecting wire linking one beehive to the next with a gap of 7 m between the post of one beehut and the next. The beehut houses an 80-cm-long Kenyan top-bar hive covered by a rainproof roof made from a cheap corrugated iron sheet and is protected from the sun by a flat-thatched roof. The roof is hung by thin binding wire, too thin for honey badgers to crawl down should they succeed in bridging the protective 70-cm iron sheets nailed to the posts. The nine foot posts must be coated in an oil-based insecticide to prevent termites. The hive is hung by drilling small holes in the side walls of the hive and feeding through stronger plain wire. This is looped easily around the top of the upright posts and once through the hive, the ends can be secured to the roof by drilling a small nail-size hole in the iron roof to prevent wind blowing away the roof. A simple twist of the hive's hanging wire on the farm side of the beehut enables a strong piece of plain wire to attach one beehive to the next beehive 10 m away. Should an elephant attempt to enter the farm, he will instinctively try to pass between the beehuts, and as the wire stretches, the pressure on the beehives will cause them to swing erratically and, if occupied, release the bees. The wire is only looped through the hoop, not twisted tightly back onto itself, so that excessive pressure from an elephant will release the wire rather than pulling down the hive

beehives were constructed on site and deployed between June and August 2008 and the remaining 21 in April 2009 at a cost of US$22 per hive. Relying on data from a previous pilot study where elephants would not walk closer than four metres to a beehive (King *et al.*, 2009), the beehive fences were built with one beehive to every 10 m. This resulted in 1700 m of beehive fences incorporating 170 beehives, around the boundaries of seventeen community farms, leaving any thorn barriers in place behind the beehive fences. A further 1700 m of farm boundaries were allocated as 'control' farms where just the thorn bush barriers were left in place along the seventeen farms. Two long stretches of farm land boundaries at the rear of the communal farm areas were not included as 'controls' because of this section was populated with houses and therefore identified by the community as an area too risky for elephants to traverse. All farms planted maize, often intercropped with beans, and they all relied entirely on natural rainfall.

Six farmers from both communities were trained to fill in simple data sheets detailing each farm and fence layout allowing the monitors to simply draw the movements of any elephants approaching or entering with details such as the time, date and number of elephants. These farmers worked on the farms daily and periodically walked around or slept near the farms at night during the crop-growing season. However, we could not measure guarding effort with any accuracy. Each farmer was given a personal beekeeping training session to help them manage their section of the beehive fence.

All farms were monitored over successive crop-growing seasons in an attempt to identify any variability there may be in seasonal differences in elephant behaviour. A farm invasion was defined as an elephant, or a group of elephants, crossing a barrier (either bee or thorn) to enter a farm and later exiting either through this or through another barrier. If those same elephants chose to re-enter a second farm across a separate barrier, that second attempt was recorded as a second invasion. Elephants crossing into different farms within the communal area were not counted as separate farm invasions because of there being no internal barriers between the communal farming plots. Elephants that approached a barrier and turned away was a separate event, classified as 'prevented from entering

