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Field guarding as a crop protection method: preliminary implications for improving field guarding

Leah J. Findlay, Department of Anthropology, Durham University, Durham DH1 3LE, United Kingdom; and Primate & Predator Project, Alldays Wildlife & Communities Research Centre, P.O. Box 483, Alldays 0909, South Africa *l.j.findlay@durham.ac.uk*

Russell A. Hill, Department of Anthropology, Durham University, Durham DH1 3LE, United Kingdom; Primate & Predator Project, Lajuma Research Centre, P.O. Box 522, Louis Trichardt (Makhado) 0920, South Africa; and Department of Zoology, University of Venda, Thohoyandou 0950, South Africa

Abstract: Negative interactions between crop farmers and wild primates are an issue of significant concern. Despite many crop farmers using field guards as a method of crop protection against foraging primates, there are very few published accounts of how effective this technique is and how it might be improved. To bridge this knowledge gap, we used direct observations from a hide to collect the behaviors of field guards, chacma baboons (*Papio ursinus*; baboons), and vervet monkeys (*Chlorocebus pygerythrus*; vervets) foraging in a 1-ha butternut squash (*Cucurbita moschata*) field for 4 months (May to August) in 2013 on a 564-ha commercial farm in the Blouberg District of South Africa. Only half of the crop-foraging events were chased by field guards, with vervets being chased much less frequently than baboons. Guards responded more often to events with greater primate numbers and to those that occurred earlier in the day. Guard delay in responding to crop-foraging events and baboon delay in responding to the guard both increased in the low productivity season. Baboon response delay also increased with more animals involved. Based on this case study, we suggest recommendations to improve the effectiveness of field guarding. This includes implementing an early warning alarm system, shortening field guard shifts, increasing guard numbers during the morning and low productivity season, and increasing the perceived fear of field guards, potentially by employing male guards or providing uniforms and deterrent accessories. Further evaluation in other local contexts will help determine how these findings can be adopted on a wider scale.

Key words: baboon, *Chlorocebus pygerythrus*, crop damage, crop guarding, crop raiding, human–wildlife conflicts, mitigation, *Papio ursinus*, South Africa, vervet monkey, wildlife damage management

The complex nature and increasing severity of human–wildlife conflict has made it a serious issue to wildlife management (Anand and Radhakrishna 2017). One of the most common causes of conflict is crop foraging (often termed crop raiding), defined as wild animals moving from their natural habitat onto agricultural land to feed on the produce that humans grow for their own consumption (Hill 2017*a*). Crop foraging results in economic and opportunity costs for people and when retaliation is lethal, increased mortalities for wildlife (Starin 1989, Mackenzie et al. 2015, Ango et al. 2016, Anand et al. 2018). Primates are among the most problematic species that damage crops, with baboons (*Papio* spp.) often recorded as the most damaging of all primates (Hill 1997, Linkie et al. 2007, Hill 2018, Findlay and Hill 2020). As such, many agriculturalists attempt to deter primates from entering their crops using a number of methods.

Strategies to keep primates and other wildlife away from crops must increase the risk of foraging enough to outweigh the nutritional benefits of feeding on crops (Lee and Priston 2005, Fehlmann et al. 2017) and/or use up the extra time afforded to the animals by the increased foraging efficiency of feeding on crops (Strum 1994, 2010; Hill 2017*b*). However, as primates are highly intelligent and adaptable, farmers often have little success preventing them from damaging their crops (Mason 1998, Warren 2008, Pahad 2010, Mackenzie and Ahabyona 2012). While many crop protection strategies have been proposed, few have been evaluated for their effectiveness (Hill 2018); further work is therefore required to develop and evaluate effective solutions.

Guarding is one of the most common mitigation strategies used by crop farmers (Naughton-Treves 1997, Sekhar 1998, Arlet and Molleman 2010, Mackenzie and Ahabyona 2012). Crop guarding involves maintaining human presence at crop fields and chasing animals away when they enter the fields to forage. Crop guarding requires low financial investment (Wang et al. 2006) but is labor and time intensive (Hill 2005, Lee and Priston 2005), and it carries the risk of guards being harmed by the wildlife they chase and contracting diseases such as malaria when spending the extra time outdoors, especially if guarding at night (Tchamba 1996, Osborn and Hill 2005). Guarding can also lead to missed opportunity costs, such as children being held back from school to protect crops (Mackenzie et al. 2015).

