Fall 12-21-2018

The Effects of Tactile and Visual Deterrents on Honey Badger Predation of Beehives

Abigail S. Johnson

The Effects of Tactile and Visual Deterrents on Honey Badger Predation of Beehives

By

Abigail Johnson

Submitted in partial fulfillment
of the requirements for the degree of
Master of Arts Animal Behavior and Conservation, Hunter College
The City University of New York

2018

Thesis Sponsor:

12/20/2018	Dr. Jessica Rothman
Date	Thesis Advisor
12/20/2018	Dr. Lucy King
Date	Second Reader

Acknowledgements

I would first like to thank my thesis advisor and mentor, Dr. Jessica Rothman at Hunter College. Dr. Rothman has always led by example in life and in science. I am gratefully indebted to her for her valuable comments on this thesis. Additionally, I would like to acknowledge Dr. Liv Baker Van de Graaff at Hunter College for her input on this thesis.

I would also like to thank my second reader, Dr. Lucy King, for allowing me to join her merry band of researchers at the base of Sagalla Hill. She has created a haven were many young scientists have developed, including myself. The Elephants and Bees Research team, Esther Serem, George Troup, Gloria Mugo, Kennedy Leneuyia**,** Luca Guadagno, Lydia Tiller and Naiya Raja, have pushed me to be a better human being and scientist. Thank you for being a continuous source of inspiration.

I would be remised if I didn't thank the real experts in deterring honey badgers, Emmanuel Mwambingu and Hesron Nzumu and all the farmers of Sagalla. Without their acceptance and input, this study wouldn't have been possible. And I thank the Government of Kenya and Kenya Wildlife Service for permission to conduct this research in Kenya.

I am grateful for my core funding from Hunter College, Idea Wild, Animal Behavior Society, and the Sophie Danforth Conservation Biology Fund at Roger Willams Park Zoo which enabled me to conduct my research as a part of the Animal Behavior and Conservation Concentration in the Department of Psychology at Hunter College.

Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of writing this thesis. The creativity, design and problem-solving attributes of this study were a result of my artistic upbringing. This accomplishment would not have been possible without them. And to my brother for his reassurance and for setting such a high standard to follow, thank you. I am truly privileged to have such a supportive community surrounding me.

Table of Contents:

List of Figures:

List of Tables:

Abstract

As human and elephant populations grow in Kenya so does human-elephant conflict. One of the most substantial contributors to this conflict, the crop-raiding behavior of elephants (*Loxodonta africana*), is alleviated through the use of The Elephants and Bee Project's beehive fences. A threat to these beehives are the honey badgers (*Mellivora capensis*) who try to obtain honey, causing damage to the hive and the colony to abscond. The objective of this study was to improve the effectiveness of these beehive fences through identifying and testing novel honey badger deterrent methods. On-farm experiments in Taita Taveta County, Kenya were conducted to determine if visual and tactile deterrents could reduce the frequency and severity of honey badger hive predation of the hives compared to a previously used method. Prior to the start of the study, 77.1% percent of hives absconded within a week following a honey badger attack. After the addition of the novel deterrents (motion activated light deterrent, cone baffle, and hive cage deterrent), only 11.1% percent of the hives attacked by honey badgers absconded, suggesting the deterrents effectively reduced the amount of successful honey badger attacks. No relationship was found between deterrent type and amount of damage, nor for the duration and deterrent type. All deterrent methods effectively prevented honey badgers from raiding hives with variance in the success rates and economic feasibility. This project complemented the Elephants and Bee Project's ongoing research by providing much-needed insight into the role honey badger deterrents could play in preventing damage to the elephant deterring beehive fences. This research purposes deterrent recommendations based on cost effectiveness and ability to reduce honey badger raiding. These deterrents not only reduce honey badger hive raiding but also to improve human-honey badger coexistence as well as human-elephant coexistence.

Keywords: honey badger, deterrents, elephant, human-wildlife conflict

Chapter 1: Introduction

1.1 Modern Day Human-Elephant Conflicts

As humans encroach on wildlife resources, human-elephant conflict has increasingly become a major conservation challenge (Tchamba, 1996; Smith & Kasiki, 2000). Human-elephant conflict often involves damage to crops and property through elephant crop-raiding. Crop raiding is the destruction of agricultural plots, through consumption or trampling which is resulting in a major struggle between the farmers and the elephants (Mackenzie & Ahabyona 2012). Elephant crop-raiding is often problematic for farmers due to the severity of damage to farms rather than its frequency (Hoffmeier-Karimi & Schulte 2015). When assessing a wide variety of crop-raiding species in Western Africa on the frequency and severity of crop-raiding damage, the majority of participants reported that elephants damaged their crops (84%) and soil (71%) (Harich et al., 2013). Elephant crop-raiding is especially severe for farmers living adjacent to protected areas where elephant movement and populations are increased. These farmers consider elephants to be one of the most substantial causes of crop damage (Hoare 2015; Megaze et al. 2017). One such area in Taita Taveta County, Kenya, the Tsavo-Mkomazi ecosystem has experienced a 14.7% elephant populations increase between 2014 and 2017 alone (Ngene et al. 2017). Elephant population growth and greater agricultural activity have increased the frequency of elephant crop-raiding in the Sagalla hills region of Taita Taveta County, Kenya (Weinmann, 2018). The Wasaghala people of Lower Sagalla have farmed under these conditions for only a few decades (i.e. 1990 to 2018), and therefore lack the expertise and resources necessary to address the increasingly problematic elephant crop-raiding (Weinmann, 2018).

To address these knowledge gaps, an NGO called Save the Elephants (STE) is coupling a knowledge of wildlife ecology with cultural traditions to develop human-elephant conflict mitigation strategies. Since 2009, STE's Elephants and Bees Project (EBP) has constructed beehive fences to prevent crop-raiding in the rural communities of the Sagalla Hills in Taita Taveta County (King et al., 2017). Surrounding an agricultural plot, a beehive fence consists of beehives suspended between posts, and connected by wire. These fences utilize elephants' natural avoidance of honeybees (King et al., 2007) to deter them from consuming crops (King et al. 2009; King et al. 2011; King et al., 2017). The beehive fences are a non-lethal method of protecting crop fields, while also providing a source of income for the host farmers through the production of honey (King et al. 2011; King et al., 2017). The beehive fence is comprised of two elements, individual beehive units, and the connecting wire linking one beehive to the next with a gap of 7 m between the post of one beehive and the next. Should an elephant attempt to enter the farm, he will instinctively try to pass between the beehives, and as the wire stretches, the pressure on the beehives will cause them to swing erratically and, if occupied, release the bees (King et al., 2011, Fig. 1).

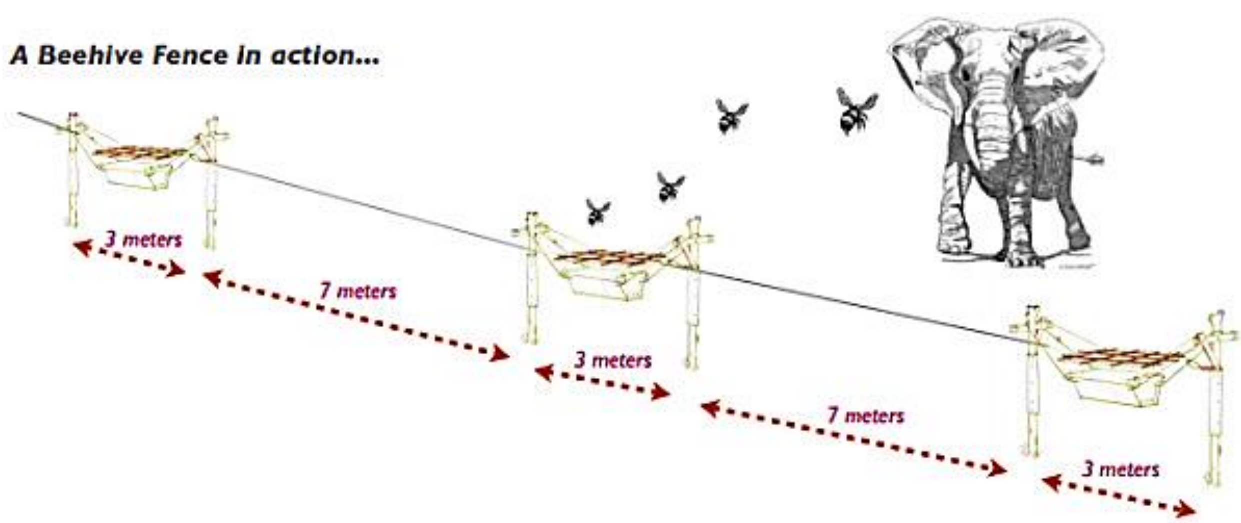

Figure 1: The elephant deterring beehive fence consists of 3-meter-wide beehive units spaced 7 meters apart and connected by wire. Disrupted bees are pictured deterring the elephant.

Most human-elephant conflict studies conclude that there is not just one solution, rather it is necessary to train and equip farmers with a ‘toolbox’ of various deterrents. These can then be combined or rotated with greater effect than relying on any one method alone (Walpole et al., 2006; Hedges & Gunaryadi, 2009). Electric fences exclude elephants from human-designated areas (Hoare, 2003; Kioko et al., 2008), but require diligent maintenance, and are costly (Thouless & Sakwa, 1995; Thouless, Georgiadis & Olwero, 2002; Okello & D’Amour, 2008). The use of buffer zones, firecrackers, dogs, watchtowers or drums are proving to be viable elephant deterring options (Hoare, 1995; Osborn & Parker, 2003; Sitati & Walpole, 2006; Graham & Ochieng, 2008). Concentrated chili extract in various forms has also been tested as an elephant deterrent (Osborn, 2002; Sitati & Walpole, 2006). The addition of the beehive fence to this toolbox of deterrents was an important component. The rapid adoption and spread of the beehive fence method within the Sagalla community speaks to the farmer support for this deterrent, and anecdotes suggest that farmers believe beehive fences effectively reduce elephant crop-raiding (King et al. 2017; Weinmann, 2018).