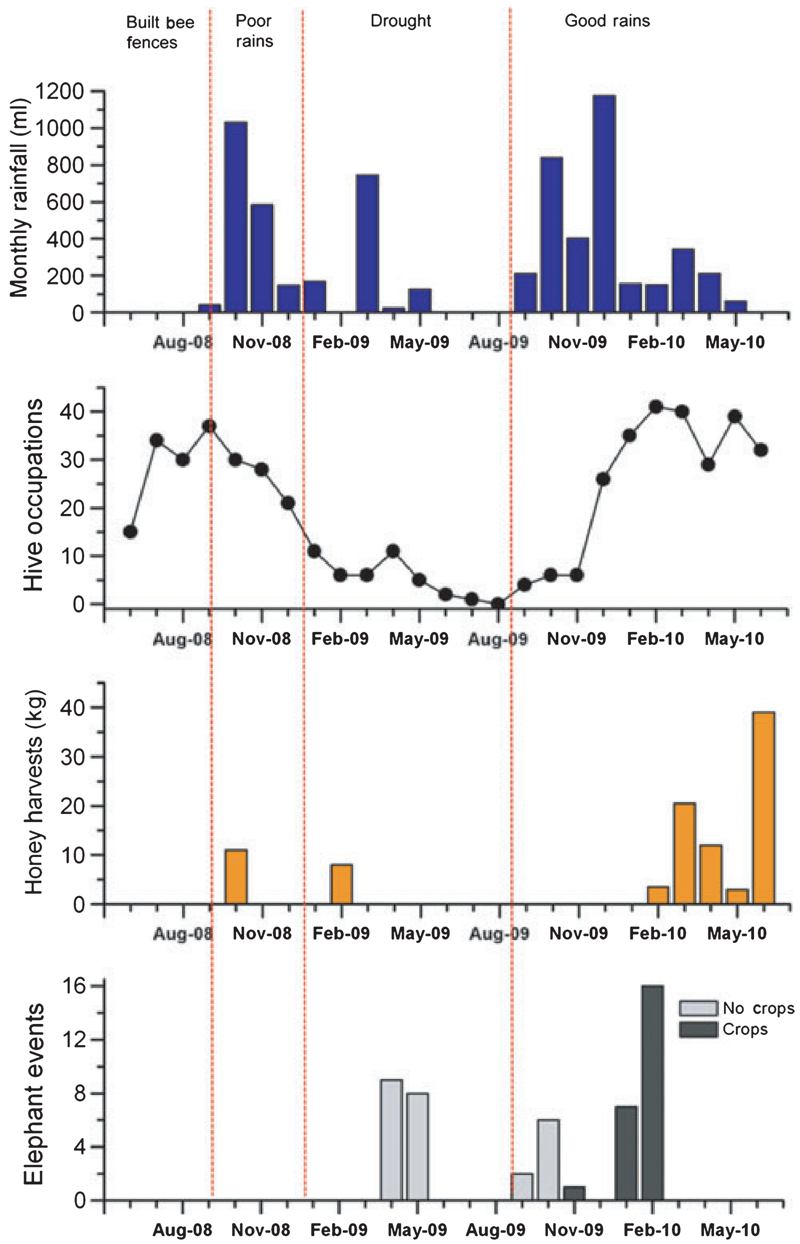

Fig 3 Over 2 years, we observed that hive occupations closely followed rainfall patterns with peak occupations occurring during peak rainfall months. Honey harvests were poor during the first year and half of the project, but as occupations and rainfall increased, so did successful honey harvesting. Elephant events occurred mainly during harvest periods when rainfall resulted in successful crop growth. It was noticeable that elephants started to appear in the community at the same time that hive occupations were peaking

farm', even if those elephants were then to walk around and enter another farm at a different location on the same night.

We visited the study site once a week to help with fence maintenance and collect data on elephant raids, rainfall, maize growth, hive occupations and honey-harvesting events. Planting dates for each of the 34 front line farms were collected each season, and weekly maize growth rates were recorded in each farm by selecting three random maize stalks and taking an average of the three, which gave enough of an indicator of the condition of each farm over the passing weeks. This allowed us to test whether crop-raiding behaviour was biased towards riper fields. Rainfall was measured in millilitres by one farmer using a simple home-made rain gauge constructed from an inverted soda bottle. Although basic, this was an accurate enough intensity indicator of rainfall events. Data were analysed using Genstat v.11.2 (VSN International, Hemel Hempstead, U.K.) using nonparametric statistics.

Results

To identify seasonal variation in elephant-raiding behaviour, 34 farms were monitored over three crop seasons from June 2008 until June 2010. However, a harsh drought occurred in northern Kenya during most of the first year of the study period severely curtailing crop growth. Additionally, fatal tribal conflicts between our Turkana community and the neighbouring Borana tribe resulted in several farmers migrating during the trials and a consequent variation in planting success. Thus, the first crop season (October 2008–January 2009) saw only 18 days of light rainfall leading to failure of the harvest in 83% of the farms (Fig. 3). The second crop season (March–May 2009) had only 7 days of rain resulting in failure of the harvest in 100% of the farms. Finally, the third crop season (September 2009–February 2010) had 34 days of rain spread over 5 months resulting in a successful harvest of crops in 50% of the farms, all in Chumviyere. Of the remaining farms, 38% failed to plant and 12% planted but the crops failed. Increases in beehive occupancy rates were closely associated with successful rainfall events, with poor occupancy occurring during the drought months of 2009, but high occupancy during the end of 2009 and early 2010 resulted in healthy honey harvests (Fig. 3).

Elephants visited the community between 29 April 2009 and 15 February 2010 when 45 elephant farm invasion attempts were recorded. Twenty-four farm events were recorded where elephants entered, or attempted to enter, and farms without crops (over a 259-day period) and 21 farm invasion attempts were recorded where crops were present (over an 82-day period) (Fig. 3).

