# Panic at the disco: solar-powered strobe light barriers reduce field incursion by African elephants *Loxodonta africana* in Chobe District, Botswana

TEMPE S. F. ADAMS, ISAIAH MWEZI and NEIL R. JORDAN

**Abstract** Managing interactions between humans and wild elephants is a complex problem that is increasing as a result of agricultural and urban expansion into and alongside protected areas. Mitigating negative interactions requires the development of new tools to reduce competition and promote coexistence. Many studies have tested various mitigation techniques across elephant ranges in Africa and Asia, with varying levels of success. Recently, strobe lights have been suggested as a potential mitigation strategy in deterring African lions *Panthera leo* from kraals or bomas, but this technique has to date not been tested to reduce negative human–elephant interactions. Over a 2-year period (November 2016–June 2018), we tested the effectiveness of solar-powered strobe light barriers in deterring African elephants *Loxodonta africana*, in collaboration with 18 farmers in a community adjacent to the Chobe Forest Reserve and Chobe National Park in northern Botswana. Although elephants were more likely to pass by fields with solar-powered strobe light barriers (which was probably a result of selection bias as we focused on fields that had previously been damaged by elephants), they were less likely to enter these treatment fields than control fields without such barriers. Our findings demonstrate the efficacy of light barriers to reduce negative human–elephant interactions in rural communities.

**Keywords** African elephant, Botswana, conservation, human–elephant conflict, human–wildlife interactions, *Loxodonta africana*, mitigation, solar-powered strobe light barrier

## Introduction

Human population increase and rapid urbanization are resulting in increased negative interactions between people and elephants across their range (Osborn & Parker, 2003; Kansky & Knight, 2014; Ngama et al., 2016; Mumby & Plotnik, 2018). Consequently, there is a growing need to develop, test and implement effective mitigation methods that reduce such interactions (Karidozo & Osborn, 2015; Mumby & Plotnik, 2018; Shaffer et al., 2019). Management of negative human–wildlife interactions requires a holistic approach that considers social and cultural aspects, combined with political support, to implement meaningful and successful mitigation (Demotts & Hoon, 2012; Hoare, 2015; Adams et al., 2017b). Although the drivers of these so-called human–wildlife conflicts are complex, and include social, historical and economic factors, there is a dearth of technical solutions to these problems (Webber et al., 2007; Mackenzie & Ahabyona, 2012; Kansky & Knight, 2014; Shaffer et al., 2019).

Many wildlife species come into conflict with humans, in a wide variety of situations (Balmford et al., 2001; Crespin & Simonetti, 2019). One of the most iconic species involved in negative interactions with humans is the African elephant *Loxodonta africana*, which is forced into closer contact with people as more of the species' historical range is transformed to accommodate a rapidly expanding human population (Hoare, 2015). As a result human–elephant interactions, including human–elephant conflicts, which are broadly defined as any interaction which 'results in negative effects on human, social, economic, or cultural life, on elephant conservation, or on the environment' (Parker et al., 2007, p. 11), are increasingly common. The best approach to reduce such interactions is to prevent them, for example through careful land-use allocation that does not encourage crop production adjacent to wildlife areas. However, in most of the elephant's range the opportunity for land-use planning that takes into account the needs of wildlife has been missed and most land has already been allocated and developed (Gunaryadi et al., 2017). It is thus necessary to implement effective mitigation methods to manage human–elephant interactions.

Competition for resources can have a complex and long-term impact on the livelihoods of communities who live amongst elephants (Mayberry et al., 2017). Incidents are often most common where elephants occur in large numbers and where protected areas abut agricultural fields (Mackenzie & Ahabyona, 2012; Hoare, 2015; Shaffer et al., 2019). Negative interactions can result in biodiversity loss, damage to property, social costs (including loss of income), and loss of human and elephant lives (Parker et al., 2007; Mackenzie & Ahabyona, 2012; Hoare, 2015). There is thus a need across the elephant's range for effective and low-cost methods for keeping elephants out of fields, especially

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techniques that farmers can and want to implement (Davies et al., 2011; Gunaryadi et al., 2017).