Crop guarding is often perceived by farmers as one of the most effective methods at reducing crop damage by wildlife (Studsrød and Wegge 1995, Sekhar 1998, Arlet and Molleman 2010, Thapa 2010), yet few studies have systematically investigated its effectiveness (Riley 2007, Warren 2008, Hill and Wallace 2012, Schweitzer et al. 2017). Furthermore, despite being the favored strategy by many farmers, crop guarding does not provide 100% protection against wildlife crop damage (Sekhar 1998, Hill 2000, Nyirenda et al. 2018), yet there is no published literature detailing how to improve it. Lastly, most current literature focuses on subsistence farming, with no published studies about crop guarding on commercial farms.

While most crop-foraging literature focuses on subsistence farming (Tchamba 1996, Siex and Struhsaker 1999, Nahallage et al. 2008, Waters 2015), primate crop damage on commercial farms, where both large corporate farms and family farms send produce to national and international markets, is also a major problem and presents challenges of its own. While commercial farmer livelihoods may not be completely at risk from crop damage, as can be the case with subsistence farmers (Naughton-Treves 1997), access to staff and technology means they often have a greater impact on or even can eradicate crop foragers from their area (Lamarque et al. 2008).

Several studies, however, have provided anecdotal evidence on factors that may affect the success of guarding. Guarding will only be effective if the animal being chased is afraid of people. King and Lee (1987) suggest that a uniformed guard known to primates as dangerous is enough to make a group flee, while Strum (1994) suggests adding elements that animals perceive as life-threatening improves guarding by increasing risk. As such, guards carrying stones, slingshots, or other accessories are more successful at deterring crop-foraging animals (Osborn and Hill 2005). Men are more effective at deterring primates than women or children with primates retreating more readily when approached by male guards (Strum 1994, Hill 1997, Strum 2010, Lemessa et al. 2013).

The success of crop guarding is also determined by how it is performed. For maximum effectiveness, guards need to take an active approach, patrolling fields and making noise (Nijman and Nekaris 2010, Strum 2010, Hill and Wallace 2012, Hill 2018). Chasing must be vigorous to use up the extra time primates gain from foraging on crops (Strum 1994). Guarding improves when performed continuously throughout the cropping season, particularly prior to and during harvests, and when it is intensified during crop foragers' activity peaks (Hill 2000, Lee and Priston 2005, Ango et al. 2016). Increasing the number of guards should also increase effectiveness (Admassu 2007). Lastly, cooperation between farmers can reduce costs and time investment required to guard (Marchal and Hill 2009, Hedges and Gunaryadi 2010), while sharing of information between farmers about crop-foraging animals has also been shown to benefit crop protection strategies (Ango et al. 2016).

In a paper on primate crop-foraging behavior on a commercial farm in South Africa (Findlay and Hill 2020), we showed that chacma baboons (*Papio ursinus*; baboons) caused more crop damage than vervet monkeys (*Chlorocebus pygerythrus;* vervets), foraged on crops more in the mornings than the afternoons, and their rates of crop foraging were influenced primarily by natural vegetation productivity, increasing significantly when normalized difference vegetation index (NDVI) values dropped below 0.32. Vervet monkey rates of crop foraging were primarily influenced by the presence of baboons. Recommendations to improve current deterrent methods were also suggested, namely

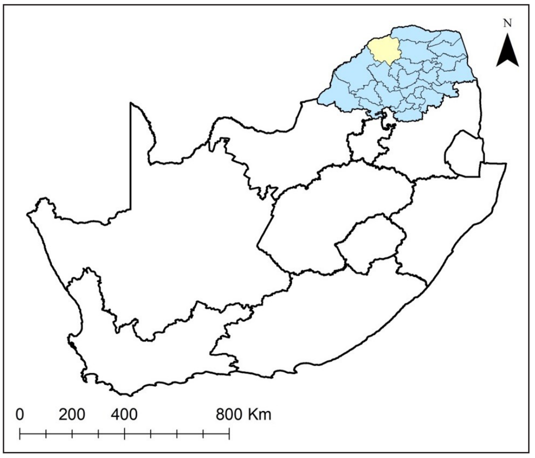

Figure 1. Location of Blouberg Municipality (yellow) within Limpopo Province (blue), South Africa, where the commercial crop farm was located.

increasing deterrent efforts during mornings and when natural vegetation drops below an NDVI value of 0.32, chasing baboons and vervets further from the farm rather than just out of the crop fields, and increasing the perceived risk of guards.

The paper did not, however, consider the impact of crop guarding on primate crop-foraging behavior. In this paper, we investigate current field guarding behavior on the same commercial farm in South Africa to determine its effectiveness in deterring baboons and vervets from crop foraging. We also determined factors that affect the success of guarding, generating suggestions for how commercial farmers and guards could improve guarding effectiveness and implement some of the recommendations made in Findlay and Hill (2020).