1.2 The Emergence of Human-Honey badger Conflict

While beehive fences can deter elephants once they arrive at a field, honey badgers (*Mellivora capensis*), a small (5-16 kg) mammalian species, often damage the fences. As opportunistic and generalist carnivores, they feed on a variety of prey, varying in size from insect larvae to the young of ungulates (Begg et al. 2003a). Despite their name, honey badgers do not actually consume a lot of honey and mainly consume the brood of the hive. Their unique adaptations, claws and thick skin, make them especially successful at raiding beehives. Honey badgers are thought to be highly impervious to bee stings due to their coarse hair, loosely fitting skin, and thick subcutaneous fat deposits (Astley Maberley 1951, Smithers 1960, Botha 1970), making them one of the few mammalian species capable of beehive predation. Local Sagalla Hill farmers and researchers correlate the honey badger attacks to abandoned hives (King, unpublished data). A study conducted in Sagalla found the second most commonly mentioned challenge in maintaining hive occupancy was honey badger damage to the hives (Weinmann, 2018). The beehive fences rely on occupied hives to effectively deter elephants. However, ultimately bees do not deter honey badgers as they do with elephants because honey badgers have thick skin and can withstand numerous bee stings (Kingston 1987). Their fearlessness and resistance to bee stings, coupled with an increase in African beekeeping, has resulted in increased conflict with humans (Begg et al., 2001a). Increasing numbers of apiaries have been brought into honey badger habitats resulting in more conflicts with humans. An analysis of nearly 50 years of beehive data from the United Nations Food and Agriculture Organization, found a 45 percent increase in the global population of managed honey-bee hives, largely due to the expansion of the bees into areas such as eastern Asia, and Africa (Aizen et al., 2009), thus there is a likely increased threat for honey-badger populations. Honey badgers are seen as one of the biggest threats facing beekeepers in Africa. In a study identifying the pests and predators of beehives, 40% of participants in Tigray, Ethiopia, ranked the honey badger as the most serious pest facing their beekeeping community (Gebretsadik, 2015). The loss of honey production and income due to honey badger attacks can cause resentment of the species in beekeeping communities. The beekeeping industry poses a serious threat to the conservation of honey badgers, particularly in the Western Cape Province, where some beekeepers are killing these animals in large numbers (Begg, 2002). Half of 82 commercial beekeepers surveyed admitted to killing honey badgers despite their protected status (Begg et al., 2001a).

On the other hand, some African beekeepers have made considerable progress in developing and implementing cost-effective, non-lethal methods of hive protection such as stands and securing techniques (Begg et al. 2001a), indicating that these methods could be used on a broader scale to protect honey badger populations. Africa's traditional beekeepers have suspended log hives from branches in order to contend with honey badgers (Fichtl, 1995; Kigatiira, 1984; Robinson, 1982; Rosevear, 1974). Several beekeepers in the Sagalla Hill region have proposed ways to decrease beehive fences' vulnerability to honey badgers such as increasing the height of the hives and adding additional metal sheeting to the hive posts (Weinmann, 2018). There is immense communal motivation to protect the hives, one beehive fence farmer explained "One time I had full occupation, all my hives, I had struggled to maintain them, but then a honey badger destroyed all fifteen of them . . . I harvested nothing because of honey badger" (Weinmann, 2018). Additionally, non-occupied hives potentially grant crop-raiding elephants access to the farm (King, 2009). The Sagalla community experiences a unique need for honey badger deterrents as there is a dual motivation to protect the hives, protect the honey income as well as the crop income the hives ensure. Therefore, to mitigate elephant crop-raiding through beehives honey badgers must also be deterred. The objective of this research was to investigate a variety of methods in deterring the honey badgers in order to protect the beehives that deter elephant crop-raiding.

1.3 Human-Wildlife Conflict Mitigation Methods

Conflicts between humans and wildlife over crops and other resources are increasing (Woodroffe et al. 2005) thus the need for animal deterrents. Deterrents fall into several groups, including visual, acoustic, tactile and chemical repellents. Deterrents discourage the presence of an animal in a specific area (Follmann et al., 1980). Private commercial companies, the Canadian

Department of Renewable Resources, the US Department of Agricultural have been spearheading deterrent development across a wide range of species for decades (Smith et al., 2000). The application of these deterrents to the beehive fence setting as a honey badger deterrent was evaluated.

Chemical Deterrents

Chemical sprays are often used to make crops unpalatable to birds, rodents and deer (USDA, 2017). In Europe, various smell and taste repellents, primarily of aluminum ammonium phosphate, have been marketed for European badgers, *Meles meles,* yet have seen little success in repelling badgers from farms (Cheeseman, 2007). Additionally, the chemical sprays were found to be successful in the moderate rainfall region of North America, the seasonal rains of Kenya would conceivably wash away the aluminum ammonium phosphate. These factors make the use of chemical deterrents as a honey badger deterrent incongruous.

Acoustic Deterrents

In North America, there is a growing market of ultrasonic acoustic devices used to prevent unwanted wildlife contact (Bomford et al., 1990). Some animals can hear ultrasound, however, there is controversy around its ability to deter mammals (Bomford & O'Brien 1990). The Yard Gard and the Usonic Sentry are ultrasonic devices marketed to repel pests. Both motion activated products emit ultrasound for about 7–18s. The Yard Gard was ineffective at repelling deer and the Usonic Sentry, with and without a white strobe light, was ineffective in repelling deer for more than a week. (Curtis et al. 1997; Belant et al. 1998). Similarly, these acoustic devices only work as carnivore deterrents for a limited time period (Smith et al. 2000). Furthermore, evidence suggests that ultrasonic deterrent devices may even have attract rather than deter badgers. When the ability of a commercially available ultrasonic device was tested on

Eurasian badgers (*Meles meles*) in the UK to prevent access to farm buildings, the device was associated with higher badger activity at baited plots in comparison to control plots, and bait consumption was higher when the ultrasonic device was used (Ward et al., 2008) thus researchers concluded that the ultrasonic device was not an effective solution to the problem of urban badger damage (Ward et al., 2008). Considering the unreliable results of acoustic deterrents, it was not considered a viable option for deterring honey badgers and wasn't included in this study.

Visual Deterrents

Strobe lights (Linhart *et al*. 1992; Green *et al*. 1994) and floodlights are often used to deter animals from an area. Some animals have a fear of new objects (neophobia) in their environment and may avoid that area for a short time (Koehler *et al*. 1990). There are several commercially available motion-activated lights claiming to scare off wildlife. These devices consist of a timer, a blinking strobe light, a photocell, and a motion detector. They automatically activate and deactivate at sunset and sunrise, respectively. When motion activated within that time frame, the device flashes for about 7–10 s at about 6–7 min intervals. Linhart *et al*. (1992) found one such device was effective in protecting sheep on their summer range from coyote attacks. Additionally, honey badgers avoided raiding hives in open lit fields, perhaps due to fear of detection (Begg et al., 2000). Therefore, motion activated lights could be a viable candidate for deterring honey badgers from predating the beehive fences.

Tactile Deterrents

In North America, commercially available cone baffles are in use to prevent birdfeeder raiding squirrels as a tactile deterrent. The baffle will create a protective barrier around a post and prevent predators from climbing up the post (Rainey, 2018). Using data from Cornell

University's NestWatch records, Bailey et al. tested the effectiveness of predator guards in promoting the nesting success of multiple species of birds. All guards were associated with improved nesting success, however, birds nesting in boxes with cone-type baffles were most likely to result in successful nesting (Bailey et al., 2018). A Sagalla based beehive fence farmer presented a similar design, "If you tie an iron sheet around a post, there's a possibility that a honey badger can fly over the iron sheet and climb on to the hive, but if you use that flat one the possibilities are very high that it is blocked" (Weinmann, 2018). The commercial, academic and local use of a cone baffle design suggests it is an effective and feasibly honey badger deterrent.

The Michigan Department of Natural Resources also suggests constructing an electric fence to protect hives from bear predation, and this was found to be 100% effective (Otto, 2013). The electric fencing method is not a viable option in developing regions considering the lack of recourses available for this type of construction. However, a Sagalla beehive fence farmer, designed a more economical method, a wire grid cage over the top of his beehives and has had some anecdotal success with it (Perso. Comm., 2017). Additionally, wire fencing was used successfully in excluding Eurasian badgers from their burrows (Ward et al., 2016). Begg (2002) also found that wire wrapping and steel strapping of hives to be an effective way of preventing hive predation. These methods prevented honey badgers from gaining access to the hive as they could no longer remove the lids. This wiring method is implemented in Sagalla, where beekeepers wire the beehive components together (King, 2014). Yet, honey badgers can circumvent the measure by directly breaking through the top of the hive, indicating the need for a stronger version of this deterrent (Weinmann, 2018).

