Received: 19 January 2023 | Revised: 15 March 2023 | Accepted: 16 March 2023
DOI: 10.1111/aje.13151

RESEARCH ARTICLE

African Journal of Ecology WILEY

Human-wildlife conflicts in communities bordering a Savannah-Fenced wildlife conservancy

Marc Dupuis-Desormeaux[1,2] | Timothy N. Kaaria[2] | John Kinoti[2] | Adrian Paul[2] | Saibala Gilisho[2] | Francis Kobia[2] | Reagan Onyango[2] | Geoffrey Chege[2] | David Kimiti[2] | Mary Mwololo[2] | Zeke Davidson[2,3] | Suzanne E. MacDonald[2,4]

[1]Multidisciplinary Studies Department, Glendon College, York University, Toronto, Ontario, Canada
[2]Lewa Wildlife Conservancy, Meru County, Kenya
[3]Zoological Society London, London, UK
[4]Psychology Department, York University, Toronto, Ontario, Canada

Correspondence
Marc Dupuis-Desormeaux, Multidisciplinary Studies Department, Glendon College, York University, Toronto, Ontario, Canada.
Email: marcd2@yorku.ca

Abstract

We discuss various human-wildlife conflicts (HWC) inherent within communities bordering a mid-sized, semi-porous wildlife conservancy in Kenya. HWC are a growing issue as human population expands into wildlife habitat to put people and wildlife in more frequent contact and compete for scarce resources. In 2018, we surveyed the crop-raiding and livestock depredation experiences of 918 households from 10 separate villages and asked about the experiences of the villagers with HWC over the past 3 years. These communities are protected from wildlife with two different fence designs, a standard 12-strand electrical fence, and an upgraded predator-proof fence design. We found that between 70% and 91% of respondents had experienced some form of HWC including 39.5% who reported threats to their person from wildlife encroachments despite electrical perimeter fencing. HWC happened more often at night and during the dry seasons. The most common encroachments were from elephants, hyenas, leopards, and baboons. Community respondents rated that the upgraded predator-proof fences performed better than the standard 12-strand fences. However, even the predator-proof design had issues with keeping monkeys from entering the communities and crop raiding. We discuss potential mitigation measures, including an improved predator-proof fencing design that incorporates butterfly stingers that may offer better protection.

KEYWORDS
baboon, community conservation, elephant, fencing, human-wildlife conflicts, hyena, leopard, rhinoceros

Résumé

Nous discutons des différents conflits homme-faune (HWC) inhérents aux communautés bordant une réserve naturelle de taille moyenne et semi-poreuse au Kenya. Les HWC constituent un problème croissant à mesure que la population humaine s'accroît.dans l'habitat de la faune et de la flore, ce qui entraîne des contacts plus fréquents entre les hommes et les animaux sauvages et une concurrence pour des ressources limitées. En 2018, nous avons enquêté sur les expériences de pillage des cultures et de déprédation du bétail de 918 ménages dans 10 villages distincts et nous avons posé des questions sur les expériences des villageois avec les HWC au cours des trois dernières années. Ces communautés sont protégées de la faune par deux types de clôtures : une clôture électrique standard à 12 brins et une clôture améliorée à l'épreuve des prédateurs. Nous avons constaté qu'entre 70 et 91 % des personnes interrogées avaient subi une forme ou une autre de violence domestique, dont 39,5 % avaient signalé des menaces contre leur personne en raison d'empiètements d'animaux sauvages malgré l'installation d'une clôture électrique autour du périmètre. Les HWC se produisent plus souvent la nuit et pendant les saisons sèches. Les empiètements les plus fréquents sont ceux des éléphants, des hyènes, des léopards et des babouins. Les personnes interrogées au sein de la communauté ont estimé que les clôtures améliorées à l'épreuve des prédateurs étaient plus performantes que les clôtures standard à 12 brins. Cependant, même la conception à l'épreuve des prédateurs a posé des problèmes pour empêcher les singes de pénétrer dans les communautés et de s'attaquer aux récoltes. Nous discutons des mesures d'atténuation potentielles, y compris une clôture améliorée à l'épreuve des prédateurs qui incorpore des aiguillons de papillon qui peuvent offrir une meilleure protection.

1 | INTRODUCTION

The human footprint is expanding globally, encroaching on wildlife habitat and traditional animal migratory routes, and as a result putting people and wildlife in closer and more frequent contact with resultant loss of crops and/or livestock (Di Minin et al., 2021; Foley et al., 2005; Nyhus, 2016; Ripple et al., 2014). Communities living on the border of natural reserves or in the migratory corridors that connect protected areas suffer disproportionately from other communities that are further removed from high contact areas (Hartter et al., 2016) and the communities suffering from these human-wildlife conflicts (HWC) can be less tolerant to conservation efforts (Madden, 2014).