Study area

We conducted our case study on a commercial farm located within the Blouberg District Municipality, Limpopo Province, South Africa (22°40′08.05″S, 28°46′47.73″E; Figure 1). The farm lies within the Limpopo Sweet Bushveld vegetation type, with the region recognized as an important area for crop production in South Africa (Tibane 2015). The climate is semi-arid with warm, wet summers (October to March) and cooler, dry winters (April to September); mean annual temperature is 25°C and an annual rainfall is 650 mm. More detailed information on the study site is given in Findlay (2016) and Findlay and Hill (2020).

We selected a representative farm in northern Blouberg for our case study that was also the focus for our research exploring the behavior of the crop-foraging primates (Findlay and Hill 2020). Briefly, the study farm was 564 ha in size, with 80 ha for crops, and was typical to the area in terms of size, crops grown, and farming and mitigation activities. Crops had been produced on this farm for 14 years, and crop-foraging primates had been subjected to shooting for many years (commercial farmer, personal communication). The remaining property was used for game farming of a variety of antelope species (including *Hippotragus* spp., *Tragelaphus* spp., and *Connochaetes* spp.) and contained large areas of more natural habitat. The farm was surrounded by other similar farms. A 1-ha crop field known to receive significant wildlife crop damage served as our primary study area (Findlay and Hill 2020). The farmer planted butternut squash (*Cucurbita moschata*) on January 29, 2013 and harvested for the first time at the end of June and for the last time on August 20, 2013.

Most farmers in the area employ field guards 7 days a week from dawn to dusk to protect their crops, most often unarmed women who chase, shout, and sometimes throw stones at wildlife entering crop fields (Findlay 2016). The study farm employed 7 women as field guards, 3 of which were tasked with protecting 13 adjoining 1-ha crop fields, including our focal field. When primates entered the crop, guards would run toward them while shouting. Often they would pick up stones from the ground and throw them into the natural vegetation surrounding the field where the primates had retreated. On occasion, the guards would also pick up sticks and hit them against a small cattle fence approximately 10 m from the field that bordered the natural vegetation. When primates were not present, guards often carried out other activities at the edge of the crop fields such as cooking, washing, and gardening. Patrols of the fields were not conducted. We do not feel that there was any skewed guarding effort toward the focal field, as all 3 guards were often not visible from the observation point when chasing primates out of other fields.

Methods

We recorded our field observations using binoculars from a blind placed in a corner of the squash field closest to natural bushveld,

Figure 2. Observation hide from which behavioral data collection took place on a commercial farm in Limpopo, South Africa, 2013.

where we could also see the other crop fields (Findlay and Hill 2020; Figure 2). We recorded the number of individuals observed and their locations for baboons, vervets, and field guards (Altmann 1974) from May 7 to August 20, 2013, for 5 days per week from dawn until dusk. We separated days into 2 sessions, morning (0600–1200 hours) and afternoon (1200–1800 hours), swapping observers between sessions to avoid researcher fatigue. We calculated field visits from the time a baboon or vervet was first seen or heard anywhere from the observation point until the last individual was seen or heard, with >1 hour passing with no sightings or vocalizations for a subsequent sighting to be classed as a new field visit. Crop-foraging events started when the first individual entered the crop field and ended when the last individual exited the crop field. A field visit could contain any number of crop-foraging events, including none at all, and several field visits could occur on the same day (Findlay and Hill 2020).

We video-recorded (Canon Legria HFR506, Uxbridge, United Kingdom) and coded primate and guard behaviors (primate species, time when first individual entered the field, the number of additional individuals that entered the field, time when the last individual exited the field, and number of butternut squash each individual was carrying on exit, following Findlay and Hill [2020] as well as guard behavior (whether the event was chased [i.e., the guard walking or running toward the primates] and time of chasing by the field guard). From these data, we extracted the duration of each crop-foraging event, number of individuals involved in each event, number of items removed during each event, whether the field guard chased the animals, guard delay (i.e., the time from the start of the crop-foraging event to the time the field guard starts chasing), and primate delay (i.e., the time from the onset of chasing to the end of the crop-foraging event; Wallace 2010). We estimated the economic costs of baboon and vervet crop damage by using the market value of butternut squash at the time of harvest (R35–40 ZAR [South African rand] per bag, averaging 8 butternuts per bag) and extrapolated the number of items removed from the field to include days we did not observe. We did not survey the crop field for damage, as we did not want our presence within the field to affect subsequent crop-foraging behavior. We were therefore unable to assess the additional damage to crops remaining in the field, and our measure of damage was therefore an underestimate.

Because baboon crop foraging in the same region was shown to increase when NDVI values dropped below 0.32 (Findlay and Hill 2020), we divided the data into 2 seasons, with values above 0.32 classified as high productivity season and values below 0.32 classified as low productivity season. The NDVI was downloaded from Global Land Cover Facility (2015) and calculated from an area with a 2.5-km radius with the study field at its center, with a bimonthly spatial and a temporal resolution of 250 m.