The systematic study of negative human–elephant interactions and possible interventions began in the mid 1990s and a wide range of mitigation methods have since been developed and tested in areas with high levels of such interactions in both Africa and Asia (Hoare, 2015; Shaffer et al., 2019). Many methods focus on exclusion, aiming to prevent negative interactions by separating elephants and people (Shaffer et al., 2019). These methods include fencing, olfactory and auditory deterrents, explosive devices, beehives, ecological wildlife corridors and zonation (Osborn & Rasmussen, 1995; O'Connell-Rodwell et al., 2000; Sitati et al., 2003; Parker & Osborn, 2006; Sitati & Walpole, 2006; Graham & Ochieng, 2008; King et al., 2009, 2011; Davies et al., 2011; Hoare, 2015; Adams et al., 2017a). Electric fences in particular have been used extensively in southern Africa (O'Connell-Rodwell et al., 2000; Hoare, 2003; Parker et al., 2007; Davies et al., 2011) and although they are often effective in separating elephants and areas used by people, their dependence on electricity makes them costly to install and maintain (Hoare, 2003, 2015). The same applies to Geo-fencing, an alert system working with GPS collars, which is effective when known so-called problem elephants can be monitored and deterred from entering a particular area (Hoare, 2015). However, Geo-fencing is time- and cost-intensive, and not effective in areas that are heavily frequented by elephants. As a result lower-cost solutions have also been developed. For example, the burning of chili seeds is an effective elephant deterrent for protecting small crop fields or nurseries, although the success of this intervention depends on the method of application (Osborn & Rasmussen, 1995; Parker & Osborn, 2006; Sitati & Walpole, 2006). Beehive fences have also been successfully installed to reduce negative interactions between elephants and people, primarily in East Africa (King et al., 2009, 2011, 2017); they are relatively low-cost and can provide additional economic and nutritional returns to farmers (King et al., 2017).

Even when effective in certain situations, no single solution can be expected to be successful in all circumstances. For example, the demand for chilli peppers in the quantities needed to be effective can surpass the supply in some regions (Parker & Osborn, 2006; Hoare, 2015). Beehive fences may not be effective in areas with a low bee population, where elephants do not display strong avoidance behaviours (Adams, 2016b). There remains a need for research and development of additional mitigation tools and strategies, especially given that elephants are intelligent (Mumby & Plotnik, 2018) and can become habituated by repeated use of existing tools (O'Connell-Rodwell et al., 2000).

Botswana is home to the largest elephant population in Africa (c. 125,000; Chase et al., 2019). The Chobe District has an estimated population of 32,712 elephants in the dry season (Chase et al., 2019), which live alongside a human population of 23,347 (Census Office, 2015). As a result, this district is a hotspot for human–elephant interactions in Botswana (Gupta, 2013; Adams et al., 2017a), and elephants cause the greatest proportion (48%) of problem animal control reports in the area (DWNP, 2018). Incidences of elephants feeding in crop fields and gardens, and causing other property damage, are the most common reports received by the problem animal control officers in the Department of Wildlife and National Parks. Given the size of the elephant population in Botswana and the high rates of problem animal control reports, developing successful mitigation solutions is of high priority to stakeholders in the country (Adams et al., 2017b).

We tested a novel method for reducing human–elephant interactions in the Chobe District of Botswana. Our objective was to investigate whether night-time incursions into fields previously damaged by elephants could be reduced by installing solar-powered strobe light barriers. Although similar techniques have been tested to deter predators and birds from livestock, gardens and properties (Lesilau et al., 2018; Foxlights, 2019; NiteGuard, 2019; Ohrens et al., 2019; Predator Guard, 2019) to our knowledge this is the first trial testing whether solar-powered strobe light barriers can deter elephants from entering fields. Based on results from other species (e.g. lions; Lesilau et al., 2018; Ohrens et al., 2019) and observations of elephants retreating from single torches (Davies et al., 2011) and vehicle lights (Adams, 2016a) we predicted that solar-powered strobe light fences would reduce the frequency of field incursions by elephants.

## Study area

We conducted the study near the villages of Muchenje, Mabele, Kavimba and Kachikau (combined human population 4,034; Census Office, 2015) in the Chobe Enclave, in the 22,560 km² semi-arid Chobe District of northern Botswana (Fig. 1).