In Africa, most of the elephant and other wildlife home ranges are located outside protected areas and lie in an anthropogenic landscape matrix (Hoare, 2000; Wall et al., 2013). The HWC tolerance of people living on borders of nature reserves, parks or other forms of wildlife conservancies depends partly upon the severity and regularity of the HWC occurrences (Ripple et al., 2014). In some landscapes, migratory corridors are also positively correlated with the frequency of HWC (Buchholtz et al., 2020). Although there may be benefits to living next to a wildlife reserve, these benefits are often limited to the people directly or indirectly employed in the tourism sector (Nyhus, 2016). Community members that experience crop raiding or livestock depredation can suffer catastrophic economic damage that can lead to impoverishment and destitution (Ogra, 2008; Sibanda & Omwega, 1996). People experiencing regular HWC can become disillusioned with conservation efforts and as a result, may actively oppose it (Madden, 2014; Oldekop et al., 2015; Soliku & Schraml, 2018). In a survey conducted in Laikipia County, Kenya, people suffering from HWC reported feeling that wildlife was viewed as more important than people and that wildlife conservation was being used as a conduit for resource appropriation (Bond & Mkutu, 2018). When HWC tolerance limits are reached, affected people may turn to shooting or poisoning the suspected culprit animal, often causing collateral wildlife mortality (Kissui, 2008; Ogada et al., 2012). These retaliatory actions can then lead to further conflicts with the government bodies responsible for protecting wildlife (Dickman, 2010).

People affected by HWC use a variety of problem-focused strategies and emotional coping mechanisms (Texeira et al., 2021; Treves et al., 2006). How well people cope with HWC is of vital importance to community resilience. In the province of Assam, India, people that had strong natural support networks (Hirsch, 1980) such as family, friends, and neighbours that shared the burden of an HWC event fared better and were less antagonistic towards wildlife (Gogoi, 2018). There are also hidden costs to HWC such as fear, anxiety, and loss of productivity (Barua et al., 2013). Fear and anxiety can lead to livestock owners perceiving predator impact as disproportionally high in relation to actual livestock losses (Koziarski et al., 2016). Regardless of the actual costs, perceived or real, HWC leads to calls for action. For example, in Meru, Embu and Tharaka Nithi Counties, Kenya, residents have pleaded to their respective County representatives for increased protection from wildlife in the form of more electrical fences (Areri & Mwiti, 2018).

Around the world, fences are the tool of choice to help reduce HWC (Hayward & Kerley, 2009; Hayward & Somers, 2012). Fencing wildlife protected areas can reduce HWC and is increasingly being used in Africa as a tool for wildlife conservation. Fence design needs to balance costs and community protection, and permit wildlife migration needs (e.g., elephant migration) to be sustainable in the long run (Hayward & Kerley, 2009; Jakes et al., 2018). There are many fence designs ranging from simple semi-permeable (to small animals) farm fences, to designs that incorporate barbed wire, to others that include woven wire (to restrict smaller animals), with or without buried sections (to prevent digging animals from crossing) and all of these can be electrified or not (Jakes et al., 2018). In certain countries such as Australia, fencing is viewed as necessary for the livestock industry to exist because of the prevalence of predators (Pacioni et al., 2020).

Wildlife that once freely moved across the land is now often blocked by private fenced holdings thus restricting movement, concentrating herds, increasing dependence on local resources all of which could cause ecosystem breakdown (Lovschal et al., 2017). Directional fencing combined with gaps in the fences can offer a solution by directing wildlife to safe movement corridors, either to existing historical routes or to new migratory corridors that are strategically placed in areas of low human population density (Dupuis-Désormeaux et al., 2016). Fencing offers the best solution to keeping wildlife out of communities (Kioko et al., 2008), but current border fences between wildlife reserves and communities can vary greatly in design across Kenya as well as across the rest of Africa (McInturff et al., 2020). Fence design is often far from optimal and fence incursions may occur through fence breakage, tunnelling or climbing (Kioko et al., 2008; Thouless & Sakwa, 1995; Weise et al., 2014). Electrical fencing is an expensive conservation and HWC mitigation tool and fence upkeep is often underfunded (Kesch et al., 2015; Pekor et al., 2019).

At our study site in northern Kenya, fence design has evolved over time as a tool to protect the endangered wildlife and to reduce HWC incidents. Using an adaptive management approach, fence design is constantly being modified and improved as time and budgets permit. Thus, our study site has a mix of older and newer fence designs. As part of the adaptive management review process, we asked a large random sample of people living near the border of the conservancy to share their experiences with HWC, through a household questionnaire administered by trained community members. This study reports on the first community wide HWC survey for our study site and will act as a baseline for future surveys that will explore how newer fence designs and other HWC mitigation measures might improve the HWC incidence rate. As such, we hoped to glean important information from this survey that might shed light on the ongoing struggle with HWC amongst the communities surrounding our protected area. Specifically, we hope to better understand the types of HWC that are prevalent in those communities and also compare two electrical fence designs in their effectiveness at reducing HWC.

2 | MATERIALS AND METHODS

2.1 | Study site

We conducted our survey study (Appendix S1) in 10 villages in the counties of Meru, Laikipia and Isiolo (for a map of the area, see Supplementary Materials) that surround a 25,000 ha black rhinoceros (*Diceros bicornis*) protected area, the Lewa Wildlife Conservancy (Lewa), in Meru County, Isiolo, Kenya (0.20°N, 37.42°E). The study area is surrounded by a dozen communities representing over 42,000 people that subsist both by farming and livestock rearing. Farming along the Lewa border ranges from large commercial farms growing wheat and flowers to the small plot community farming which consists mainly of subsistence crops including maize, carrots, onions, potatoes, and wheat.