Culling

Culling is currently in use for the Eurasian badgers in the U.K. in the fight against cattle TB. However, social perturbation of badger populations after culling is a proposed explanation for the failure of culling to reduce cattle TB. Eurasian badgers are a carrier of cattle TB and thought to be spreading the virus between cattle populations (Carter et al., 2007). However following removal, the remaining badgers were observed to have either moved greater distances or increased individual home range sizes (Carter et al., 2007). Furthermore, studies by Begg and Begg (2002) in the Western Cape have clearly shown that the ongoing persecution of honey badgers for the sake of beekeeping has little rational justification, whether economic or ethical. In 2000, beekeepers set traps in apiaries affected by honey badgers and killed a total of 13 animals. Yet, the beekeepers still lost approximately 14% of their hives to honey badgers even after utilizing trapping equipment indicating they are not always efficient in securing hives. Culling while never truly a viable option for ethical reasons, additionally, isn't an effective method in removing the overall presence of the species in a community.

Current Honey badger Specific Deterrents

No research has been conducted investigating methods for preventing honey badger damage to beehive fences. The beehive fences pose a unique problem because the hives require some mobility in order to be disturbed enough to deter elephants. When an elephant attempts to enter the farm, the individual will instinctively try to pass between the beehives causing him to hit the connecting wire; as a result, the beehives swing erratically which releases the bees (King, 2014). Therefore, the beehives cannot be stationary as the tire, barrel and drum designs utilized in Begg's study. Additionally, although steel posts could be utilized instead of the *Commiphora* tree and iron sheeting combination, this is not an economically practical solution for the farmers

(King, 2014). EBP is aware of the honey badger problem and is combating these attacks with the implementation of iron sheeting on the posts. During the first year of the EBP project, only 50 cm metal strips were used on the hive posts and as a result lost honey from 38 occupied hives to suspected attacks by honey badgers over a few weeks (King, 2011). In response, EBP extended the protective iron sheets to 70 cm and then only lost seven occupied hives to attacks by honey badgers (King, 2011). The iron sheets need to be wired to the upright post at least 2 feet off the ground to prevent honey badgers from climbing up the posts (King, 2014, Fig. 2).

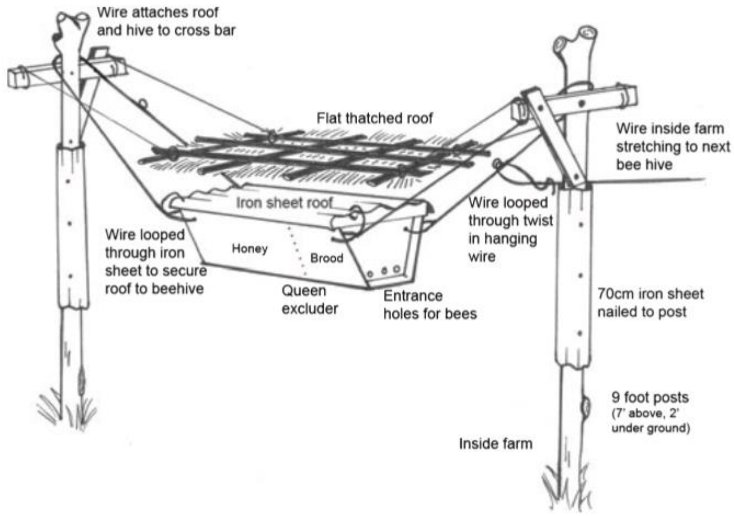

Figure 2: Beehive unit design (King, 2011) – The beehive unit is comprised a beehive hung between two nine-foot posts with 70cm iron sheeting nailed to the posts as a honey badger deterrent.

However, any inconsistency in the smooth surface of the iron sheeting or tilting of the post provides the honey badger with an opportunity to climb. One farmer explained that the “Honey badger comes and destroys it [beehive], tears the iron sheet” (Weinmann, 2018). In addition to the sheeting, the grass and wood shades and iron lid that hang over the hive have been effective in preventing honey badger attacks (King, person. comm, 2017). However, even with all of these barriers, the honey badger is often able to reach the hive. According to EBP data, Sagalla beehive fence farmers in two years (2015-2017) experienced 222 recorded hive raids with various amounts of damage and hive absconding rates across 21 farms (King, unpublished data). This emergence of the human-honey badger conflict has led to local experimentation in honey-deterrents (Weinmann, 2018). A study in the Western Cape investigated the use of non- lethal hive protections, more specifically different lid fasteners and hive stands (Begg et al., 2002). Beekeepers that incorporated these types of protections experienced 23.8% hive damage before and 1% after deterrents were implemented (Begg, 2002). Elevating the hives and the use of car tires, steel drums, and posts were successful protection measures. These types of deterrents provide evidence that non-lethal protection is possible and can be a feasible option for local communities. However, beehive fence specific solutions now must be developed.

1.4 Thesis Objectives

The objective of this research was to improve bee hiving practices to mitigate elephant crop-raiding. Since honey badgers often destroy beehives, this study aimed to improve the design of beehives through different types of badger deterrents. It tested whether cage, light and cone deterrents affected honey badger use of hives. These specific deterrents were chosen for this study based on their success in preventing animals such as bears and skunks from raiding hives in the Americas (Philadelphia Animal Management Services, 2014), as well as their feasibility in a Kenyan environment. Considering all guards were associated with improved nesting success (Bailey et al., 2018), the following was predicted:

1) A smaller proportion of protected hives would abscond with the novel deterrents than with the previously used methods.

2) That there would be minimal damage to the honey badger visited hives when the novel deterrents were in use.

3) Honey badgers would direct foraging behaviors such as looking, scratching, biting and vocalizations at the novel deterrents.

Chapter 2: Methodology

2.1 Study Area in Kenya

The study site is located in Taita Taveta County between Tsavo East National Park and Tsavo West National Park. This study was conducted in partnership with the Nairobi-based non-profit organization Save the Elephants, specifically within the Elephants and Bees Project (EBP). The EBP, a beehive fence project led by Dr. King has worked with the farmers of Sagalla Hill in Taita Taveta County since 2009 (Fig. 3). Sagalla is comprised of seven Taita (Wasaghala) people sub-villages located around Sagalla Hill (King 2010). These farmers rely on small-scale subsistence agriculture as their primary source of income (King 2010). Until a few decades ago much of the communities farming was conducted within the protected peaks of the Sagalla Hills, away from crop-raiding elephants. With the congestion of Upper Sagalla came the development of Lower Sagalla (Weinmann, 2017). This agricultural food source and the proximity to the Tsavo parks makes Lower Sagalla more prone to human-elephant conflict. Overall, nineteen (n=26, 73.1%) Sagalla farmers reported elephants as one of the community's top three challenges (Weinmann, 2018). This vulnerability has made elephant deterring beehive fences a necessity in for the Taita people. This presence of beehive fences, coupled with known honey badger activity positioned the Sagalla communities as a vital data source. The EBP project began the beehive fence project in 2009 the Sagalla Hill village of Mwakoma and expanded to Mwambiti Village in 2015 (King, 2017). For the purpose of this study, those two villages were collectively split into three sub-regions to ensure proper distribution of deterrents (Fig. 4).

Figure 3: Location of study site near the Tsavo East National Park in Taita Taveta County, Kenya. Arrows represent elephant movement corridors into the park.

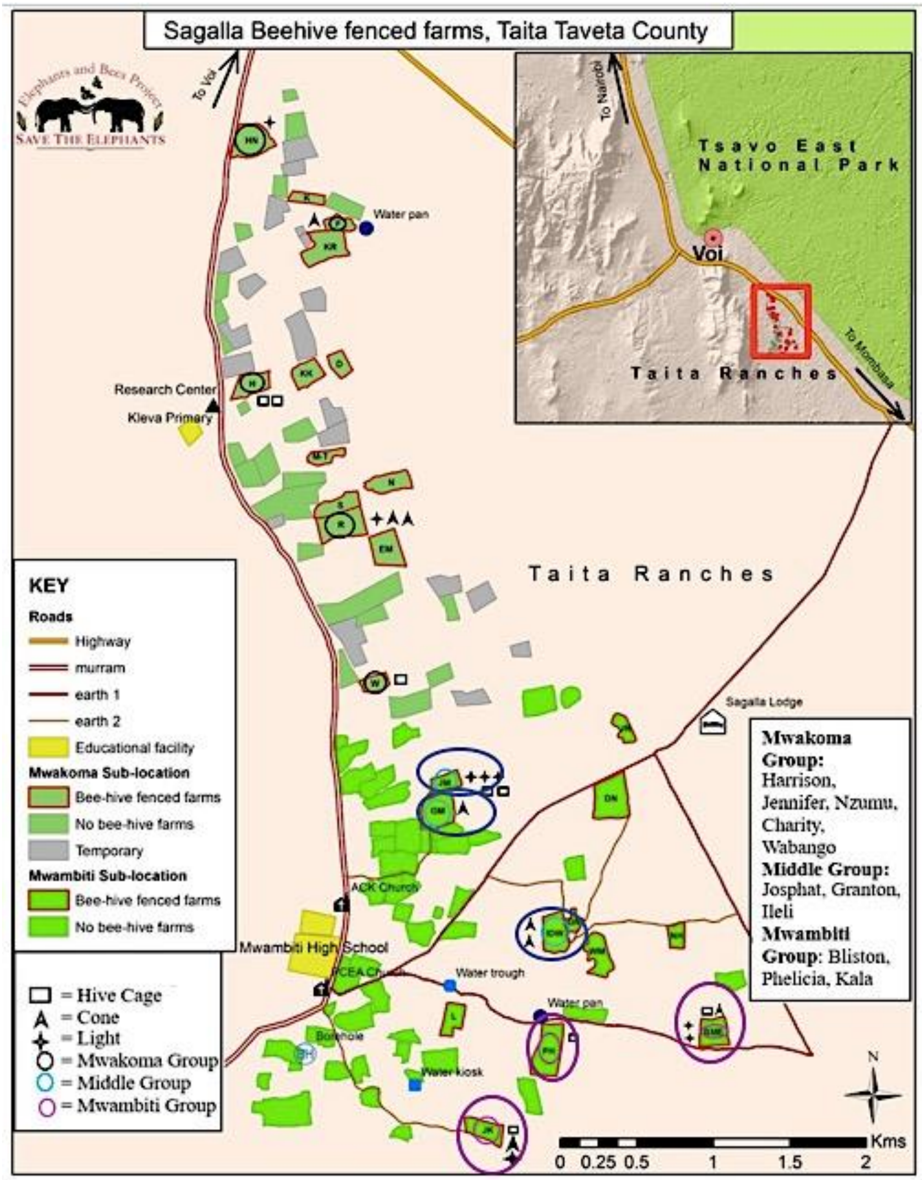

Figure 4: Location of specific experimental sites (beehive fence farms) within the Sagalla Hill community used in study. General beehive fence farms are outlined in red, while the honey badger deterrent farms have an additional circle. Modified map from King et al. 2017