The area is surrounded by unfenced protected wildlife areas, the 10,740 km² Chobe National Park and the 1,545 km² Chobe Forest Reserve on the eastern and southern boundaries of the Chobe Enclave and the Namibian border and the Kwando-Linyanti-Chobe river system on the northern and western boundaries (Fig. 1). A large proportion of the Chobe Enclave is a seasonal floodplain that is reliant on rainfall in the mountains of Angola. The soil in Chobe District is predominately Kalahari sand, but is nutrient-rich in the floodplain, characterized by alluvial and lacustrine deposits. The district contains the only forest in Botswana with a relatively closed canopy (Lepetu, 2007). The vegetation is dominated by *Baikeaea plurijuga* and *Acacia erioloba* and is consistent with the Zambezian biogeographical region (Lepetu, 2007). North Botswana has four seasons, including a hot dry (August–October), wet (November–March), post-

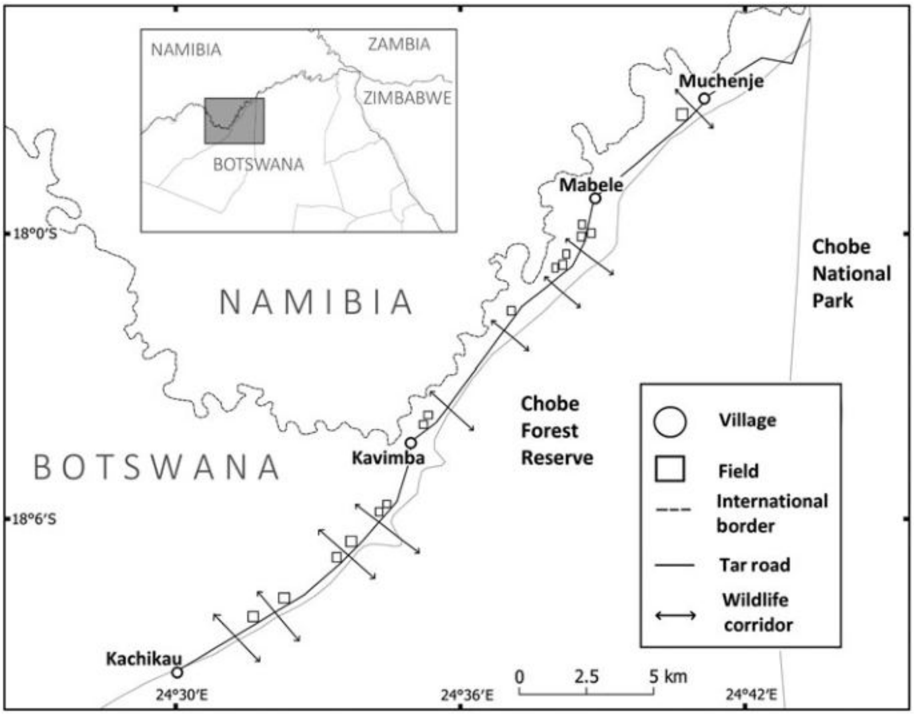


FIG. 1 Location of the study crop fields in and around each village located in the Chobe Enclave in north-eastern Botswana.

wet (April) and cold dry (May–July) season (Adams et al., 2017a).

The floodplain area is dominated by small-scale subsistence farming, with cultivation occurring in October–November and harvesting during February–May, depending on the timing of annual rainfall. Arable farming and livestock production are the primary traditional livelihoods in the area (Gupta, 2013). The Chobe Enclave has one of the highest dry-season densities of elephants in the country, with an estimated 2.94 elephants per km$^2$ (Chase et al., 2019). Elephants travel from the Chobe National Park and Chobe Forest Reserves through the Chobe Enclave to access water on the floodplain, browse on acacia *Vachellia tortilis* and *A. erioloba*, and graze on nutrient rich grass, during the night-time. In all study villages elephants are responsible for the majority of problem animal control reports made to the Department of Wildlife and National Parks, with 60% of reports relating to elephants in Kavimba, 51% in Muchenje and Mabele and 52% in Kachikau (DWNP, 2018). The majority of damage occurs at night-time. Given the area's high elephant density, the human reliance on crop cultivation and the close proximity of human settlements to protected areas, it is not surprising that the rate of negative human–elephant interactions is one of the highest in the country (Gupta, 2013).