We conducted all data collection under the guidelines and approval of Durham University's Animal Welfare Ethical Review Board (formerly Life Sciences Ethical Review Process Committee), the Department of Anthropology Ethics Committee, and a permit issued from the Limpopo Department of Economic Development, Environment and Tourism. Data collection methods adhered to the American Society of Primatologists Principles for the Ethical Treatment of Non-Human Primates.

Data analyses

We used a generalized linear mixed-effects model (function glmer with binomial distribution) to determine the effects of species, season, session, number of individuals involved, and the raid number for that day on whether the guard responded to crop-foraging events. We used a random sample of 220 data points (49% of available data) balanced across factorial variables for this model to increase model stability,

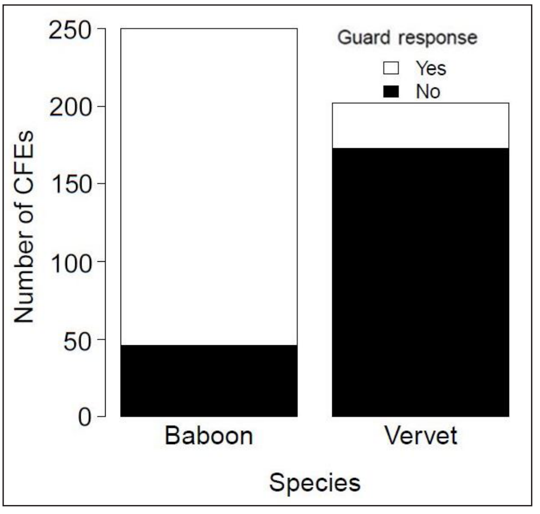

Figure 3. Number of chacma baboon (*Papio ursinus*) and vervet monkey (*Chlorocebus pygerythrus*) crop-foraging events (CFEs) that were chased by field guards, on a commercial crop farm in Limpopo, South Africa, May to August 2013.

with day as a random variable to account for autocorrelation among data points.

We used a linear mixed-effects model (function lmer) to determine the effect of the season, session and raid number for that day, on guard delay. The number of individuals involved was not included in this model as it was too highly correlated with the other predictors. We used baboon data only for this analysis as the sample size for vervets was too small (n = 26). We used a random sample of 66 data points (59% of available data) balanced across factorial variables for this model to increase model stability, with day as a random variable to account for autocorrelation among data points.

We used a linear mixed-effects model (function lmer) to determine the effect of the guard delay, number of individuals, season, session, and raid number for that day on the delay in primates responding. Again, sample sizes were too small for vervets (n = 18), and for baboons we used a random sample of 62 data points (58% of available data) balanced across factorial variables to increase model stability, with day as a random variable to account for autocorrelation among data points.

In all models, we ensured all test assumptions were met (normal distributions for predictors and residuals, collinearity, autocorrelation, and homoscedasticity). Data were transformed and influential cases removed where necessary. Variance inflation factors were used to test for collinearity between predictors, using a cut-off of 4; sample size was always >10 times the number of predictors in the model (R. Mundry, Max Planck Institute for Evolutionary Anthropology, Leipzig, personal communication).

We used a Pearson's correlation to test the effect of guard delay and primate delay on the number of butternut squash removed from the field. We performed all statistical analysis using R (R Core Team 2014) and the following packages within R: lme4 (Bates et al. 2015) and car (Fox and Weisberg 2011).

Results

We recorded 504 crop-foraging events, 4 of which (2 for each species) were removed from further analysis due to their incomplete data on guard behavior. This left a sample of 285 baboon and 215 vervet crop-foraging events. Only 52% (261) of the crop-foraging events were chased by field guards. Field guards were more likely to chase baboons than vervets (β = -4.39, SE = 0.86, z = -5.12, P < 0.001; Figure 3), with 81% of baboon crop-foraging events being chased, while only 14% of vervet crop-foraging events were chased. Guard delay ranged from 0 to 7 minutes and 50 seconds (mean 49 seconds) for baboons and from 0 to 11 minutes and 15 seconds (mean 3 minutes and 48 seconds) for vervets and was positively correlated with the number of butternut squash removed for both baboons (r = 0.551, n = 108, P < 0.001; Figure 4A) and vervets (r = 0.541, n = 26, P = 0.004; Figure 4B). Primate delay ranged from 0 to 6 minutes and 35 seconds (mean 29 seconds) for baboons and from 1 second to 1 minute and 9 seconds (mean = 26 seconds) for vervets and showed a positive correlation with the number of butternut squash removed for baboons (r = 0.220, n = 124, P = 0.014) but not for vervets (r = -0.027, n = 19, P = 0.914).

