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Short communication

Can zoo enclosures inform exclosure design for crop-raiding primates? A preliminary assessment

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Introduction

Crop raiding by wildlife is one of the major causes of human–wildlife conflict in Africa with many primate species cited as problematic (Naughton-Treves, 1998; Hill, 2000; Hoffman & O'Riain, 2012; Healy & Nijman, 2014). Primates are intelligent, opportunistic animals, and baboons (*Papio* spp) have nonspecialised omnivorous diets (Hill, 2000) that allow them to adapt quickly to living alongside humans and exploiting human food resources (Hill, 2000). Crops, in particular, can provide wild primates with an alternative and accessible food source (Hill & Wallace, 2012). As group sizes of raiding species such as baboons can exceed seventy individuals, the effect of a single raid on a crop field can have devastating effects for farmers (Hill, 2000).

Research into crop-raiding prevention has shown that it is a complex issue requiring mitigation methods to be tailored towards specific species and situations (Saraswat, Sinha & Radhakrishna, 2015). Farming practices can be adapted to reduce crop damage by wildlife through planting unpalatable crops, planting buffer zones of highly palatable crops to protect main crops or leaving land fallow (McGuiness & Taylor, 2014). Alternative methods employed by farmers to prevent crop losses range from noise-making scaring devices, net wires, scarecrows, trenches, biofences (Thapa, 2010), reflective prisms (Kaplan & O'Riain, 2015), spraying chilli grease around farm boundaries (Sitati & Walpole, 2006), as well as poison, snares, traps (Naughton-Treves, 1998) and lethal removal of problem animals (McGuiness and Taylor, 2014). Many methods tend to have only temporary success, with raiding wildlife driven away initially but subsequently returning to raid crops (Thapa, 2010).

Active guarding by people and guard animals (McGuiness & Taylor, 2014) and improved fencing are mitigation methods shown to be effective in reducing crop-raiding damage in the long term (Hill, 2000; Hill & Wallace, 2012; Karanth, Naughton-Treves & Gopalaswamy, 2013). Active guarding is time-consuming and labour-intensive for farmers (Thapa, 2010) and can impose social costs on communities where children are needed to guard crop fields when they would otherwise be attending school (Linkie *et al.*, 2007). Fences provide protection for crops against damage by wildlife, but their use is often limited by the costs of construction and maintenance (McGuiness & Taylor, 2014; Hill & Wallace, 2012; Thapa, 2010). Where fences are employed, their heights (most often between 1–1.5 m) may be sufficient to exclude animals such as porcupine (*Hystrix africaeaustralis*) and pig species (*Phacochoerus africanus, Potamochoerus larvatus*), but are not always effective in excluding primates which can climb and larger ungulates that can jump over the fence (Thapa, 2010). Increasing the height of a farm's barbed wire fence resulted in an 80% reduction in maize damage by primates in Uganda (Wallace & Hill, 2012), while electric fencing has also been used by farmers with some success to deter primates. This is an expensive, maintenance-heavy option (Thouless & Sakwa, 1995), however, and not available to many subsistence farmers living in rural locations. Additionally, electric fences also pose high risks to other, nontarget wildlife species (Beck, 2010).

Here, we tested whether a fence design typically employed in preventing captive primates escaping zoo enclosures (Fig. 1) could be used to prevent wild primates from accessing food. If successful, the design would improve on existing physical barriers with little additional maintenance and labour costs, while reducing the financial costs and wildlife damages associated with electric fences.

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Fig 1 Examples of barrier fence designs used in zoo enclosures of (a) one acre housing lemurs at Yorkshire Wildlife Park, UK, and (b) 60 acres housing Barbary macaques at Trentham Monkey Forest, UK

Methods

The trials were conducted at the Lajuma Research Centre in the Soutpansberg Mountain Range, South Africa (23°02′23″S & 2920′05″E). The climate is temperate-mesothermal with vegetation types including forest, grassland and savannah biomes (Mostert *et al.*, 2008). Several wild chacma baboon (*Papio ursinus*) groups are present at the site with one group fully habituated to human observers. We thus had the potential to determine the effectiveness of the fence design on both habituated and nonhabituated groups; this is important as habituated animals may be more relaxed around man-made structures and so are more willing to enter farmland and spend more time trying to gain access to food.