## Methods

### Selection of study fields

The NGO Elephants Without Borders has been working in the Chobe Enclave community since 2015 and has conducted surveys with farming family households in both Mabele and Kavimba villages. For this study, we held multiple participatory community meetings (*kgotlas*) in each of the study villages and monitored wildlife corridors using elephant movement data collected with GPS collars and motion detection camera traps, to identify fields frequently visited by elephants. We identified and monitored 18 fields for two cropping seasons, during 1 November 2016–30 June 2018. Farmers participated on a voluntary basis and were eligible if they had fields $< 7$ ha in which elephants had previously damaged crops, and if they resided in or next to the field, to ensure that lights would not be stolen or damaged. All treatment (with a solar-powered strobe light barrier) and control fields (without barrier) contained growing crops. During season 1 (2016/2017) there were four control and six treatment fields, and in season 2 (2017/2018) there were seven control and nine treatment fields. Four fields acted as both control and treatment at different times within the same season (fields 15–18; Table 1); they were control for part of the season and became treatment for remainder of the season. We prioritized farmers located alongside and closest to the wildlife corridors in the area in the allocation of study fields. We predicted that because their fields were closer to the corridors used by wildlife to access the floodplain, they would have a higher likelihood of being damaged by elephants and would experience more incidents (Songhurst et al., 2015). Although some were directly adjacent to wildlife corridors, none of the participating farmers' fields were located within the corridors themselves. We avoided fields that were surrounded by other farmers' fields, so as to not encourage elephants to forage in other farmers'

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TABLE 1 Summary of the study fields, showing whether they were used as control or treatment, during which season they were included in the study, village location, field size, distance from a wildlife corridor, distance from another field and the type of crops grown.

| Field number | Control/ treatment[1] | Season[2] | Village | Field size (ha) | Distance from corridor (m) | Distance to another crop field (m) | Crops grown |
|---|---|---|---|---|---|---|---|
| 1 | Treatment | 1 | Mabele | 1.59 | 0 | 0 | Sorghum, maize, sweet reed |
| 2 | Treatment | Both | Mabele | 0.65 | 0 | 50 | Sorghum, maize, beans |
| 3 | Treatment | Both | Mabele | 3.20 | 0 | 0 | Sorghum, maize |
| 4 | Treatment | 1 | Kavimba | 3.90 | 0 | 1,065 | Sorghum, maize |
| 5 | Treatment | 1 | Kachikau | 2.48 | 0 | 1,006 | Maize, sweet reed |
| 6 | Treatment | 1 | Kavimba | 0.32 | 222 | 323 | Sorghum, maize |
| 7 | Treatment | 2 | Kavimba | 5.52 | 371 | 0 | Sorghum, maize, watermelon |
| 8 | Treatment | 2 | Kavimba | 1.50 | 0 | 0 | Maize, cabbage, tomatoes, pumpkin |
| 9 | Control | 1 | Mabele | 1.36 | 513 | 123 | Sorghum, maize, sweet reed |
| 10 | Control | 1 | Mabele | 0.80 | 282 | 0 | Sorghum, maize |
| 11 | Control | 1 | Kavimba | 5.60 | 0 | 0 | Maize, beans |
| 12 | Control | 2 | Mabele | 1.31 | 0 | 0 | Sorghum |
| 13 | Control | Both | Mabele | 1.30 | 0 | 0 | Sorghum, maize |
| 14 | Control | 2 | Kavimba | 0.87 | 0 | 135 | Sorghum, maize |
| 15 | Control/ treatment | 2 | Muchenje | 0.37 | 280 | 0 | Sorghum, maize |
| 16 | Control/ treatment | 2 | Mabele | 3.26 | 0 | 0 | Sorghum, maize |
| 17 | Control/ treatment | 2 | Kavimba | 6.13 | 0 | 0 | Maize |
| 18 | Control/ treatment | 2 | Kavimba | 3.54 | 0 | 0 | Sorghum, maize |

[1]Fields 15–18 started as control fields and became treatment fields within the same season.
[2]Season 1 = 2016/2017; season 2 = 2017/2018.

fields if the lights were successful in deterring them from a treatment field.