With each additional individual involved in crop-foraging events the likelihood that the guard responded increased (β = 1.02, SE = 0.41, z = 2.52, P = 0.011; Figure 5A), as did the baboon delay (β = 0.49, SE = 0.10, t = 4.91, P < 0.001; Figure 5B). Crop-foraging events in the morning were more likely to be chased than those that occurred in the afternoon (β = -1.66, SE = 0.66, z = -2.54, P = 0.011; Figure 6). However, when the guard did chase baboons and vervets away in the afternoon, the guard delay was not differ-

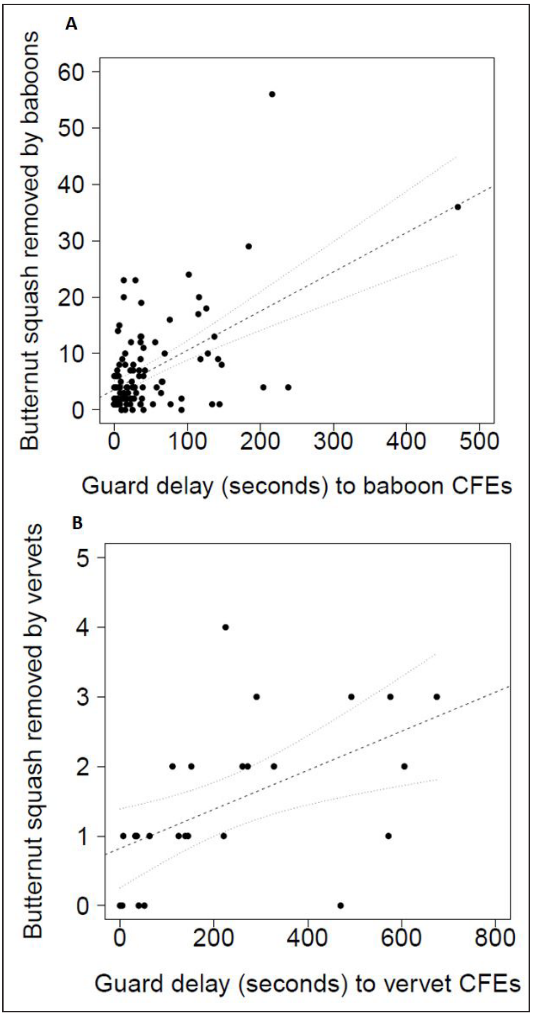

Figure 4. Relationship between the number of butternut squash (*Cucurbita moschata*) items removed by (A) chacma baboons (*Papio ursinus*) and (B) vervet monkeys (*Chlorocebus pygerythrus*) and the guard delay to crop-foraging events on a commercial crop farm in Limpopo, South Africa, May to August 2013. The dashed lines show the linear regression; dotted lines show the confidence interval for the slope estimate.

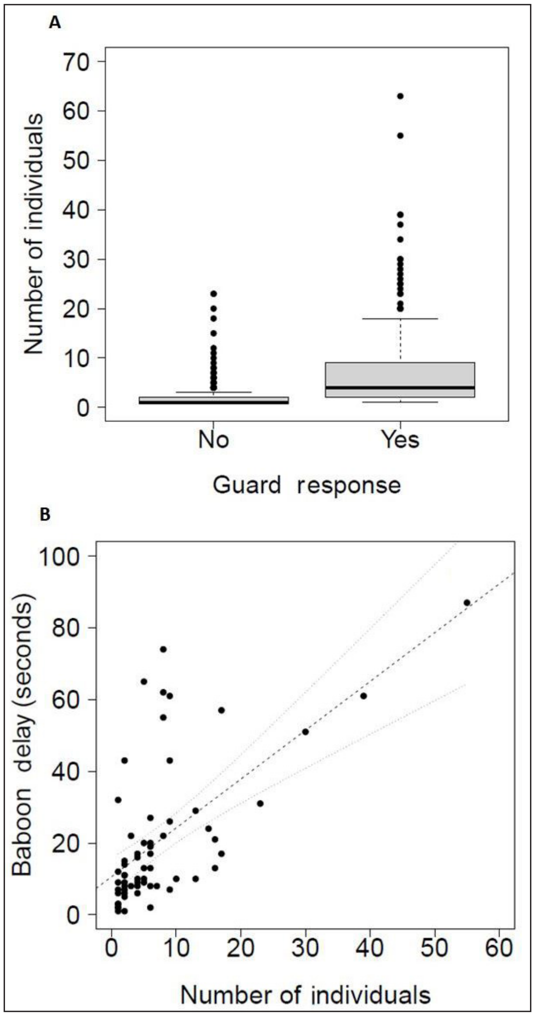

Figure 5. (A) Number of chacma baboon (*Papio ursinus*) and vervet monkey (*Chlorocebus pygerythrus*) individuals involved in crop-foraging events when the field guards do and do not chase the events and (B) relationship between the number of baboons involved in a crop-foraging event and the time it takes them to leave the field once the guard starts chasing, both on a commercial crop farm in Limpopo, South Africa, May to August 2013.