Electrical fences surrounded the 142 km perimeter of Lewa except for a few gaps in these fences to permit the migratory movement of elephants and other wildlife but restrict the movement of rhinoceros (Dupuis-Désormeaux et al., 2016). The western boundary fence between Lewa and the neighbouring Borana Wildlife Conservancy (Borana), in Laikipia County (0.22° N, 37.31° E) was removed in sections between Oct 2014 and September 2015, to merge the two neighbouring conservancies which now form the Lewa-Borana Landscape (see Dupuis-Désormeaux et al., 2018). Lewa acts as a pinch point for elephants migrating from Mount Kenya towards Northern Kenya and back. Elephants can leave Mt. Kenya via the Mt. Kenya elephant corridor (the southern terminus being close to the village of Ntirimiti), cross into The Ndare Ngare Forest Reserve then into Lewa, and exit through the Northern fence-gap into the Leparua Community Conservancy (Leparua) or migrate westward into Borana and out multiple other fence-gaps. Although the gaps in the fences were designed for elephant movement, these also permit other wildlife (except rhinoceros) to disperse and access community lands.

2.2 | Survey methods

A cross-sectional mixed research design comprising both quantitative and qualitative data collection was employed. The clustering sampling approach was then used to categorise the study locations into three main clusters bordering our study site. The sample size was determined based on the number of households within the identified clusters using the Raosoft sample size calculator (Raosoft Corp., Seattle, WA). The sample sizes (number of households) per cluster were as follows: Eastern (312), Western (308) and Northern (298). A simple random sampling technique was then used to select households within the identified clusters for an interview. The 21-question survey was administered by five trained community liaison officers of the Lewa Community Department who collected the data from respondents in the identified locations. Questions were in three major categories: background demographics (age, gender, source of livelihood, land ownership, time in village),

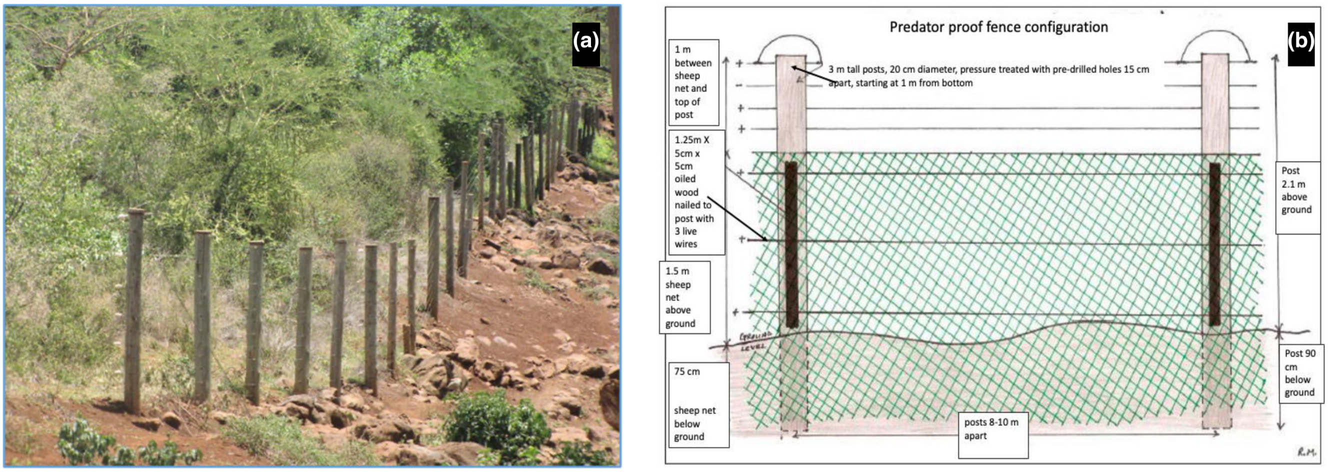

FIGURE 1 (a) Older style 12-strand electrical fence (Photo A. Paul). (b) Schematic drawing of the initial predator-proof fence design (without the added stingers) (Illustration R. Moller).

experience with wildlife (type and frequency of animals seen in the community) and perception of HWC (type and severity HWC over the last 3 years – see Appendix S1 for the complete questionnaire).

These community officers visited the various villages between 26th February 2018 and 9th March 2018. The survey was conducted by issuing the questionnaires to the respondents and interpreting using local dialect to those who could not read supplemented with cue cards to identify the various animals that the villagers had encountered. Respondents were not paid for their participation. The questionnaires were administered to one person (preferably the household head) in the households that were randomly selected. Respondents were required to be 18 years or older. Some of the key questions from the survey that we want to highlight were:

1. What was the type and frequency of the HWC experienced by the respondents?
2. When did the HWC occur (time of day and time of the year)?
3. How would the respondents rate the effects of the HWC (on a sliding scale from minor to very high)?
4. How did the respondents rate the effectiveness of Lewa's fences? Were there differences in the performance of both existing designs?
5. What did the respondents think was the most likely cause of HWC?