## Solar-powered strobe light barriers

We assisted participating farmers with setting up a solar-powered strobe barrier for treatment fields. Farmers were responsible for the security of the lights, and we agreed with them that if any lights were stolen or broken then all remaining lights would be removed. A barrier consisted of 6–13 solar-powered LED strobe lights (Repro Supplies, Boksburg, South Africa) that were set up adjacent to the growing crop, 1.5–1.7 m off the ground at 10-m intervals. The lights were purchased from South Africa at a cost of ZAR 220 per unit, and with the internal solar charger system, they can run independently for up to 3 years. The lights were placed on the side of the field that the farmer indicated the elephants were most likely to pass by or enter the field from. Each light in the barrier constantly flashed a single colour (red, green, amber, white, blue or yellow) both day and night. To reduce habituation, the colour pattern of the array was rotated weekly, so that it appears differently to the elephants each time they pass by. Lights remained in place until the farmer completed their harvest, for 1–3 months during January–June. Harvest time depended on when an individual farmer ploughed and planted their field within that season.

To verify whether elephants crossed the barriers or not, we gathered reports about elephant movements in the area, and deployed a camera trap (Bushnell Trophy Cam Brown HD, Bushnell Corporation, Overland Park, USA) perpendicular to the light barriers at each treatment field, at a distance of 1–10 m from the lights. We downloaded images weekly.

## Assessing incursions

We recorded elephant behaviour and activity in and around the selected fields over successive years, during the 2016/2017 and 2017/2018 crop seasons. We based our definitions of elephant behaviour on King et al. (2011), with an incursion being defined as an elephant, or a group of elephants, entering a field from any direction, which included both walking through a field and feeding on the crop. If the same elephants left the field and then re-entered it in the same night, we recorded the second event as a second incursion. The primary aim of our study was to determine whether elephants crossed the light barriers. Occasions during which elephants approached a field (i.e. came within a distance of < 30 m from the field) and turned away were defined as prevention (King et al., 2011).

Assessments of elephant activities in and around fields were dependent on timely feedback from farmers. When an incursion was reported, a member of our research team assessed the field, recording the location where the elephants entered the field, following the path they walked and estimating the group size based on spoor in the field.

### Additional methods used to deter elephants

The trial of the solar-powered strobe barriers aimed to assist farmers in deterring elephants from entering their fields and to complement rather than replace other methods. Farmers were thus encouraged to continue defending their crops as they would have done without the lights. To take additional measures into consideration, we recorded the date of any elephant activity (incursion or prevention), and whether the farmer had used any other mitigation methods since the lights had been deployed. Farmers reported using the following additional deterrents: chilli peppers (in any form), banging a drum and using a battery-powered torch. We also recorded whether domestic dogs were present in the field, whether the farmer was present during the activity, and whether the Department of Wildlife and National Parks attended the report to determine if the farmer could claim compensation.

### Statistical analysis

To determine the factors that deterred elephants from entering a field (0 = prevention following approach, 1 = incursion following approach), we developed a series of generalized linear mixed models in *R 3.4.0* (R Development Core Team, 2017), using the *lme4* package (Bates et al., 2015). Models had a binomial error distribution and a logit link function. As we had multiple measures from each farm, we included farmer identity (N = 18) as a random term in all models. We used Akaike's information criterion corrected for small sample size (AICc) to select the best model from a set of plausible options. All parameters, including presence of lights (yes/no), field size, whether the farmer engaged in one or more other active mitigation efforts (including the use of chillies, dogs, drums or torches; yes/no), distance to the nearest known elephant corridor, and the two-way interaction Treatment × Other mitigation, were sequentially removed from a saturated model. We compared the AICc of all resulting models with the previous model and retained parameters only if their removal inflated AICc by > 2 (Burnham et al., 2011), because lower AICc values correspond to better relative support for a given model (Akaike, 1974). To validate that there was no improvement to the minimal model, we returned all original parameters to the model one by one, thereby creating our model set together with the basic model that contained only the intercept and the random term. We then calculated Akaike weights to determine the relative importance (Akaike, 1974) of these final models. As the Akaike weight of the best model was < 0.9 (Grueber et al., 2011) and several models had deviance in the AICc < 7 units (Burnham et al., 2011), we conducted model averaging using the *MuMIn* package in *R* (Bartoń, 2012). We selected the top models with cumulative Akaike weights > 0.95 to construct model-averaged estimates of the parameters (Grueber et al., 2011).