ent from those chased during morning sessions (β = -0.36, SE = 0.41, t = -0.89, P = 0.38), nor was the primate delay (β = 0.002, SE = 0.18, t = 0.01, P = 0.991). The crop-foraging event number of the day did not affect whether the guard chased baboons or vervets away (β = -0.405, SE = 0.365, z = -1.109, P = 0.268), guard delay in starting to chase (β = -0.208, SE = 0.266, t = -0.781, P = 0.438), or the baboon delay (β = 0.109, SE = 0.123, t = 0.883, P = 0.382).

Season did not affect the likelihood that the guard chased baboons or vervets (β = 0.78, SE = 0.57, z = 1.36, P = 0.175), but guard delay did increase in the low productivity season (β = -1.37, SE = 0.42, t = -3.27, P = 0.003; Figure 7A), as did primate delay (β = -0.61, SE = 0.18, t = -3.31, P = 0.005; Figure 7B). Guard delay did not have an effect on primate delay (β = 0.02, SE = 0.07, t = 0.30, P = 0.767).

Discussion

Field guards were regularly observed successfully chasing baboons and vervets out of crops on a commercial farm in Limpopo

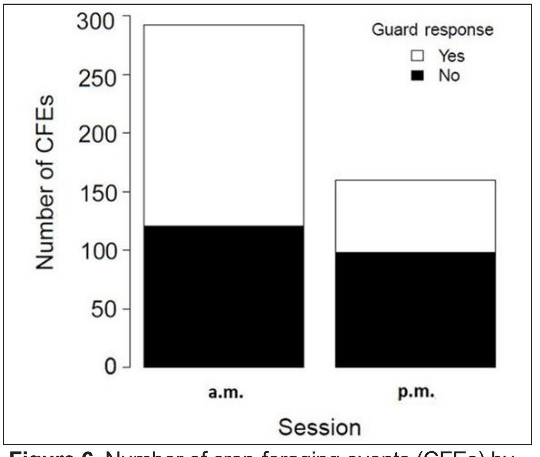

Figure 6. Number of crop-foraging events (CFEs) by chacma baboons (*Papio ursinus*) and vervet monkeys (*Chlorocebus pygerythrus*) during each session that were and were not chased by field guards, on a commercial farm in Limpopo, South Africa, May to August 2013.

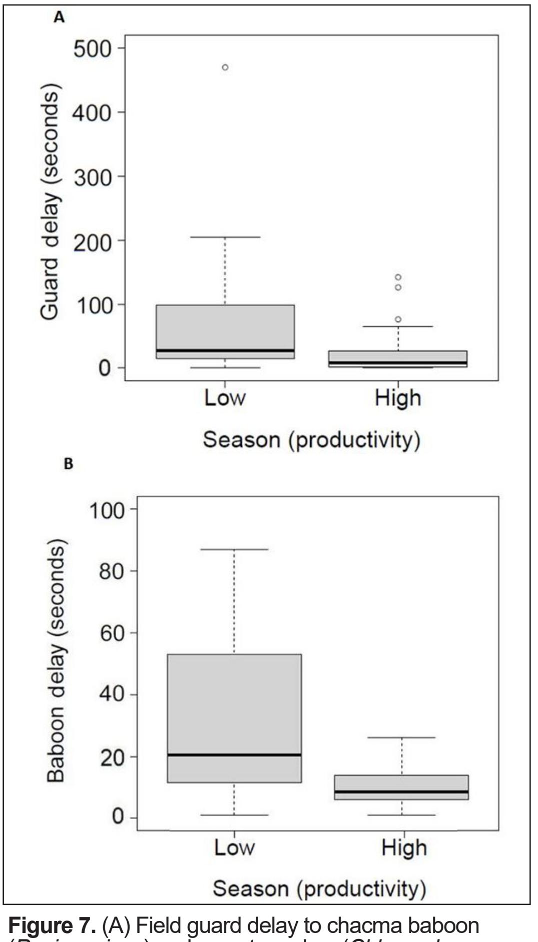

Figure 7. (A) Field guard delay to chacma baboon (*Papio ursinus*) and vervet monkey (*Chlorocebus pygerythrus*) crop-foraging events and (B) baboon delay to the onset of guard chasing, during the high and low productivity seasons, both on a commercial crop farm in Limpopo, South Africa, May to August 2013.