We observed 32 events where elephant approached and were successful at invading the farms. Of these 32 invasions, 31 entries occurred through the thorn bush barriers, which was significantly different to the number of entries, n = 1, that occurred through the beehive fences (n = 31 (Thorn) vs n = 1 (Bee); $\chi^2 = 28.125$, df 1, $P < 0.001$; Table 1). In that case, an elephant, identified by the farmer as a bull, pushed through the wire connecting the hives thus avoiding the beehive huts. His family did not follow allowing the farmer to chase the bull back out. Both beehives on either side of the entry point were unoccupied at the time.

We observed thirteen attempted farm invasions where the elephants approached the beehive fences but did not push through. During eight of these thirteen events, the elephants (recorded by their footprints) walked alongside the length of the beehive fence structure, often approaching the wire within a metre or two and then backing away. However, in five events, the elephants walked along the

Table 1 Comparing the effectiveness of beehive fences to thorn barriers in farm invasions and exits by elephants

Elephant behaviour	Farm condition	Thorn bush barrier	Beehive fence barrier
Prevented from entering farm	No crops	0	8
	Crops	0	5
Entered farm	No crops	16	0
	Crops	15	1
Exited farm	No crops	14	2
	Crops	12	4

Analysis of 45 successful farm invasions showed that 31 invasions occurred through thorn barriers and only one through a beehive fence. A further thirteen attempts to enter a farm were deterred by the beehive fences, but in five of these cases, the elephants walked along the entire line of the beehive fence before breaking through a thorn bush barrier. Elephants exiting a farm after a crop-raid, or chased out by farmers, were more likely to exit through the thorn bush than the beehive fences. However, there were more observations of elephants exiting through the beehive fences than when entering a farm suggesting that elephants do not necessarily get trapped inside a protected farm by a beehive fence. Elephant behaviour and deterrent effects of the barriers were similar for elephants entering farms with or without crops.

entire length of the beehive fences until they came to the end of the line where they broke through the thorn barriers to invade a farm. At no point did we record elephants approaching the thorn bush barriers and turn away, every approach to the thorn bush barriers resulted in a successful entry to the farm. This result supports previous studies that thorn barriers are often ineffective barriers for elephants (Sitati, Walpole & Leader-Williams, 2005).

To further examine the effectiveness of the beehive fences, we analysed five successful crop-raids that occurred within the first 10 days of February 2010, the peak ripening time for maize in Chumviyere. In all five cases, the elephants broke into the farms at either end of Chumviyere's 360-m beehive fence. We found no difference in mean maize height between the five neighbouring farms protected by the beehive fence (n = 5, mean height 229 cm ± SD 40.7) and the four control farms invaded at each end of the line of the beehive fence (n = 4, mean maize height 251.7 ± SD 25.9; Mann–Whitney *U*-test, $U = 18.5$, $P = 0.647$). This strongly suggests that invasions were not because of differences in crop attraction but because of differences in protection status.

Furthermore, in the 32 successful invasions, elephants also left a farm, both with crops and without, significantly more often through the thorn bush rather than through the beehive fences (n = 26 and n = 6, respectively; $\chi^2 = 12.5$, df 1, $P < 0.001$; Table 1). Indeed, in nine events, elephants already inside a farm walked along the inside of the beehive fences until reaching the thorn bush barriers where they pushed through to exit the farm. Nevertheless, in six events, elephants did run through a beehive fence when chased out by a farmer (Table 1). Of these six escapes, two occurred between beehuts where the wire had been removed by the farmer, three exits resulted in the wire detaching (as designed) and only once did the wire not detach effectively, and the occupied beehive was brought down. This beehive was successfully harvested by the famer producing 8 kg of honey before it was repaired and rehung.

While the beehive fences protected the farms quite effectively, they also added to the productivity of a farm. Of the 150 beehives initially deployed around the community farms, 82 (55%) were occupied at least once between June 2008 and June 2010. A further 21 beehives deployed in early April 2009 had sixteen occupations (76%) up until the end of monitoring in June 2010 (Fig. 3).

During year one, we lost the honey from 38 occupied hives to suspected attacks by honey badgers *Mellivora capensis* over a matter of a few weeks. In response, we extended the protective iron sheets from 50 to 70 cm and since that design improvement, we only lost seven occupied hives to attacks by honey badgers. Additionally, we lost the honey from fourteen hives to suspected theft, but no beehives were stolen during the 2-year period.