We report differences by geographical clusters. We use a Chi-Square test of independence to compare the responses and their geographical clusters adjusting the p-value for multiple comparisons using a Šidák correction (1967) to show that some clusters are differently affected by HWC.

2.3 | Fence design

Perimeter fence design around the conservancy has evolved over time and continues to do so as management seeks to improve the design and reduce HWC. The 12-strand electrical fences (Figure 1a) were the standard at Lewa since 1995. Improving on this earlier design, predator-proof fencing incorporated an electrified buried mesh into the 12-strand (Figure 1b). This predator-proof design has been introduced initially in certain historical HWC hot spots such as the Manyangalo village (which is enclosed inside Lewa) in 2004, the Ndare Ngare village in 2006 (which sits between Lewa, Borana and Ngare Ndare Forest Reserve), the village of Ntirimiti (along the Mt.Kenya elephant corridor), the villages of Matunda in 2011 (and Subuiga in 2011—not in this study) which had suffered from historically high HWC.

3 | RESULTS

3.1 | Demographics by region

Respondents were surveyed from three separate clusters split along rough geographic lines with 41.6% of the respondent households selected from the Eastern cluster, 36.1% from the Western cluster and 22.6% from the Northern cluster. A statistically equal number of males (483) and females (435) responded to the survey ($X^2(1) = 1.584$; $p = 0.113$).

Most respondents listed farming as one of their principal sources of income with many also combining farming with livestock rearing or trading or all three (for a complete breakdown of livelihoods per village, see Supplementary Materials). Farming was the main source of income in all villages surveyed except one (Leparua, in the Northern cluster), followed by livestock keeping and trading.

Respondents reported their ages as being between 18 and 100 years old (mean = 37.7 years, STD 13.7 years). Most respondents (593 of 913, 64.9%) had lived in their current village for more than 20 years, with only 7.2% (66) having lived in their village for <5 years. Most respondents owned or rented land that they cultivated (750 of 918, 81.6%), with most people (69.6%) indicating that the area under cultivation represented fewer than five acres and 32.5% with fewer than one acre. One hundred and eleven (12.1%) respondents had farms of more than five acres.

3.2 | Human-wildlife conflicts

Most of the respondents (767 of 918 or 83.5%) experienced HWC in the last 3 years (2015–2017), with 680 (74%) respondents experiencing crop-raiding, and 496 (54%) had suffered livestock depredation. These responses did not differ by gender ($z=1.15$, $p=0.25$) but the responses did differ by time living in the village ($X^2=47.353$, $p<0.001$), the respondents having lived 5 years or less reporting fewer HWC (given that we surveyed for HWC in the last 3 years, it is possible that some respondents had not yet suffered HWC). If we include only respondents that lived in their current villages for more than 5 years, then the percentage increases to over 85%. The most common encroachments reported were from elephants (*Loxodonta africana*), hyenas (*Crocuta crocuta*), leopards (*Panthera pardus*), and baboons (*Papio anubis*). HWC were reported as happening at all times of the day although respondents reported much more frequency at night (86.3%) versus during the morning (40.8%), afternoon (23.4%) or evening (32.6%).

Our study site has two rainy seasons, typically September–November and March–April. HWC were reported to happen during all months of the year, but more often during the dry seasons with the months of January (61.9%), February (67.5%) and July (59.9%), whereas the months of March (49.9%), April (46.2%) and September (47.5%) had the lowest reported incidence in the aggregate. Crop-raiding incidents were described as having either a high or very high detrimental effect 58.2% of the time with destruction of food stores listed as the main outcome of crop raiding incidents (97.1%). At the most extreme, 95% of respondents from the village of Mutunyi in the Eastern cluster reported facing crop-raiding over the last 3 years and that 87.2% of crop depredation had either a high or very high detrimental effect. Mutunyi did not get an upgraded predator-proof fence until 2018 (after this survey period). Perhaps most concerning for all the villages was the finding that 39.5% respondents had been injured or physically threatened by wildlife.

3.3 | Fencing design and perceived effectiveness of the fences

The older 12-strand fence design, which is often the standard fence design in east Africa, has not proven to be very effective against wildlife incursions, either against elephant, monkeys or predators and was more often rated as not very effective. Problem predators breaching the fence and entering communities will trigger a series of actions: capture, translocation, or elimination (either legally or illegally) and these actions necessitate tremendous labour/hours and cooperation with the local Kenya Wildlife Service. Elephants and monkeys (baboons and vervet monkeys) were also able to easily penetrate through the older 12-strand fence configuration – elephants pushed the posts down and the monkeys climbed the posts. The percentages of reported HWC were different between the villages protected by a 12-strand fence (90.4%) versus villages that had a predator-proof design (77.3%) and this difference was statistically significant ($X^2=5.327$, $p<0.001$). Crop raiding was reported less often in villages with the predator-proof fence ($X^2=3.664$, $p<0.001$) as was livestock depredation ($X^2=3.698$, $p<0.001$) and threats to the person ($X^2=4.082$, $p<0.001$). Respondents reported fewer encounters with elephants ($X^2=7.353$, $p<0.001$), lions ($X^2=6.960$, $p<0.001$), leopards ($X^2=9.845$, $p<0.001$), hyenas ($X^2=3.975$, $p<0.001$) but not with baboons ($X^2=0.031$, $p=0.975$). When rating the perceived effectiveness of the fences, respondents from villages nearby a predator-proof fence were more likely than respondents living on the border with a 12-strand design fence to rate the fence as effective (30.6% vs. 21.3%) ($X^2=3.196$, $p<0.001$).