2.2 Farmer Selection

In October 2017, a meeting with the EBP research team was held to describe the project objectives and proposed research plan. As per local protocol, Mwakoma's sub- chief was consulted to understand his perspective on human-honey badger conflict, explain the project's methods and objectives, discuss opportunities for collaboration, and receive his support before implementing the project. Mwambiti's sub-chief was on leave, so Mwakoma's sub-chief attended the meeting on behalf of both villages. With the sub-chief's approval, a community meeting was held at the EBP research center to select participants, understand their perspectives on human-honey badger conflict, explain the project's methods and objectives, and request their advice on the chosen deterrents. Approximately 30 people attended, 97% of the attendees were male. All attendants were beehive fence farmers with the EBP. Prototypes of the deterrents were presented to solicit feedback regarding their viability for the project in this environment. Anecdotal accounts of honey badger attacks collected from the meeting and EBP reports collected from beehive fence monitoring data were used to assess the current honey badger problem and select farmers. The EBP team had previously trained each participating farmer to record hive occupation events (King, 2017). These data included the frequency of honey badger attack hives per farmer over the course of the project. These EBP data (King, unpublished data) served as the primary means for identifying which farms are most vulnerable to honey badger attacks and therefore good candidates for the study (Fig. 5).

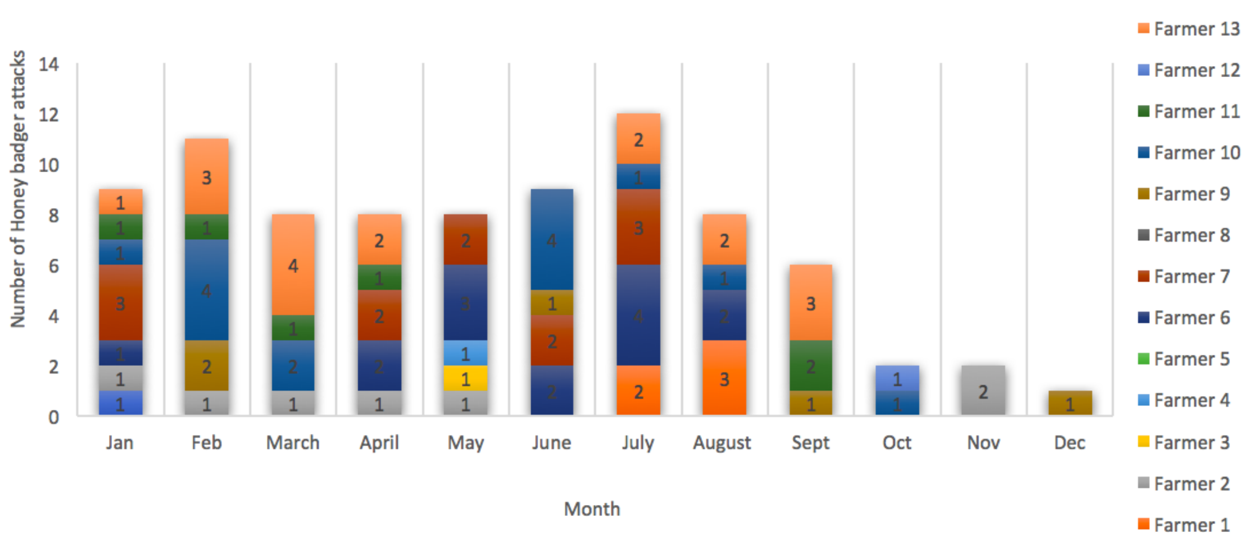

Figure 5: Average number of honey badger attacks to beehives per month over 2 years (2016 & 2017) for the 13 farms that experienced honey badger attacks is Sagalla, Kenya. Data were collected by EBP research team (King, Unpublished data).

Farmers from Sagalla were selected for participation based on: 1) interest in participation; 2) presence of a beehive fence; and 3) history of honey badger hive-raiding. Based on these criteria 11 farmers were selected out of the 21 farmers in attendance that expressed an interest with a total of 24 occupied hives, 8 per deterrent condition used in the study: cone deterrent, light deterrent, and the cage deterrent. With a randomized block design, the farmers were divided into village subgroups (‘Mwakoma’, Middle, and “Mwambiti’) such that the variability within these blocks is less than the variability between blocks (Proulx et al., 2016). Then, subjects within each block were randomly assigned to the deterrent treatment conditions. This ensured an even distribution of deterrent methods across the greater Sagalla Hill area. Upon assignment of the deterrents, the farmers were provided with a written and verbal description of what was expected from them and the project including: The purpose and methodology of the study, my proposed activity on their land, participant requirements and an outline of the reimbursement program to offset any loses farmers experience during the study.

After this selection period of a month, deterrents were installed over the course of November 2017. Each selected beehive fence farmer received a deterrent for their occupied hives. The study and EBP team installed these deterrents for the farmers and set up camera traps to monitor the hives. By December 2018, 24 deterrents and 24 cameras were installed.

2.3 Deterrent Designs

The deterrent designs used for this study were determined through a collaborative effort between local community members, commercial deterrent companies and the primary investigator. A beehive fence farmer and EBP staff member, Nzumu designed the cage deterrent used in the study cage deterrents. This design had been deployed on three hives for the six months prior to the start of the study. Those hives were reported to have zero honey badger attacks during that time (Nzumu, pers. comm., 2017; King, unpublished data, 2018). This preliminary testing and the influence of this local leader enabled a smooth transition into the more formal investigation of the methods' viability as a successful honey badger deterrent. The light and cone deterrents were modeled after commercially available products (Rainey, 2018). The community meetings held at the start of the study provided additional modifications to the deterrent design. A farmer remark that the presented cone deterrent prototype 'wouldn't stop a rat', therefore the size of the cone was increased to a diameter of a meter. For the majority of the study, the three deterrent types had eight replicates of each. However, the total of number hives in the experiment varied throughout data collection because of hive absconding. Over the course of the experiment, Lower Sagalla experienced lower than average rainfall. Only 4.2 millimeters of rain fell in January 2018 compared to the normal 30mm (King, unpublished data). This lack of rainfall negatively impacted the experimental hives and by mid-January, the hives were showing signs of drought stress through increase hive abandonment. At the start of data collection, December 2017, there were eight hives per treatment. In February 2018, the hive occupations had decreased to six per deterrent treatment, but returned to eight by April. There weren't any recorded honey badger visitations to these hives so they were excluded from the data set.

Characteristics of Light Deterrent

During previous research, honey badgers avoided raiding hives in open lit fields (Begg et al., 2000), therefore a light deterrent was selected for testing. Each occupied hive in the light deterrent treatment had a light attached to the hive post (Fig. 6). The light was a 400 lumens motion activated solar powered LED light. The lights were placed at 1.5 meters from the ground in order to be triggered by a honey badger approaching the hive. The light featured a motion angle of 120°and a 10ft detection range. The light automatically turned off after 30 seconds if the motion sensor was not triggered again. The deterrent costs $15 per light and about 15 minutes unskilled labor to install.

Figure 6: Image of motion activated solar powered LED light deterrent used in preventing honey-badger attacks (right) and light deterrent installation on hive (left).

Characteristics of Cone Deterrent

Cone deterrents prevent climbing predators from accessing the desired resource (Bailey et al., 2018). Each occupied hive in the cone treatment had a metal cone attached to each hive post 1.2m off the ground with the apex orientated upwards (Fig. 7). The cone was constructed out of 16 gauged galvanized steel sheeting, had a diameter of a meter and was attached to the tree with wire and angled wooden blocks. This height was chosen based on the honey badgers' maximum recorded height of 28 cm, and length of 77 cm for a reach of 1.05 meters (Proulx et al., 2016). This deterrent costs $21 per cone and took a day of skilled labor to construct.

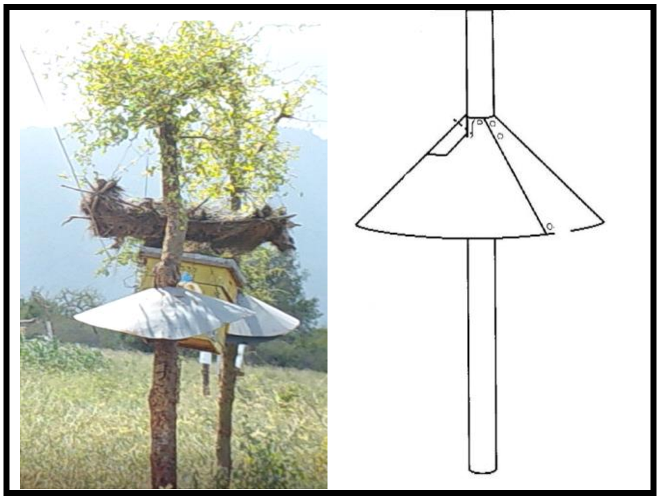

Figure 7: Cone deterrents installed 1.05 meters high on two Commiphora trees flanking a hive (left) within a beehive fence farm and diagram of cone deterrent on post (right)

Characteristics of Cage Deterrent

The cage deterrent experienced successful preliminary testing prior to the start of the study (Nzumu, pers. comm., 2017; King, unpublished data, 2018), therefore was included in the study as one of the testing conditions. Each occupied hive in the cage deterrent treatment was protected by a box made of 14-Gauge galvanized steel welded wire fencing with 2 in. x 4 in. mesh openings on a wire grid to the top of the hive (Fig. 8). The deterrent costs $7.50 to make and took an hour of unskilled labor to construct.