Province, South Africa, with baboons being chased far more consistently and more quickly than vervets. The likelihood of field guards chasing crop foragers was higher in the mornings and increased with increasing number of individuals involved in the event. Guard delay was greater during the low productivity season, when natural habitat productivity was lower, as was baboon delay. Baboon delay also increased with increasing number of individuals involved in the event. Our results concur with other studies that crop guarding is not 100% effective at keeping primates from damaging crops (Warren 2008, Hedges and Gunaryadi 2010, Schweitzer et al. 2017). Nevertheless, our analysis of guarding behavior identified some of the reasons for this as well as avenues to improve guarding success.

The field guards only responded to just over half of all the crop-foraging events, and baboons were chased substantially more often than vervets. Because guard response is relatively high for baboons (81%), the low response rate to vervets is unlikely to be caused by guard negligence. Instead, responding to vervet crop-foraging events may be more difficult because they often enter the crop fields unnoticed. Baboons are larger in body size, enter crop fields in higher numbers, and are more vocal when approaching crops, while vervets are smaller, raid in smaller numbers, and were rarely heard when near the crops (L. Findlay, Durham University, personal observation). Vervets are therefore more difficult to spot when entering crop fields, and with >1 field to protect, the field guards did not detect the majority of vervet crop-foraging events. With 13 fields to protect between 3 guards, this may also be the reason that not all baboon crop-foraging events were chased. Guards not responding to crop-foraging events simply because they are unaware that they are taking place has been seen elsewhere (Wallace 2010, Zak and Riley 2017).

Carrying out activities unrelated to guarding may have also had an effect on the guards' response rates. Hill and Wallace (2012) showed that guarding by individuals specifically employed to guard was more successful than guarding carried out by farmers who were often distracted and preoccupied with other tasks. Similarly, actively patrolling fields has been shown to improve guarding effectiveness and has been recommended elsewhere (Nijman and Nekaris 2010, Hockings 2016, Zak and Riley 2017). Our field guards' response rates may have therefore been improved if they had not engaged in other activities and instead patrolled the fields regularly. Field guards were more likely to respond to crop-foraging events that involved a larger number of individuals, something that has also been reported on subsistence farms (Wallace 2010). This suggests that larger groups are easier to detect and lends credence to the assumption that vervet crop-foraging events are rarely chased because they often go undetected, as they tend to come into crops in smaller numbers than baboons (Findlay and Hill 2020). Developing a system that alerts field guards to the presence of crop foragers has proven effective elsewhere (Osborn and Parker 2002, Sitati and Walpole 2006, Hedges and Gunaryadi 2010, Hill and Wallace 2012) and would both increase the proportion of vervet crop-foraging events chased and aid the guards in responding to events with a low number of participating individuals. This would also allow guards to continue with other activities, such as cooking and washing, without diminishing their ability to detect approaching primates. Further investigation into the type of alarm systems that will work on large-scale commercial farms is required.

The time field guards took to respond to crop-foraging events had a significant effect on both baboon and vervet crop damage; as guard delay increased, so did the number of butternut squash removed from the field. This implies that guarding effectiveness could be improved by reducing the delay between the onset of a crop-foraging event and the start of chasing. The average time it took the guards to respond to crop-foraging events also differed between the 2 species, with guards taking longer to respond to vervet crop-foraging events than baboons. Warren (2008) also recorded guard reaction time to be longer for some species (long-tailed macaques [*Macaca fascicularis*]) than others (olive baboons [*P. anubis*]). Once again, primate body size and strategies of approaching crop fields could explain the difference between species. An early warning alarm system could also help to decrease the reaction time of field guards, irrespective of what species is approaching.

More crop-foraging events were chased during the morning hours than the afternoon. However, when afternoon crop-foraging events are chased, it appears that the field guards do this with as much effort as in the morning, as the delay between the start of the event and the onset of chasing does not change. The crop-foraging event number of the day also appears to have no influence on the time it takes the guards to respond, suggesting that it is not how many raids in a day they must chase that affects their performance, but rather the time that has passed since they started their shift. Guards are employed from sunrise (as early as 0600 hours) to sunset (as late as 1830 hours) and remain at the fields all day. With such long shifts, it is not surprising that fewer events are chased later in the day; it has been shown that performance reduces with longer working hours (Spurgeon et al. 1997). Shortening crop guarding shifts by replacing guards at mid-day with a fresh staff member to avoid the detrimental effects of guard fatigue could increase guarding success.