Across all villages, the effectiveness of Lewa's fences were rated as mostly moderately effective (1 = effective, 2 = moderately effective, 3 = not effective) as we found that only 26.2% of respondents rated the fences as effective, 50.5% rated the fences as moderately effective and 20.5% as not very effective (with 2.8% that did not know). We found that the assessments of the effectiveness of Lewa's fences and the geographical cluster of the respondents were not independent (X^2 (6) = 15.778, $p=0.03$). Both the Eastern and the Western cluster had statistically similar responses (X^2 (3) = 2.986, $p=0.632$) but the Northern cluster differed from both (Northern vs Eastern X^2 (3) = 11.937, $p=0.15$; Northern vs Western X^2 (3) = 11.016, $p=0.023$).

We feel that it is instructive to examine some of the responses of individual villages to the perceived effectiveness of the fences. If we examine the Northern cluster responses more granularly, the villages of respondents and the perceived effectiveness are not independent (X^2 (9) = 36.839, $p<0.001$), where only 2.9% of respondents from Leparua felt that the fence was effective, significantly different than the other villages in that cluster (X^2 (3) = 16.801, $p=0.002$). Leparua village is on the immediate Northern border with Lewa, has an older 12-strand fence and it also has the northern fence-gap that opens into its community conservancy. The village of Ntalabany is further away but still in the northern direction for migrating elephants and both these villages reported the greatest proportion of elephant conflicts over the past 3 years. The respondents from these two villages also reported the highest proportion of livestock depredation [Leparua (88.6%) and Ntalabany (100%)].

3.4 | Perception of HWC causes

When we asked respondents to choose from three options (wildlife food scarcity, increase in wildlife population, human settlements encroaching on wild habitat) on what they thought was the most likely reason for HWC, the reason most reported was ‘scarcity of wild animal food in their natural habitat’ (83.7%) versus increase in wildlife population (39.3%) or human settlement encroaching on wildlife habitat (8.2%).

4 | DISCUSSION

Over our survey period, we found that the surrounding communities suffered a regular barrage of HWC. We found that the predator-proof fence design was an improvement and did reduce

HWC to some extent; however, as our results show, there is lots of room for improvement. The prevalence of HWC was consistent with other wildlife-rich areas in eastern Africa, and our results, although telling of the high frequency of HWC, are in no way extreme. For comparison, in a survey conducted on the border of the Savé Valley Conservancy, Zimbabwe, 93% of respondents reported HWC, mostly with elephants and large carnivores (Matseketsa et al., 2019). In Taita Taveta County, Kenya, where Tsavo National Park is located and where the greatest density of Kenyan elephants resides, over 62% of the reported HWC involved threats to people by elephants (Munyao et al., 2020). In Narok County, Kenya, where the Maasai Mara National Reserve is located, the three principal types of HWC were also crop raiding (50%), attack on humans (27.3%) and livestock depredation (17.6%) but in a different order of importance, with the most prominent problem wildlife being similarly elephant (46.2%), monkey species (19.5%), and then buffalo (*Syncerus caffer*) (10.6%), zebra (*Equus quagga*) (7.6%), leopard (7.3%), spotted hyena (5.8%) and lion (*Panthera leo*) (3%) (Mukeka et al., 2019).

The older 12-strand configuration is now continuously being upgraded to the predator-proof version as funds permit. The predator-proof configuration that has been in use in certain sections of the perimeter fence since at least 2004 has been effective at keeping large predators and plains game out of farm holdings. In 2020, we also started to introduce electrically charged outriggers to the predator-proof fence configuration at certain HWC hot spots which appear to have helped reduce elephant breakages into those communities (based on preliminary community discussions). We further added extra horizontal electrified outriggers (in a butterfly configuration as shown in Figure 2) to the outside of the fence posts to thwart baboon and vervet monkey climbing the posts and to dissuade elephant from pushing the posts over. Although preliminary results are encouraging, a more fulsome community survey would be beneficial to compare before and after the installation of the new butterfly outrigger fence design. We continue to collect data at these locations and should be able to report these results in a few years.