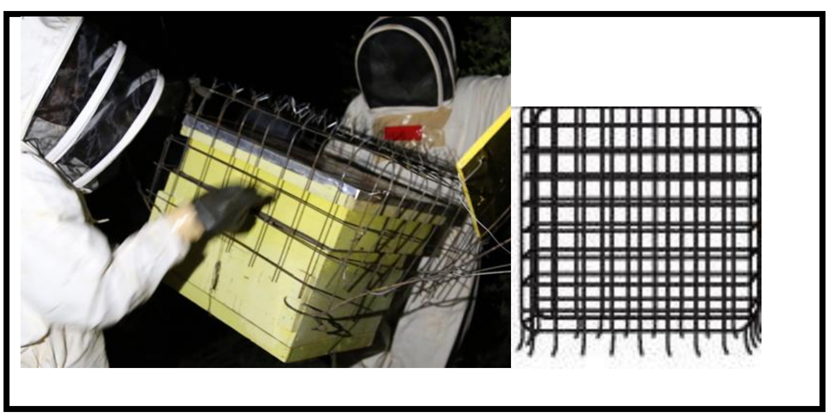

Figure 8: The cage deterrent is installed onto a hive and made of 14-Gauge galvanized steel welded wire fencing (left) and diagram of cage deterrent (right)

Characteristics of Previously Used Deterrent

The previously used deterrent was a physical obstacle already being used on the beehive fences in the community (Fig. 9). A 70 cm strip of metal sheeting was wired half way up each vertical wooden post flanking the hive and protected the hive by preventing the honey badger from climbing (King et al. 2011). This deterrent was used as the baseline for improvement because the absences of a deterrent was too high of a risk for the farmers. 2016- 2017 pre-existing EBP data on the metal sheet method were used as the comparison to the novel deterrent introduced by this study. The deterrent costs $2 to make and takes a half hour of unskilled labor to construct.

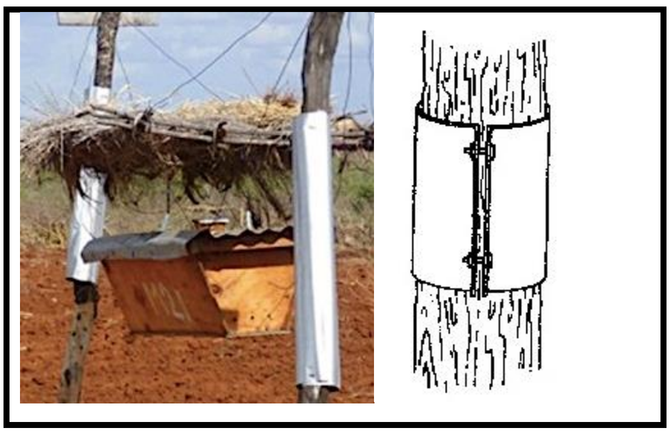

Figure 9: The previously used honey badger deterrent method featured 70 cm long iron sheeting installed on beehive unit (left) and diagram of metal sheeting installation post (right)

2.4 Data Collection

In the preliminary planning for this study, farmer recorded hive event data were examined to determine which beehive fences were targeted the most and at what time of year (King, unpublished data). Based on these attack data, honey badgers are most active in Sagalla from January to August (Fig. 6). Therefore, the data collection period for this study was conducted from December 2017 till May 2018. Additionally, honey badgers are essentially nocturnal but venture out when temperatures are cooler and there is little human disturbance

(Begg et al., 2017). During the data collection period, Sagalla experienced drought conditions compared to normal (King, unpublished data). Therefore, only night data collection was deemed to be necessary considering the area was highly populated and experienced high temperatures. Bushnell HD Aggressor Red Glow cameras monitored the protected hives and were checked weekly. The 24 camera traps recorded 3,240 nights of data collection over 5 months, during which time 21 honey badger visits were captured on film. Behavioral data were collected through the use of camera traps that were deployed and directed at each occupied hive and monitored these hives for honey badger activity (Fig. 10).

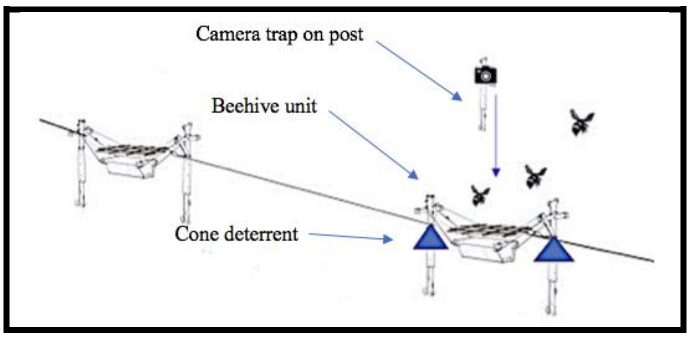

Figure 10: Diagram of testing site layout featuring a beehive unit, cone deterrents and the camera trap placement on an external post. The layout ensures the camera trap capture of honey badger behavior in response to the deterrent.

Farmers agreed to report any noticeable honey badger visitations to their hives. These hives were visited within a day of the report in order to conduct a hive assessment and collect camera trap data.

2.5 Behavioral Assessment

Camera traps provided a vital second data source to verify that honey badgers raided the hive and supplied information about the behavior of the hive-raiding. Each video was carefully analyzed and scored for the 'duration of the visitation' as well for the time spent exhibiting different behaviors (Proulx et al., 2016; Ward et al., 2016). The behaviors marked included: locomotion, hive exploration, vocalizations, and object of attention. Duration of attack was defined as the time (in minutes) between the onset of the attack on the hive and when the individual honey badger left the hive.

2.6 Hive Raid Assessments

All camera trap recorded attacks were quantified to determine the honey badger's ability to access hive. The amount of damage was quantified as a result honey badger activity and termed 'severity of attack', while it was also examined whether or not the honey badger was able to circumvent the deterrent method in order to make contact with the hive. This was termed 'success of visitation'. The severity of the attack was scored for its external structural condition, internal structural condition, and presence of bees after an attack. Following a procedure adapted from Wilson et al. (2003), the scores for each category are summed to produce a damage score for each raid on the hive. Scores could vary from 0 (no damage) to 2 (most damaged), with an overall score as high as 6 (Table 1). Success of visitation was quantified with a similar procedure; the deterrents were scored based on their ability to prevent honey badger access to the hive with a metric of 0 (unsuccessful attack) or 1 (successful attack).

Table 1: The damage categories and their assigned values for the quantification 'severity of the attack'. The scores were assigned for internal, and external damage as well as for the presence of bees in Sagalla, Kenya hives.

Type of Damage to Hive	**Damage Score**		
	0	1	2
External structural condition	No damage	Minimal damage to hive unit i.e. scratches	Extensive damage to hive unit i.e. visible damage to hive and jostling of deterrent
Internal structural condition	No damage	Minimal damage to bee colony built structure i.e. less than a bar of honey badger consumed hive	Extensive damage to bee colony built structure i.e. more than a bar of honey badger consumed hive
Presence of bees after an attack	No damage	Decreased bee colony size	Colony abandonment of hive

2.7 Absconding Rates

Past absconding records (N= 249) from 2016-2017 were used to compare the novel deterrents' ability to prevent honey badger related absconding rates to the previously used method - iron sheeting (Table 2). The EBP research team and beehive fence farmers in Sagalla collected these data prior to the start of the study during their monthly hive monitoring and reporting of major hive related events. For the purpose of this study, all hives that experienced absconding within the week after a honey badger visitation were included in the data set. This ensured hives weakened by the attack were also correlated to honey badger activity. Data from 2016-2017 were used as a comparison to the study season as it most resembled the data collection conditions of this study. Both time periods experienced drought conditions and lower beehive occupation rates compared to normal (King, unpublished data). For the novel deterrent data, only farmer reported visitations were considered for the absconding rate comparison (n=9). This was to ensure the data set was most similar to the previously used method (iron sheeting method). Prior to the start of the study honey badger visits weren't camera trap verified but instead were only collected when a honey badger visibly disrupted the hive.

Table 2: The number of absconded hives after a honey badger attack when the iron sheeting method was used to protect hives from honey badger predation in Sagalla, Kenya. 2016-2017 EBP data were used.

Number of Absconded Hives	**Iron Sheet Method**
Absconded	192
Did not Abscond	57
Total	**249**

The addition of a control treatment could not be established because of the limited number of available hives. Additionally, the farmers were not comfortable with leaving their hives vulnerable to honey badger attack through the use of a deterrent they perceived to be ineffective. Consequently, past data were utilized for the deterrent comparison.

2.8 Statistical Analysis

The small sample size and the small number of damaged hives required Pearson chi-square statistical analysis to ascertain at the relationship between a) damage and deterrent type (i.e. cone, cage or lights), and b) proportion of absconded hives before and after the intervention. An additional category of ‘deterrent installation’ was added after the data collection period. Two (one cone deterrent visitation and one cage deterrent visitation) out of 18 visitations were to deterrents that were not wired on properly during installation. Thus were labeled ‘improperly installed’ versus ‘properly installed’. Therefore, using a Chi squared analysis, the ‘improperly installed’ and properly installed’ deterrents were compared for their relationship to ‘severity of attack’. Linear regression was used to examine the relationship between duration and deterrent type. All tests were performed using SPSS (versions 25).