Forty-four of the 98 occupied beehives were occupied more than once with some hives being occupied-abandoned-occupied as often as four times. Total occupation events within the 98 beehives were 169 revealing that previously occupied hives are more likely to attract a swarm. We observed that coating the beehives with a polyeurethrene-based varnish not only attracted scouting bees but also helped protect the plywood hives from weathering. Owing to high mortality rate of bees and comb from both the drought and from honey badger attacks, only 23 beehives were successfully harvested during the trial period. Nevertheless, the total weight of 'elephant-friendly honey' was 106 kg with an average of 4.6 kg per hive (range from 2 to 15 kg) at an estimated local value of US$290.

Discussion

Here, we present evidence that beehive fences can be a useful tool for deterring elephants from entering farm land. Analysis of 32 successful crop-raids demonstrated that elephants only once broke through the beehive fences to gain access to the crops within and that traditional thorn barriers offer no defence at all against such invasions. We recorded thirteen attempts to enter where the elephants turned away and either left the area after confronting the beehive fences or walked the length of the beehive fence to choose an easier entry point through the thorn bush. Additionally, elephants avoided the beehive fence boundaries when attempting to leave the farms after crop-raiding but if chased, an elephant could break through the wire to escape.

Recorded elephant avoidance behaviour occurred consistently along the beehive fences and in all cases, occupancy of the beehives could be regarded as low with just one or two hives occupied along the line. Despite low occupancy, the beehive fence as a novel, swaying, complex barrier appeared to successfully deter approaching elephants over a core study period of 10 months. As more approaches were made directly towards the thorn bush barriers (n = 31) than to the beehive fences (n = 13), it is possible that the elephants could either (i) see the beehive fence swinging in the breeze as they approached from a distance or (ii) recognized the shape of the beehives and chose to re-orientate their approach to avoid the bees because of an expectation of a negative encounter.

More research is needed to understand how occupancy rates by live bees affect this decision-making process for elephants. As a result of the design of the beehive fence connecting the freely swinging beehives to each other with wire, the movement of one beehive actually causes up to three beehives on either side to swing. Is this physical, moving barrier alone enough of a deterrent? Does the occupancy of bees anywhere along the fence line increase the deterrent effect compared with completely unoccupied stretches of fence? If the physical barrier itself *is* the key deterrent factor, would hanging two 'dummy' beehives on the fence for every real beehive reduce the cost of construction and spread out valuable hive occupations? Study over multiple harvest seasons is needed to identify a balance between the success of the physical moving beehive fence barrier and the number of beehives that actually *need* to be occupied to prevent elephants habituating to the barrier.

Additionally, there might be a saturation point in the number of beehives that can realistically be occupied in a certain area. One could hazard a prediction that the saturation point (if there is one) would be lower in the dryer semi-arid areas of Kenya where wild flowers and nectar abundance are more seasonal and droughts are more common. Saturation points might also be avoided by deploying some dummy beehives. Furthermore, what happens should every farmer in a community build a beehive fence? Would elephants simply walk around the farms and continue on their natural migration or would they become bolder and start to break through the fence where stretches of the hives remained unoccupied by bees?

The improved design of the beehive fence structure from previous trials (King *et al.*, 2009) did prove effective, and maintenance was easier using the simplified flat-thatched roof. Kenyan top-bar hives improved the quality of the honey harvested from the hives as the honey was pure (without brood) and attracted a good price at the local market. Farmers were quick to repair the damaged beehive fence from an exiting elephant, as they clearly understood the real and potential financial value that came from maintaining the fence. Although occupancy here was on the low side, the hope of any honey from the hives plus the protection from crop-raids appeared to be a real maintenance incentive for the farmers.

Despite the need for more specific research, the positive outcome of this study strongly supports the inclusion of beehive fences into the present toolbox of elephant deterrents to be trialed on a larger scale. Not only can such fences deter a significant proportion of crop-raids, but bees provide farmers with honey and other products for sale, which helps to diversify income. If combined with other partially effective deterrents, such as the use of guarding, dogs, drum beating or lights (Sitati, Walpole & Leader-Williams, 2005), or should chilli soaked grease be spread on the interlinking wires (Osborn, 2002), the combination of farmer-managed activities could create a successful elephant barrier that would be efficient, effective and be paying for itself over and above the rewards in arable products.

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