On their own, fences might be the first line of defence, but they can never be enough to keep wildlife completely out of neighbouring communities. The Lewa-Borana Landscape will continue to be partially porous to allow for elephant migration, and because of these gaps in the fences there will always be wildlife pathways into communities. In addition to fencing, other HWC mitigation methods need to be deployed to protect against HWC, to reduce the susceptibility of communities to HWC, or to reduce the impact that the occasional HWC might create – i.e., increase community resilience to HWC. Lewa and other protected areas in East Africa have, with the participation of bordering communities, trialled several potentially useful solutions to reduce HWC such as bee fences (King et al., 2011), detusking elephants (Mutinda et al., 2014), fortifying livestock bomas (Kissui et al., 2019), predator and elephant deterring lights (Adams et al., 2021; Lesilau et al., 2018), and pepper bombs (Osborn, 2002) to name a few. Failures of mitigation projects can be traced back to poor community support (not believing that the mitigation measures were effective), misidentifying stakeholders, poor monitoring of the mitigation or insufficient long-term funding to keep the project operational (Webber et al., 2007).

FIGURE 2 Newer design predator-proof fence with buried mesh, electrified butterfly outrigger stingers and electrified posts. (Photo M. Dupuis-Desormeaux).

At our study site, HWC issues and potential solutions are discussed at community priorities meetings that are held regularly between Lewa's community liaison officers and the village elders and chiefs. Reducing both the effects and the frequency of HWC is a top priority of the Lewa management and community discussions often veer towards improving fencing to reduce HWC. During these regular engagements, the importance of coexistence between people and wildlife is reinforced and other potential solutions to HWC are considered. These discussions balance what the community members must do to help themselves (reducing attractants) and what the conservancy management can do to facilitate change (offer a more secure border, help diversify community income).

To find long-term successful solutions, constant dialogue with the community members is needed and the mitigation measures should be continuously re-evaluated as part of an adaptive management methodology. Communities should also be encouraged to diversify their income-generating activities to some that are less likely to attract HWC, more environmentally friendly and more resilient to climate change. Providing communities with micro-credit schemes (often targeting women-led enterprises) has been successful in helping to diversify the economic base of traditionally pastoral or agricultural communities (Wishitemi et al., 2015). The increases in the diversification of land use have led to improvements in the livelihood communities (Frelat et al., 2016). Although effective fences can reduce the immediate HWC burden, we maintain that a holistic approach to conservation and open dialogue between community members and conservancy staff (who are also community members) is critical to developing long-term sustainable HWC solutions.

4.1 | Future avenues of research

We encourage other conservation areas to survey their neighbouring communities to better understand the burden of HWC on these community members. We also encourage surveying for the perceived effectiveness of their perimeter fences with a view to sharing improved fencing designs.

AUTHOR CONTRIBUTIONS

Study Design: MDD, TNK, JK, RO, GC, MM, ZD, SEM. Fieldwork: TNK, JK, AP, SG, FK, RO, GC, DK, MM. Analysis and writing: MDD, TNK, JK, ZD, SEM.

ACKNOWLEDGEMENTS

The authors wish to thank the management and staff of the Lewa Wildlife Conservancy, the field survey team, the community liaison officers, and all the participants in this survey. We would also like to thank Richard Moller for his initial predator-proof fence design and illustration. This research received no specific grant from any funding agency, or commercial or not-for-profit sectors.

CONFLICT OF INTEREST STATEMENT

The researchers were either employed by the Lewa Wildlife Conservancy (TNK, JK, AP, FK, RO, GC, DK, MM, ZD) or were active as members of a support organisation that funds various conservation projects at the study site (MDD and SEM are both directors of Lewa Wildlife Conservancy (Canada), a registered charity).

DATA AVAILABILITY STATEMENT

The data are stored on the Lewa Wildlife Conservancy and can be obtained with permission by writing to Dr. Dominic Maringa, Head of Conservation, at dominic.maringa@lewa.org.

ORCID

Marc Dupuis-Desormeaux https://orcid.org/0000-0001-9224-697X

REFERENCES

Adams, T. S. F., Mwezi, I., & Jordan, N. R. (2021). Panic at the disco: Solar-powered strobe light barriers reduce field incursion by African elephants *Loxodonta africana* in Chobe District, Botswana. *Oryx*, *55*(5), 739–746. https://doi.org/10.1017/S0030605319001182

Areri, G. M., & Mwiti, K. M. (2018). Psychosocial issues reported in the Kenyan print media: A case study of Embu, Tharaka-Nithi and Meru counties. *International Journal of Social Science and Technology*, *3*(2), 17.

Barua, M., Bhagwat, S. A., & Jadhav, S. (2013). The hidden dimensions of human-wildlife conflict: Health impacts, opportunity and transaction costs. *Biological Conservation*, *157*, 309–316.

Bond, J., & Mkutu, K. (2018). Exploring the hidden costs of human-wildlife conflict in northern Kenya. *African Studies Review*, *61*(1), 33–54. https://doi.org/10.1017/asr.2017.134

Buchholtz, E. K., Stronza, A., Songhurst, A., McCulloch, G., & Fitzgerald, L. A. (2020). Using landscape connectivity to predict human-wildlife conflict. *Biological Conservation*, *248*, 108677. https://doi.org/10.1016/j.biocon.2020.108677

Di Minin, E., Slotow, R., Fink, C., Bauer, H., & Packer, C. (2021). A pan-African spatial assessment of human conflicts with lions and elephants. *Nature Communications*, *12*, 2978.