Chapter 3: Results

Over 5 months, 3,240 nights of data collection yielded 21 honey badger visits (Fig. 11). The lack of rainfall during the data collection period negatively impacted the hive numbers and the amount of honey per hive. With a diminished attractant, the number of honey badger visitations were less compared to previous years. This resulted in a small sample size. Out of these 21 visits, 18 visits yielded useable hive raiding data. During those 3 other visitations, the honey badger made no contact with the beehive unit. Therefore, data couldn't be definitively collected in regard to the honey badger reaction to the deterrent. The 18 visitations were assessed for whether the addition of various deterrents affected honey badger predation of the hives. An analysis of 'severity of attack', 'success of visitation, 'duration of attack' and 'absconding rates' was used. All of the deterrents prevented hive damage, and honey badger access to the hives, while also reducing the honey badger associated absconding rates compared to the previously used method.

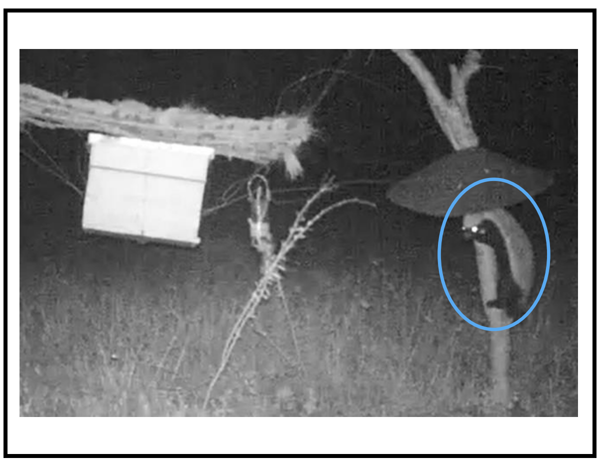

Figure 11: Camera trap capture of honey badger visit to cone protected hive. The honey badger climbs the hive post and attempts to circumvent the cone deterrent before failing.

3.1 Hive Raid Assessments

It was predicted that there would be minimal damage to the honey badger visited hives when the novel deterrents were in use. No differences were found between the extent of hive damage and type of deterrent (X=3.06, df=2, p=0.41). Only two honey badger visitations resulted in damage out of 18 visitations to the beehive units. And the actual damage to the hives was minimal with an average damage score of 2.5 out of six (n=2), with two being the most damaged for each category (Table 3).

Table 3: The damage to two honey badger attacked hives in Sagalla, Kenya. The scores were assigned for internal, and external damage as well as for the presence of bees.

Type of Damage to Hive	**Type of Deterrent**		
	Cage	Cone	Average
External structural condition	0	1	.5
Internal structural condition	0	1	.5
Presence of bees after an attack	2	1	1.5
Total Damage Score (out of 6)	**2**	**3**	**2.5**

Additionally, there was no relationship between deterrent type and success of visitation (χ^2 =.8037, n=3, p=.05) indicating all novel deterrents (motion activated light deterrent, cone baffle, and hive cage deterrent) prevented attacks equally.

Table 4: The number of successful honey badger visitations to the elephant deterring hives in Sagalla, Kenya, were quantified for each type of deterrent. The observed frequencies were compared to the expected frequencies.

Expected Success of Visitation	**Type of Deterrent** Cage	Cone	Light	Total
Yes	0.89	0.56	.56	2
No	7.11	4.44	4.44	16
Total	**8**	**5**	**5**	**18**
Observed Success of Visitation	**Type of Deterrent** Cage	Cone	Light	Total
Yes	1	1	0	2
No	7	4	5	16
Total	**8**	**5**	**5**	**18**

The two damaged hives had improperly installed deterrents (1 cone deterrent and 1 cage deterrent), where the deterrents weren't secured properly. "Severity of attack' was significantly related to deterrent condition (χ^2 = 18.00, df = 1, p = 0.0012) as improperly installed deterrents were associated with more hive damage.

3.2 Behavioral Assessment

As predicted, the honey badgers directed foraging behaviors such as looking, scratching, biting and vocalizing at the novel deterrents. Individuals exhibited more variety in behaviors during the improperly installed deterrent attacks, where scratching, biting and vocalizing at the novel deterrents were observed during each visitation to an improperly installed deterrent (n=2) and not during visitations to properly installed deterrents (n=18). Moreover, honey badger visitations to improperly installed deterrents (n=2) had longer durations than those of properly installed deterrents (n=16) (β = 357.05, p = 0.0012). Duration was related to deterrent condition but could not be established for the type of deterrent because of an insufficient sample size.

Table 5: The regression results compared the deterrent type to duration of the honey badger visitation as well as the deterrent installation condition to duration of the honey badger visitation

Parameter	**Estimate**		**Standard Error**	**t Value**	**Pr > |t|**
Intercept	20.2000000	B	57.00070115	0.35	0.7283
Deterrent Installation: Improperly Installed	357.0481928	B	88.48224832	4.04	0.0012
Deterrent Installation: Properly Installed	0.0000000	B	.	.	.
Deterrent: Cage	6.2939759	B	73.49887553	0.09	0.9330
Deterrent: Cone	110.9807229	B	88.03872549	1.26	0.2281
Deterrent: Light	0.0000000	B	.	.	.

3.3 Absconding Rates Results

It was predicted a smaller proportion of protected hives would abscond with the novel honey badger deterrents than with the previously used methods. There was a difference in the proportion of absconded honey badger attacked hives before (n=249) and after the introduction of novel deterrents (n=9) ($\chi 2$ = 16.661, df = 1, $p < 0.01$). The novel deterrents collectively experienced 11.1 percent absconding hives whereas the iron sheet method experienced a 77.1 percent rate of absconding hives after a honey badger attack; Fig. 12).

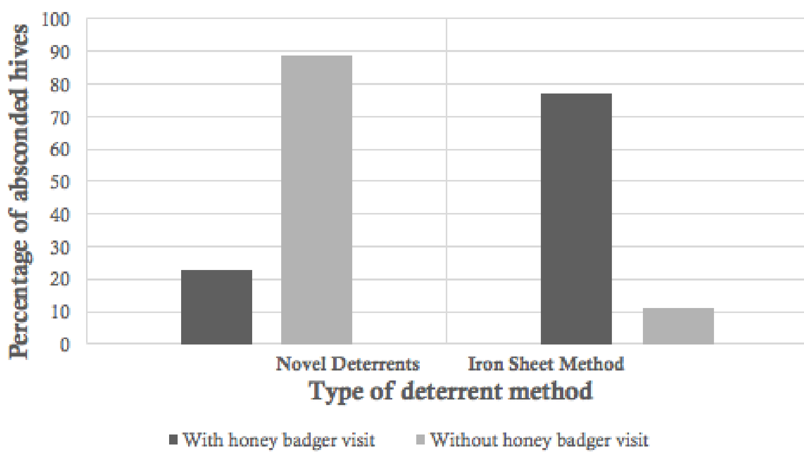

Figure 12: Frequencies of absconding after a honey badger attack to the hive where compared between the novel deterrents and the previously used method of iron sheeting. Both data sets were collected in Sagalla, Kenya from beehive fences.

Out the nine honey badger visitations where the honey badger made visible contact with the hive, only one corresponded to the hive absconding within a week of that visit (Table 6).

Table 6: The number of absconded hives after a honey badger attack to the hives in Sagalla, Kenya per novel deterrent type. Using data from beehive fence farmer reports.

Number of Absconded Hives	**Type of Novel Deterrent**			
	Cage	Cone	Light	Total
Absconded	1	0	0	1
Did not abscond	2	3	3	8
Total	**3**	**3**	**3**	**9**

Comparatively, the EBP lost 192 hives over two years (2016-2017) within the week of reported honey badger activity (King, unpublished data).

The 2016-2017 iron sheeting method data were farmer reported so this study only utilized the farmer reported data for this comparison. The novel deterrents were grouped together as an average absconding rate for a more accurate depiction of the loss rates. If examined individually the success rates would be much higher due to a small sample size of absconded hives.

Chapter 4: Discussion

This study was conducted to determine if visual and tactile deterrents could reduce the frequency and severity of honey badger hive predation compared to a previously used iron sheeting method. Prior to the start of the study, 77.1% percent of hives absconded within a week following a honey badger attack. After the addition of the novel deterrents (motion activated light deterrent, cone baffle and hive cage deterrent), only 11.1% percent of the hives attacked by honey badgers absconded, suggesting the deterrents effectively prevented honey badger’s from gaining hive access. No relationship was found between deterrent type and amount of damage, nor for the duration and deterrent type because all deterrent methods effectively prevented honey badgers from raiding hives with variance in the success rates and economic feasibility.