The season did not influence whether the guard chased a crop-foraging event. However, guard reaction time increased in the low productivity season. Guard delay may have increased during the low productivity season because guards were busy chasing other crop-foraging events in nearby fields, as the number of crop-foraging events increased as the season progressed (Findlay and Hill 2020). Additionally, with temperatures rising (temperatures increased from 22–24°C during the high productivity season to 25–30°C during the low productivity season), an increase in guard delay could reflect the guards' lethargy due to increased temperatures. Increasing the number of crop guards to ensure 1 guard per field when crop-foraging events start to rise, coupled with their replacement in the middle of the day, could thus bring significant benefits for crop protection; increasing the number of people on guard has also been suggested in other regions (Nijman and Nekaris 2010, Ango et al. 2016). Because a decrease in natural habitat productivity was found to coincide with an increase in baboon crop foraging (Findlay and Hill 2020), a good indicator for commercial farmers to place extra guards at their crops could be linked to NDVI or when the farmers start putting out supplemental feed for their game animals.

Baboon reaction time to the field guards, measured from the time the guard starts chasing to the time the crop-foraging event ends, was also greater in the low productivity season. Since low natural habitat productivity sees an increase in the frequency of crop foraging, presumably because there is little else to eat (Findlay and Hill 2020), it is likely that the benefits gained through crop foraging increase during this time, and as such outweigh the risk of being caught by the field guards. This reaction time also increases as the size of the foraging group increases. While it could be assumed that it takes longer for more participants to leave the field, it is known that smaller groups perceive themselves to be more at risk (Hill and Lee 1998; something that would be predicted by the dilution effect: Hamilton 1971), and therefore, larger foraging groups perceive less of a risk from the guards. Both these observations suggest that guarding could be improved by increasing the perceived fear of field guards.

Guards that are known to be dangerous are more effective than unfamiliar guards (King and Lee 1987), and those with weapons are perceived as more of a threat (Strum 1994, Hill 1997, Strum 2010). There are also many accounts of women and children not being particularly effective guards; men appear to be more intimidating to primates (Box 1991, Sillero-Zubiri and Switzer 2001, Hill 2005, Lemessa et al. 2013). To increase guard effectiveness, we therefore recommend equipping guards with uniforms and nonlethal accessories, such as projectiles and noise makers, which are regularly used toward but not directly at the baboons and vervets to maintain levels of intimidation. We also recommend using the same guards on the same fields and not rotating where guards are located on the farm so they become known to the animals and are able to learn how the animals behave in their crop fields, such as where their common entry points are. A last resort would be to use men rather than women guards, but the socioeconomic effects on the women being replaced should be seriously considered before any decisions are made.

We recognize that our study was conducted on a single-crop field in a single-crop season, and thus our recommendations are site-specific to our local context. However, we feel our results provide a good starting point for the gathering of information on the effectiveness of crop guarding on commercial farms and for commercial farmers to consider strategies to improve guarding. While mitigation recommendations exist in the literature for subsistence farming, commercial farmers differ in terms of the scale of investment they are able to put into deterrents as well as the scale of their farming areas and should be considered separately. Furthermore, our results come from observational techniques, which are empirically more robust than indirect or interview approaches that much of the current crop-foraging literature is based on.

Management implications

Crop guarding is an effective wildlife crop-foraging mitigation strategy and should continue to be employed by crop farmers. However, there are methods that could be employed to increase its effectiveness, although considerations should be made on the additional costs these will involve. At this local level, we recommend implementing an early warning alarm system, reducing the amount of non-guarding activities guards engage in, requiring guards to actively patrol fields, shortening field guard shifts, increasing the number of guards during the morning and low productivity season, and increasing the perceived fear of guards, potentially through providing uniforms and deterrent accessories. Of course, guarding may not be the only effective deterrent strategy available, and other options may be used alongside guarding. Further site and species-specific information would need to be collected to generalize our results beyond the study farm.

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Associate Editor: Francesco M. Angelici

Leah J. Findlay is the research coordinator at Durham University's Primate and Predator Project's Alldays site, South Africa. For the last 8 years, her research has focused on primates and their interactions with people, particularly crop farmers. Along with obtaining a baseline understanding of wild primate behavior within farmland, her research also involves developing and testing solutions to the negative effects of primate crop foraging.

Russell A. Hill is a professor of evolutionary anthropology and currently joint head of the Department of Anthropology at Durham University, United Kingdom. He has conducted research on baboons in South Africa for >20 years and now runs the Primate and Predator Project in the Soutpansberg Mountains and surrounding farming areas in Limpopo Province. His research focuses on the behavioral ecology of primates and other large mammals, particularly carnivores, and how predation and the landscape of fear shape behavior. Increasingly, his work investigates human–wildlife interactions from an interdisciplinary perspective that integrates qualitative and quantitative approaches.