We built three triangular exclosures (3 × 3 × 3m) of three different heights (2, 3 and 3.5 m) in an open bushveld area (30 m from the forest edge) known to be frequented by a number of baboon groups (Fig. 2a–c). We used wire mesh (squares $5\ cm^2$) and eucalyptus poles topped with a barrier of sheet metal (1 m high and 0.5 mm thick). The metal sheeting was attached to horizontal poles that were mounted on brackets fixed to the tops of the vertical poles. This held the barrier 30 cm away from the sides of the exclosure to create an overhang (Fig. 2a). Wire mesh wrapped over the horizontal poles and fixed to the sides of the exclosures closed any gaps between the fencing and the barrier. We chose a height of 1 m for the barrier as this exceeded the arm reach of the baboons. About 0.5 m of the barrier extended above the fence line and 0.5 m hung below (Fig. 2a,b) as in zoo enclosure designs (Fig. 1a,b). Although it is common practice to bury fences 0.5–1 m deep in the ground to

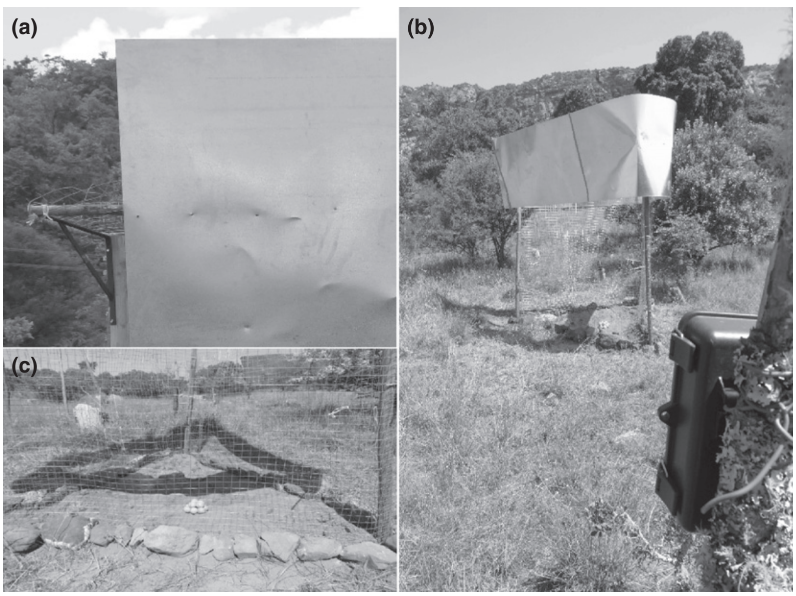

Fig 2 Fence design with (a) the bracket positioned to hold the barrier away from the fence mesh, (b) the completed 3 m high exclosure with camera trap in foreground and (c) the position of bait in centre of exclosures

deter burrowing species, the rocky terrain in the test area made this difficult. For the purposes of our experiment, we buried the mesh just 10 cm deep and surrounded the base of the fence with rocks.

We baited each exclosure with twelve oranges piled in the centre beyond the reach of the baboons from the sides (Fig. 2c). A pair of motion-activated Bushnell® Trail cameras (Trophy, model, 2010, Non Typical Inc., USA) were positioned on opposite sides of each exclosure to capture video footage of all animal visits. Videos were downloaded and reviewed daily at 18:00 hours with all visits from primates and other animals and their outcomes recorded by the first author. The habituated baboon group was distinguished from the nonhabituated groups through identification of known individuals. We tested the effectiveness of the fence design for preventing access to crops for an eight-day period between the 10 and 17 February 2015. We conducted all data analyses using IBM SPSS statistics for Windows version 20, with significance levels set at $P < 0.05$.