4.1 Hive Raid Assessments

The hive raid assessments were utilized to determine the level of damage to honey badger attacked hives as a metric for understanding deterrent effectiveness. As predicted there was minimal damage to the honey badger visited hives when the novel deterrents were in use. These intact and undamaged hives will provide the beehive fence farms with an additional source of income (King et al, 2017). While the beehive fences are primarily important for mitigating human-elephant conflict by deterring crop-raiding elephants, the additional benefit is the production of sellable honey. The EBP purchases the raw honey from the farmers, which provides the beehive fence farmers an alternative source of income. This helps keep the beehive fence farmers incentives and engaged in the project (Weinmann, 2018). Preventing damage to the hives will lead to more honey production. Honey badgers were ranked the second greatest damage causing pests in Ethiopia study on beehive pests, this damage cost the farmers substantial income (Gebretsadik, 2015). Sagalla based farmers articulate similar honey badger damage, “There are also some animals which go to break the beehives, the honey badgers… Honey badgers damage beehives and kill colonies when they steal honey” (Weinmann, 2017, pg. 112). This rhetoric and resentment of the species has led to the persecution of honey badgers in South African beekeeping communities, where some beekeepers are killing these animals in large numbers (Begg, 2002). Preventing honey badger damage protects population numbers and the income of the farmers, while also ensuring there are healthy hives to deter elephants. The beehive fences rely on strong hives to elicit the elephants’ natural avoidance behavior of bees (King et al., 2017). This is essential for mitigating the human-elephant conflict causing crop-raiding.

Furthermore, only when the deterrent was improperly installed did the hives experience this minimal damage. In the improperly installed condition, the cone deterrent hive experienced a reduction in the size of the bee colony and internal structural damage, while the cage deterrent hive experienced no damage but a loss of bee occupation. (Weinmann, 2017).

4.2 Behavioral Assessment

As predicted, the honey badgers directed foraging behaviors such as looking, scratching, biting and vocalizations at the novel deterrents. Additionally, hive raiding attacks were significantly related to deterrent condition as improperly installed hives were attacked for longer periods of time. Even with faulty deterrents the honey badgers had to exhibit more effort to gain access to the hive than the beehive fence farmers experience with the previously used iron sheeting method (Weinmann, 2017). The farmers described a much faster rate of damage when using the iron sheeting method, over the course of a month “a honey badger destroyed all fifteen of them” (Weinmann, 2017). However, this contingency of deterrent success on installation is consistent with the findings of Ward et al. (2016), where 20 of the 32 badger exclusion attempts were successful. The study was attempting to prevent Eurasian badgers from burrowing in undesirable areas. The success was less likely if vegetation was not completely removed from the sett surface prior to exclusion attempts and the gate wasn't extended far enough. Similarly, the cone deterrent requires a rigid installation and the cage deterrent requires an extended length. Therefore, it is recommended that designs be followed precisely to guarantee success.

Additionally, the increased duration at improperly installed hives indicates a decision-making ability. When there was a perceived weakness in the deterrent, the honey badger seemingly did a cost-benefit analysis, perhaps understanding there was a greater chance for a nutritional gain than with the properly defended hives. For Eurasian badgers, time allocation is dictated by the foraging difficulty of different habitat types (Shepherdson et al., 1990). This U.K. based badger diet study suggests that badgers can determine optimal foraging strategies based on food abundance and degree of effort. Honey badgers spent more of that time looking at the hive and exploring the hive than the visitations to the properly installed deterrents, further supporting the premise that there was deliberation at the weaker deterrents. Tactics used by North American badgers (*Taxidea taxus*) when hunting ground squirrels (*Spermophilus richardsonii*) suggest that this type of complex thinking is present in similar species. North American badgers frequently hunt by plugging the openings of ground-squirrel tunnels. In a study on the hunting strategies of North American badgers, one hunting bout involved the movement of 37 objects to plug openings of 23 ground-squirrel tunnels on 14 nights (Michener, 2004). This aimed movement of objects for hunting qualified this badger as a tool user. There is anecdotal evidence to suggest that honey badgers have similar abilities. The Moholoholo Wildlife Rehabilitation Centre has found it difficult to house honey badgers in their facility because of their problem-solving skills and ability to circumvent enclosures (Jones, personal communication, 2017). Considering this ability to escape human-made structures, the necessity for such extreme deterrents is understandable.

4.3 Absconding Rates

By examining the absconding rates of honey badger attacked hives, this study established that more hives absconded after a honey badger visitation with traditional iron sheet method than with the novel deterrents (cage, light and cone methods). This prevention of abandoned hives is crucial for honey production and elephant deterring. Eighty percent of the elephants that approached the beehive fence protected farm were kept out of the areas, and elephants that broke a fence were in smaller than average groups. The farmers also benefited socially and financially from the sale of 228 kg of elephant- friendly honey. These results were with 88% of the beehives being occupied at least once during the 3.5-year trial (King et al, 2017). These occupation numbers could grow as honey badgers are deterred. It stands to reason that there will be subsequent growth in the amount of elephants deterred and honey income.

4.4 Limitations

The study was conducted in the midst of a drought so there were fewer established hives (King, unpublished data). Hive occupation rates increase as rainfall increases with the onset of the biannual rainy seasons (November –December, and March-April each year), which trigger both crop and natural vegetation growth that provided ample water and foraging sources to attract wild bee swarms to the beehive fences (King et al.,2017). The November-December 2017 rains were not sufficient to maintain a healthy population of hives, so the hives decreased from 30 to 18 during the study (King, unpublished data). Beehive availability in a drought season influenced the location of the beehive and site selection. To control for the unexpected variation in hive location, the deterrent types were evenly distributed across the study site. The drought also influenced honey production and potentially honey badger prevalence (King, unpublished data). During the five months of data collection, there was an insufficient honey supply and bee production so income from honey was not a viable option for the farmers. Moreover, without a normal honey stock and brood, honey badger motivation to raid hives was most likely diminished, which could account for the low number of hive visits. A larger number of honey badger visits would have provided a more complete idea of the most viable deterrent option and additional studies with more farms and hives would provide valuable insight into the honey badger- human conflict.

4.6 Deterrent Validity

As predicted, the introduction of the novel hive protections prevented hive absconding more effectively than the previously used iron sheet method. As with Cornell University's study testing the effectiveness of predator guards in promoting the nesting success of multiple species of birds, all guards were associated with preventing honey badger access to the hives. Improved nesting success was most likely in nest protected by cone-type baffles, stovepipe baffles, or entrance hole extenders (Bailey et al., 2017). The honey badger cone deterrent was an expanded version of the cone baffle, the honey badger cage deterrent features a similar wire grid design as the entrance excluders and the honey badger iron sheeting deterrent is similar to the stovepipe baffle. With fate data from 24,114 nest records, the more extensive sample of the nesting study gives validity to the design aspect of the deterrents. These deterrents have been tested on a larger scale and now have been tested against honey badger predation on a smaller scale.

Yet when considering a human-wildlife mitigation strategy, it is essential to deliberate on the economic feasibility and the setting. Although the light deterrent experienced the greatest success, with a 100% success rate, the expense may exceed the reward. In two years of the EBP

(January 2014 - December 2015), six farmers earned a total income of $627 (King et al., 2017). At $15 per light (two lights per hive) this additional cost would cut into their profit margin. Furthermore, 25% of the motion activated lights were stolen during the study making the reliability of this deterrent questionable. Therefore, it is not recommended to utilize motion activated lights for a similar community-based deterrent project. Similarly, the cost of the cone deterrent coupled with the labor-intensive installation process makes it difficult to recommend, even though it was effective in preventing hive damage. The cage deterrent is far more cost effective than the other options at $7.50 per cage, easily constructed, and was effective at preventing honey badger access to the hive. Of these three methods, the cage deterrent is the most viable option for deterring honey badgers from the predation of beehives and recommended to the community.

4.5 Conclusion and Future Applications

Hive raiding is a common cause of human-honey badger conflict in Africa. It fosters animosity towards honey badgers and creates resistance to wildlife conservation efforts. In serious instances, it can lead to the loss of honey badger populations (IUCN 2018). Honey badgers have a wide distribution, nevertheless, the IUCN considers the current population to be decreasing because of a continuing decline of mature individuals and extreme fluctuations in population numbers (2018). These changes are likely due to the direct persecuted of honey badgers through the use of steel-jawed traps and poison by apiculturists and small livestock farmers (IUCN 2018). There is evidence to suggest honey badgers have gone locally extinct in many areas through this intentional poisoning (Begg et al. 2013). With such widespread and varying threats to honey badger populations, more research into human-honey badger conflict mitigations strategies is crucial. Effective honey badger deterrent methods and beekeeper involvement have the potential to greatly reduce honey badger hive-raiding and the conflict it fosters (Weinmann, 2017). This could prevent the farmers from growing resentful of the honey badger, a type of resentment that led to the persecution of South African honey badger populations (Begg, 2002). Reducing honey badger hive predation within the beekeeping community will promote conservation efforts and improve human- honey badger co-existence. By reducing the severity and frequency of hive raiding, these techniques will also benefit local communities by decreasing negative economic impacts on the farmers such as loss of honey income. This study could be of value and interest to community members partnering with the EBP as it may result in greater protection of their hives and the income they gain from them (Weinmann, 2017). Improved human-honey badger co-existence will ameliorate local farmer livelihoods and financial security.

Since the conclusion of the study, the Elephants and Bes Project has deployed and funded the implementation of the cage deterrent across all of their beehive fences in the Sagalla region. This decision was a result of a community request for the deterrent and the preliminary findings of this study (King, person. comm., 2018). In addition, results will also be utilized by STE in outreach and education throughout the EBP locations. This research will have wide-reaching implications for the future of human-wildlife interactions by demonstrating how non-lethal deterrents can reduce human-wildlife conflict. These results and recommendations will provide other communities in the world valuable information to aid in creating effective human-wildlife co-existence strategies.

References

Allen, M. L., Peterson, B., and Krofel, M. (2018). No respect for apex carnivores: Distribution and activity patterns of honey badgers in the Serengeti. *Mammalian Biology*, *89*, 90–94.