## Results

We recorded a total of 107 elephant activities (incursions and preventions) over the two seasons in control and treatment fields, of which 49 were in the 2016/2017 season and 58 during the 2017/2018 season. Overall, more activities (counting both incursions and preventions) occurred in the treatment fields (80) than the control fields (27), but a higher percentage of activities resulted in preventions in the treatment fields (75%) than the control fields (30%).

The likelihood of an elephant entering a crop field was significantly lower when lights were present compared to control fields ($z = 4.59 \pm$ SE 1.66, $P < 0.05$; Tables 2 & 3). Although incursions were recorded in fields equipped with strobe light barriers, we documented only two occasions where elephants crossed the light barrier. In one of these two incidents the farmer reported that the elephants were being shot at when they crossed the lights and were leaving the field. In the second instance two of the lights were not working so the barrier was compromised. No elephants were captured by the camera traps erected facing the light barrier.

Model 1 best fits the data with the fewest explanatory parameters and lowest AICc. Six models had deviance in the AICc < 7 units and were used in model averaging (Tables 2 & 3).

## Discussion

The likelihood of an elephant incursion into a crop field was significantly reduced in the presence of a solar-powered strobe light barrier, supporting the hypothesis that lights are effective in deterring elephants at night-time. To our knowledge this is the first trial to test the efficacy of solar-powered strobe lights in reducing field incursions by elephants. The effects of solar-powered strobe lights were greater than the collective effects of any other deterrents (chilli pepper burning, guard dogs, torches or the banging of drums).

Table 2 Summary statistics for the generalized linear mixed model set predicting factors affecting African elephant *Loxodonta africana* response (prevention or incursion) to strobe light barriers in northern Botswana. The model parameters, Akaike information criterion corrected for small sample size (AICc), difference in AICc from best-performing model (ΔAICc) and Akaike weight are shown for each model.

| Model no. | Model parameters | AICc | ΔAICc | Akaike weight |
|---|---|---|---|---|
| Basic | | 118.21 | | |
| 1 | Lights + (Farmer) | 98.80 | 0.00 | 0.25 |
| 2 | Lights + Other mitigation + (Farmer) | 99.76 | 0.96 | 0.15 |
| 3 | Lights + Field area (Farmer) | 100.09 | 1.29 | 0.13 |
| 4 | Lights + Corridor distance + (Farmer) | 100.41 | 1.61 | 0.11 |
| 5 | Lights + Other mitigation + Field size + (Farmer) | 101.16 | 2.36 | 0.08 |
| 6 | Lights + Other mitigation + Lights × Other mitigation + (Farmer) | 101.56 | 2.66 | 0.07 |

Table 3 Model-averaged effects (full average, i.e. the average taken across all models, regardless of whether that parameter was present or not) of each parameter from Table 1 on elephant response following an approach to a field boundary, for the six models with deviance in the AIC < 7 units.

| Parameter | Estimate ± SE | *Z* | P | 95% CI | Relative importance |
|---|---|---|---|---|---|
| (Intercept) | −1.224 ± 1.629 | 0.744 | 0.457 | −4.445–1.906 | |
| Treatment (Lights)[1] | 4.589 ± 1.657 | 2.739 | 0.006 | 1.299–7.854 | 1 |
| Other mitigation (Yes)[2] | −0.563 ± 1.177 | 0.476 | 0.634 | −4.335–1.729 | 0.44 |
| Field area | −0.154 ± 0.348 | 0.440 | 0.660 | −1.351–0.491 | 0.35 |
| Corridor distance | −0.001 ± 0.004 | 0.338 | 0.735 | −0.016–0.007 | 0.28 |
| Other mitigation (Yes)[2] × Treatment (Lights)[1] | 0.203 ± 1.008 | 0.200 | 0.842 | −3.066–6.886 | 0.11 |

[1]Effect relative to 'no lights' as the reference category.
[2]Effect relative to 'no other mitigation' as the reference category.

Although Songhurst et al. (2015) reported that fields < 1.2 km from an elephant path or corridor were 50% more likely to experience an incursion than those further away, we found that distance to wildlife corridors and the size of the field did not have a significant impact on the likelihood of elephants entering the fields. This could be a result of different drivers of interactions in different areas (Pozo et al., 2017), but suggests that strobe lights can be effective as a mitigation method in fields close to wildlife corridors.