Results

Upon discovery of the bait, baboon groups visited every day until the end of the study. A total of 161 individual baboons from at least two different groups were filmed at the exclosure site, including individuals of all age/sex classes (adult males 18%; adult females 25%; adolescents/juveniles/infants 57%). In 34 cases, individuals showed no apparent reaction to the exclosures or the bait within. Of the remaining events, 49 baboons were observed repeatedly circling the exclosure while glancing at the barrier and bait (Video S1), while 78 were standing or sitting at the exclosure fence and looking towards the barrier and bait (Video S2). In 80 of these 127 cases, individuals then made no further attempts to reach the bait within the exclosures. Secondary responses included 47 active attempts to reach the bait through climbing the fence or manipulating it (reaching through the mesh, pulling on the mesh, moving the rocks or digging at the base of the fence) (Table 1). Each fence height proved successful in keeping out both habituated and nonhabituated wild baboons.

The habituated baboon group spent significantly longer at the bait site than nonhabituated baboons (habituated group: 85.3 ± 56.7 min; nonhabituated groups: 31.3 ± 15.6 min; $t = -2.41$, df = 7.03, $P = 0.047$). Habituated baboons also made significantly more attempts per visit to manipulate the structure to gain access to the bait (habituated group: 5.86 ± 3.97 attempts; nonhabituated groups: 1.26 ± 0.52 attempts; $t = -3.06$, df = 7.38, $P = 0.017$). There was a trend for duration of visit to decline over time for habituated group ($r = -0.671$, n = 7, $P = 0.099$), but not the nonhabituated groups ($r = 0.673$, n = 6, $P = 0.143$).

Table 1 Number of visits, duration of visit at the experimental site and number of active attempts made per visit to gain access to the bait in both groups

	Habituated baboons		Non-habituated baboons	
Visit number	Time at site (minutes)	Active attempts on bait	Time at site (minutes)	Active attempts on bait
1	162	11	6	0
2	157	0	31	2
3	22	4	46	3
4	104	3	23	0
5	35	8	34	1
6	58	10	48	0
7	59	5	–	–
Mean	85.3	5.86	31.3	1.26

Discussion

Game fences are widely used to mitigate human–wildlife conflict, but appropriate design, alignment and maintenance are key to their effectiveness (Kesch, Bauer & Loveridge, 2015). The results presented here suggest that crop depredation by wild primates may be reduced or even prevented through the use of relatively simple fencing techniques based on zoo exhibit design, where a barrier is placed around the top of the fence. Furthermore, a fence as low as 2 m could be effective in excluding baboons of all age–sex classes.

The habituated baboons spent more time at the exclosures and attempted to reach the bait more times than the nonhabituated baboons. Despite the short duration of our study, therefore, the results cannot be explained by neophobia, as animals regularly exposed to human presence spent long periods interacting with the fences and attempting to reach the food. The fact that time spent at the exclosure declined on subsequent visits suggests that the animals in the group became increasingly aware of the inaccessibility of the food.

After initial construction efforts, physical barriers require little from farmers other than maintenance costs and labour (Hill & Wallace, 2012). The barrier and overhang elements of the design are the important features which prevent the primates from climbing over. Any durable material can be used for the barrier around the top of the fence – heavy duty plastic (most common in zoos), metal and wood – and should be applicable to a broad range of species. The fence design tested here provides an adaptable, nonlethal, long-term method of protecting farmers' crops against primates. The next step will be to conduct a larger, field-scale trial using this fence design to further assess its utility in reducing human–primate conflict.

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Supporting information

Additional Supporting Information may be found in the online version of this article:

Video S1. Camera trap video footage showing baboons repeatedly circling the exclosure fence and glancing at the bait and barrier.

Video S2. Camera trap video footage showing baboons standing or sitting outside the exclosure fence and looking at the bait and barrier.