Astley Maberley, C.T. (1951). Animals of the Kruger National Park. A.C. *Whyte & Co. Bloemfontein*, *12.*

Baryshnikov, G., Academy, R., and Baryshnikov, G. (2000). A new subspecies of the honey badger *Mellivora capensis* from Central Asia. *Acta Theriologica*, *45*(1), 45–55.

Begg, C. M. (2001). Feeding ecology and social organisation of honey badgers (*Mellivora capensis*) in the southern Kalahari. Ph. D. Thesis, *University of Pretoria*.

Begg, K. (2001). Report on the conflict between beekeepers and honey badgers, *Mellivora capensis* with reference to their conservation status and distribution in South Africa. Unpublished report for the Endangered Wildlife Trust, Johannesburg.

Begg, K.S. and Begg, C.M. (2002). The conflict between beekeepers and honey badgers in South Africa: A Western Cape perspective. *The Open Country, 4*, 25-37.

Begg, C. M., K. S. Begg, J. T. du Toit, and M. G. L. Mills. (2003a). Sexual and seasonal variation in the diet and foraging behaviour of a sexually dimorphic carnivore, the honey badger (*Mellivora capensis*). *Journal of Zoology, 260*, 301–316.

Begg, C. M., K. S. Begg, J. T. du Toit, and M. G. L. Mills. (2003b). Scent-marking behaviour of the honey badger, *Mellivora capensis (Mustelidae)* in the southern Kalahari. *Animal Behaviour, 6*6, 917–929.

Begg, C. M., K. S. Begg, J. T. du Toit, and M. G. L. Mills. (2005a). Life-history variables of an atypical mustelid, the honey badger *Mellivora capensis*. *Journal of Zoology 265*, 17–22.

Begg, C. M., K. S. Begg, J. T. du Toit, and M. G. L. Mills. (2005b). Spatial organization of the honey badger *Mellivora capensis* in the southern Kalahari: home-range size and movement patterns. *Journal of Zoology, 265,* 23–35.

Begg, C. M., Begg, K. S., and Toit, J. T. D. U. (2005c). Sexual and seasonal variation in the activity patterns and time budget of honey badgers in an arid environment. In G. Proulx (Ed.) *Badgers: systematics, biology, conservation and research techniques* (pp. 161–192). Alberta: *Alpha Wildlife Publications*.

Begg, C., Begg, K. and Kingdon, J. (2013). *Mellivora capensis* ratel (Honey badger). In Hoffman (Ed.) *The mammals of Africa. V. Carnivores, pangolins, equids and rhinoceroses* (pp. 12). Bloomsbury, London, UK.

Begg C.M., Begg K.S., Power R.J., van der Merwe D., Camacho G., Cowell C., Do Linh San E. (2016). A conservation assessment of *Mellivora capensis*. In M.F Child, L. Roxburgh, E. Do Linh San, D. Raimondo, H.T Davies-Mostert (Ed.) *The Red List of Mammals of South Africa, Swaziland and Lesotho*. South Africa: South African National Biodiversity Institute and Endangered Wildlife Trust.

Begg, C. M., Begg, K. S., Do Linh San, E., Du Toit, J. T. and Mills, M. G. L. (2017). An evaluation of techniques used for the capture, immobilization, marking and habituation of honey badgers. In G. Proulx (Ed.) *Badgers: systematics, biology, conservation and research techniques* (pp. 161–192). Alberta: *Alpha Wildlife Publications*, 339–362

Belant, J.L., Seamans, T.W. and Tyson, L.A. (1998). Evaluation of electronic frightening devices as white-tailed deer deterrents. *Proceedings of Vertebrate Pest Conference, 18*, 107–110.

Bomford, M. and O'Brien, P. H. (1990). Sonic deterrents in animal damage control. *Wildlife Society Bulletin. 18*(4):411-422.

Botha J.J.C. (1970). About enemies of bees in South Africa. *Gleanings in Bee Culture, 98*, 100-103.

Carter, S., du Plessis, T., Chwalibog, A., and Sawosz, E. (2017). The honey badger in South Africa: biology and conservation. *International Journal of Avian & Wildlife Biology*, *2*(2), 4.

Carter, S. P., Delahay, R. J., Smith, G. C., Macdonald, D. W., Riordan, P., Etherington, T. R., Pimley, E. R., Walker, N. J., … Cheeseman, C. L. (2007). Culling-induced social perturbation in Eurasian badgers *Meles meles* and the management of TB in cattle: an analysis of a critical problem in applied ecology. *Biological Sciences, 274*(1626), 2769-77.

Curtis, P.D., Fitzgerald, C. and Richmond, M.E. (1997). Evaluation of the yard gard ultrasonic yard protector for repelling white-tailed deer. *Proceedings of the Eastern Wildlife Damage Control Conference, 7*:172-176. United States.

Frantz, A. C., Roper, T. J., Schaul, M., Pope, L. C., Fack, F., Schley, L., and Muller, C. P. (2004). Estimating population size by genotyping remotely plucked hair: the Eurasian badger. *Journal of Applied Ecology*, *41*(5),1–15.

Gebretsadik, T. (2016). Survey on honeybee pests and predators in Sidama and Gedeo zones of Southern Ethiopia with emphasis on control practices. *Agriculture and Biology Journal of North America*, *7*(4), 173-181

King, L., Douglas-Hamilton I. and Vollrath, F. (2007). African elephants run from the sound of disturbed bees. *Current Biology 17*(19), R832-R833.

King, L., Lawrence A., Douglas-Hamilton, I. and Vollrath, F. (2009). Beehive fence deters crop-raiding elephants. *African Journal of Ecology 47*(2), 131-137.

King, L. (2010). *The interaction between the African Elephant (Loxodonta Africana Africana) and the African Honey Bee (Apis Mellifera Scutellata) and its potential application as an elephant deterrent.* (DPhil thesis). University of Oxford, U.K.

King, L. (2014). *Beehive fence construction manual* [Pamphlet]. Nairobi, Kenya: Save the Elephants.

Kissui, B.M. (2008). Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. *Animal Conservation, 11*(5), 422 - 432

Fichtl, R. (1995). Beekeeping with *Apis m. scutellata* in Ethiopia. *American Bee Journal, 135*, 749-752.

Lloyd, P., and Stadler, D. A. (1998). Predation on the tent tortoise *Psammobates tentorius*: A whodunit with the honey badger *Mellivora capensis* as prime suspect. *South African Journal of Zoology, 33*(4).

Michener, G. (2004). Hunting Techniques and Tool Use by North American Badgers Preying on Richardson's Ground Squirrels. *Journal of Mammalogy, 85*(5), 1019-1027.

Proulx, G., and Do Linh San, E. (2016). Badgers: systematics, biology, conservation and research techniques. Alberta: *Alpha Wildlife Publications*, 120-362.

Robinson, W.S. (1982). Keeping the "Kali" bees of Kenya. *American Bee Journal*, *122*(1), 745-748.

Rosevear, D. R. (1974). The carnivores of West Africa. *The British Museum Press 58*(1), 110-128.

Smith, R. J. and Kasiki, S. (2000). *A spatial analysis of human-elephant conflict in the Tsavo ecosystem, Kenya. African Elephant Specialist Report*, Kenya: IUCN/SSC.

Smith, M. E., Linnell, J. D., Odden, J., and Swenson, J. E. (2000). Review of methods to reduce livestock depredation II. Aversive conditioning, deterrents and repellents. *Animal Science, 50*(4), 304-315.

Smithers, R.H.N. (1960) The mammals of Rhodesia, Zambia and Malawi. *University of Pretoria Press*, *10*(1), 38 –39.

Smithers, R.H.N. (1983). The mammals of the Southern African subregion. *University of Pretoria Press*, 27(2), 435-438.

Smithers, R.H.N. (1986). *The South African red data book – Terrestrial mammals: South African National Scientific Programmes* (Report No. 125). South Africa: The Council for Scientific and Industrial Research.

Shepherdson D. J., Roper T. J., Lups P. (1990). Diet, food availability and foraging behaviour of badgers *(Meles meles L.*) in southern England. *Zeitschrift für Säugetierkunde*, 55, 81-93.

Tchamba, M. N. (1996). *Elephant and their interaction with people and vegetation in the Waza-Logone Region, Cameroon*. (PhD Thesis). University of Utretch, Netherlands.

USDA APHIS (2017). *Research Facility Annual Summary Report*. Washington D.C, USA: USDA.

Ward, A. I., Finney, J. K., Beatham, S. E., Delahay, R. J., Robertson, P. A., and Cowan, D. P. (2016). Exclusions for resolving urban badger damage problems: outcomes and consequences. *PeerJ. 4*:e2579

Ward, A. I., Pietravalle, S., Cowan, D. P., and Delahay, R. J. (2008). Deterrent or dinner bell? Alteration of badger activity and feeding at baited plots using ultrasonic and water jet devices. *Applied Animal Behaviour Science*, *115*(3-4), 221-232.

Wilson, G., Delahay, R., De Leeuw, A., Spyvee, P., and Handoll, D. (2003). Quantification of badger (*Meles meles*) sett activity as a method of predicting badger numbers. *Journal of Zoology, 259*(1), 49-56.

Weinmann, S., (2018). *Impacts of Elephant Crop-Raiding on Subsistence Farmers and Approaches to Reduce Human-Elephant Farming Conflict in Sagalla, Kenya* (Graduate Thesis, Report no. 11194). *University of Montana ScholarWorks*.

Woodroffe, R., Thirgood, S., & Rabinowitz, A. (2005). The future of coexistence: Resolving human–wildlife conflicts in a changing world. In R. Woodroffe, S. Thirgood, & A.

Rabinowitz (Eds.), *People and Wildlife, Conflict or Co-existence?* (pp. 388-405). Cambridge: *Cambridge University Press*.