Dickman, A. J. (2010). Complexities of conflict: The importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation*, *13*, 458–466.

Dupuis-Désormeaux, M., Davidson, Z., Mwololo, M., Kisio, E., & MacDonald, S. E. (2016). Usage of specialized fence-gaps in a black rhinoceros conservancy in Kenya. *African Journal of Wildlife Research*, *46*(1), 22–32. https://doi.org/10.3957/056.046.0022

Dupuis-Désormeaux, M., Kaaria, T. N., Mwololo, M., Davidson, Z., & MacDonald, S. E. (2018). A ghost fence-gap: Surprising wildlife usage of an obsolete fence crossing. *PeerJ*, *6*, e5950. https://doi.org/10.7717/peerj.5950

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., & Gibbs, H. K. (2005). Global consequences of land use. *Science*, *309*, 570–574.

Frelat, R., Lopez-Ridaura, S., Giller, K. E., Herrero, M., Douxchamps, S., Djurfeldt, A. A., Erenstein, O., Henderson, B., Kassie, M., Paul, B. K., Rigolot, C., Ritzema, R. S., Rodriguez, D., van Asten, P. J. A., & van Wijk, M. T. (2016). Drivers of household food availability in sub-Saharan Africa based on big data from small farms. *Proceedings of the National Academy of Sciences*, *113*(2), 458–463. https://doi.org/10.1073/pnas.1518384112

Gogoi, M. (2018). Emotional coping among communities affected by wildlife–caused damage in north-East India: Opportunities for building tolerance and improving conservation outcomes. *Oryx*, *52*(2), 214–219. https://doi.org/10.1017/S0030605317001193

Hartter, J., Dowhaniuk, N., MacKenzie, C. A., Ryan, S. J., Diem, J. E., Palace, M. W., & Chapman, C. A. (2016). Perceptions of risk in communities near parks in an African biodiversity hotspot. *Ambio*, *45*(6), 692–705. https://doi.org/10.1007/s13280-016-0775-8

Hayward, M. W., & Kerley, G. I. H. (2009). Fencing for conservation: Restriction of evolutionary potential or a riposte to threatening processes? *Biological Conservation*, *142*, 1–13.

Hayward, M. W., & Somers, M. J. (2012). An introduction to fencing for conservation. In M. W. Hayward & M. J. Somers (Eds.), *Fencing for conservation* (pp. 1–6). Springer.

Hirsch, B. J. (1980). Natural support systems and coping with major life changes. *American Journal of Community Psychology*, *8*, 159–172. https://doi.org/10.1007/BF00912658

Hoare, R. (2000). African elephants and humans in conflict: The outlook for co-existence. *Oryx*, *34*(1), 34–38.

Jakes, A. F., Jones, P. F., Paige, L. C., Seidler, R. G., & Huijser, M. P. (2018). A fence runs through it: A call for greater attention to the influence of fences on wildlife and ecosystems. *Biological Conservation*, *227*, 310–318. https://doi.org/10.1016/j.biocon.2018.09.026

Kesch, M. K., Bauer, D. T., & Loveridge, A. J. (2015). Break on through to the other side: The effectiveness of game fencing to mitigate human-wildlife conflict. *African Journal of Wildlife Research*, *45*, 76–87.

King, L. E., Douglas-Hamilton, I., & Vollrath, F. (2011). Beehive fences as effective deterrents for crop-raiding elephants: Field trials in northern Kenya. *African Journal of Ecology*, *49*(4), 431–439. https://doi.org/10.1111/j.1365-2028.2011.01275.x

Kioko, J., Muruthi, P., Omondi, P., & Chiyo, P. I. (2008). The performance of electric fences as elephant barriers in Amboseli, Kenya. *South African Journal of Wildlife Research*, *38*, 52–58.

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*, 422–432. https://doi.org/10.1111/j.1469-1795.2008.00199.x

Kissui, B. M., Kiffner, C., König, H. J., & Montgomery, R. A. (2019). Patterns of livestock depredation and cost-effectiveness of fortified livestock enclosures in northern Tanzania. *Ecology and Evolution*, *9*(19), 11420–11433. https://doi.org/10.1002/ece3.5644

Koziarski, A., Kissui, B., & Kiffner, C. (2016). Patterns and correlates of perceived conflict between humans and large carnivores in northern Tanzania. *Biological Conservation*, *199*, 41–50. https://doi.org/10.1016/j.biocon.2016.04.029

Lesilau, F., Fonck, M., Gatta, M., Musyoki, C., van't Zelfde, M., Persoon, G. A., Musters, K. C., de Snoo, G. R., & de Iongh, H. H. (2018). Effectiveness of a LED flashlight technique in reducing livestock depredation by lions (*Panthera leo*) around Nairobi National Park, Kenya. *PLoS One*, *13*, e0190898. https://doi.org/10.1371/journal.pone.0190898

Lovschal, M., Bocher, P. K., Pilgaard, J., Amoke, I., Odingo, A., Thuo, A., & Svenning, J.-C. (2017). Fencing bodes a rapid collapse of the unique greater Mara ecosystem. *Scientific Reports*, *7*, 41450. https://doi.org/10.1038/srep41450

Madden, F. (2014). Creating coexistence between humans and wildlife: Global perspectives on local efforts to address human–wildlife conflict. *Human Dimensions of Wildlife*, *9*, 247–257(2004).