The design of the solar-powered strobe light barrier used here differed from that of previous studies aimed at deterring predators (Lesilau et al., 2018; Ohrens et al., 2019) by having lights of multiple colours, and lights arranged in a line to appear as a barrier. It is thought that the lights were effective in deterring predators because they simulated torches, which predators may associate with the presence of people (Niteguard, 2019). Research conducted in Assam, India, found that a single spotlight deterred elephants from a field and reduced the probability of crop damage, but when used in combination with noise the probability of damage increased (Davies et al., 2011). The researchers suggested that because spotlights are directional (whereas noise is more diffuse), they targeted the elephants and caused them to retreat calmly (Davies et al., 2011). In our study, because crop fields were of square or rectangular shape, we arranged the lights in a single line to create the visual impression of a barrier along the edge of the field. We rotated the colour of the lights, so that they would appear different on a weekly basis to reduce the risk of habituation. Elephants can become habituated to deterrents over time, especially in areas of high elephant density (Hoare, 2015; Shaffer et al., 2019). It is therefore possible that solar-powered strobe light barriers could become less effective over time at sites where elephants encounter them more frequently (O'Connell-Rodwell et al., 2000), but this can only be determined with extended trials at the same sites.

We positioned the strobe light barriers such that the likelihood of elephants entering a crop field would be reduced (i.e. on the side of the field from which elephants were most likely to enter). Elephants did damage crops in some of the treatment fields, but not by crossing through the light barrier but by entering the field from a different side, where lights were absent.

The barriers were placed such that they would not block elephants from using a wildlife corridor or getting to a necessary resource such as water. As such, this trial aimed to deter elephants specifically from entering fields rather than blocking them from the general area, as is the case with the majority of mitigations studies (Karidozo & Osborn, 2015; Ngama et al., 2016; King et al., 2017; Lesilau et al., 2018). We strongly discourage the use of strobe light barriers to stop elephants moving through a general area. Two farmers reported that elephants started entering their fields from the side without lights, potentially shifting their movement patterns in response to the light barrier. However, we cannot conclude that a light barrier would stop elephants accessing a habitual migration path or route to water.

Although the camera traps we used to record elephants crossing the light barriers validated information reported by participating farmers, they did not effectively document elephants retreating from fields. We thus relied on farmers' reports on the type of elephant activity that occurred in and around fields with and without lights. In future studies camera traps should be placed both on the light line barrier and outside the crop field to reduce the reliance on farmers' reports for evidence of elephant movement both inside and outside the field.

Although the solar-powered strobe light barriers trialled here were effective in deterring elephants from entering crop fields, they may not work equally well in different situations. Mitigation methods often need to be combined with other techniques and should be reviewed frequently to maximize their effectiveness in deterring animals (Lesilau et al., 2018). Testing the success or failure of any method to mitigate human–elephant interactions is important (Webber et al., 2007) as it allows wildlife managers to gain knowledge of what suits different locations and situations, and can prevent investment in ineffective management techniques. Farmers are more likely to continue using a mitigation method if it is affordable and easy to use and maintain (Hoare, 2015), and if they have first-hand experience with the technique. Previous studies have demonstrated that farmers are willing to adopt and use methods that effectively reduce negative interactions with elephants (Gunaryadi et al., 2017). We hope that this will be the case with strobe light barriers and that further trials will be carried out within the Chobe Enclave and in other areas. Any future deployment of the method should consider the risk that elephants could become habituated to the lights, and plan accordingly.

In summary, we explored the potential of a novel mitigation method to reduce the likelihood of elephants entering crop fields. We found that the solar-powered strobe light barrier was successful in deterring elephants from entering these fields. Therefore it is worth exploring the usefulness and applicability of solar-powered strobe light barriers to deter elephants, and potentially other species, in other parts of Africa and Asia. Specific social, farming and environmental factors will need to be considered, and further research is required to assess the long-term efficacy and broad-scale applicability of the method to reduce negative human–wildlife interactions.

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**Author contributions** Study design: TSFA; fieldwork: TSFA, IM; data analysis: NRJ; writing: TSFA, NRJ.

**Conflicts of interest** None.

**Ethical standards** This research abided by the *Oryx* guidelines on ethical standards and was approved by the Botswana Government under research permit EWT 8/34/4 XX (34), granted by the Department of Wildlife and National Parks to Elephants Without Borders.

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