Matseketsa, G., Muboko, N., Gandiwa, E., Kombora, D. M., & Chibememe, G. (2019). An assessment of human-wildlife conflicts in local communities bordering the western part of save valley conservancy, Zimbabwe. *Global Ecology Conservation*, *20*, e00737. https://doi.org/10.1016/j.gecco.2019.e00737

McInturff, A., Xu, W., Wilkinson, C. E., Dejid, N., & Brashares, J. S. (2020). Fence ecology: Frameworks for understanding the ecological effects of fences. *Bioscience*, *70*, 971–985. https://doi.org/10.1093/biosci/biaa103

Mukeka, J. M., Ogutu, J. O., Kanga, E., & Roskaft, E. (2019). Human-wildlife conflicts and their correlates in Narok County, Kenya. *Global Ecology and Conservation*, *18*, e00620. https://doi.org/10.1016/j.gecco.2019.e00620

Munyao, M., Siljander, M., Johansson, T., Makokha, G., & Pellikka, P. (2020). Assessment of human-elephant conflicts in multifunctional landscapes of Taita Taveta County, Kenya. *Global Ecology and Conservation*, *24*, e01382. https://doi.org/10.1016/j.gecco.2020.e01382

Mutinda, M., Chenge, G., Gakuya, F., Otiende, M., Omondi, P., Kasiki, S., Soriguer, R. C., & Alasaad, S. (2014). Detusking fence-breaker elephants as an approach in human-elephant conflict mitigation. *PLoS One*, *9*(3), e91749.

Nyhus, P. J. (2016). Human-wildlife conflict and coexistence. *Annual Review of Environment and Resources*, *41*(1), 143–171. https://doi.org/10.1146/annurev-environ-110615-085634

Ogada, D. L., Keesing, F., & Virani, M. Z. (2012). Dropping dead: Causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences*, *1249*, 57–71. https://doi.org/10.1111/j.1749-6632.2011.06293.x

Ogra, M. V. (2008). Human-wildlife conflict and gender in protected area borderlands: A case study of costs, perceptions, and vulnerabilities from Uttarakhand (Uttaranchal), India. *Geoforum*, *39*, 1408–1422.

Oldekop, J. A., Holmes, G., Harris, W. E., & Evans, K. L. (2015). A global assessment of the social and conservation outcomes of protected areas. *Conservation Biology*, *30*(1), 133–141. https://doi.org/10.1111/cobi.12568

Osborn, F. V. (2002). Capsicum oleoresin as an elephant repellent: Field trials in the communal lands of Zimbabwe. *Journal of Wildlife Management*, *66*(3), 674–677.

Pacioni, C., Kennedy, M. S., & Ramsey, D. S. L. (2020). When do predator exclusion fences work best? A spatially explicit modelling approach. *Wildlife Research*, *48*, 209–217. https://doi.org/10.1071/WR19192

Pekor, A., Miller, J. R. B., Flyman, M. V., Kasiki, S., Kesch, M. K., Miller, S. M., Uiseb, K., van der Merve, V., & Lindsey, P. A. (2019). Fencing Africa's protected areas: Costs, benefits, and management issues. *Biological Conservation*, *229*, 67–75. https://doi.org/10.1016/j.biocon.2018.10.030

Ripple, W. J., Estes, J. A., Beschta, R. L., Wilmers, C. C., Ritchie, E. G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M. P., Schmitz, O. J., Smith, D. W., Wallach, A. D., & Wirsing, A. J. (2014). Status and ecological effects of the world's largest carnivores. *Science*, *343*(6167), 1241484. https://doi.org/10.1126/science.1241484

Sibanda, B. M. C., & Omwega, A. K. (1996). Some reflections on conservation, sustainable development and equitable sharing of benefits from wildlife in Africa: The case of Kenya and Zimbabwe. *South African Journal of Wildlife Research*, *26*, 174–181.

Šidák, Z. K. (1967). Rectangular confidence regions for the means of multivariate normal distributions. *Journal of the American Statistical Association*, *62*(318), 626–633. https://doi.org/10.1080/01621459.1967.10482935

Soliku, O., & Schraml, U. (2018). Making sense of protected area conflicts and management approaches: A review of causes, contexts and conflict management strategies. *Biological Conservation*, *222*, 136–145. https://doi.org/10.1016/j.biocon.2018.04.011

Thouless, C. R., & Sakwa, J. (1995). Shocking elephants: Fences and crop raiders in Laikipia District, Kenya. *Biological Conservation*, *72*, 99–107.

Treves, A., Wallace, R. B., Naughton-Treves, L., & Morales, A. (2006). Co-managing human-wildlife conflicts: A review. *Human Dimensions of Wildlife*, *11*(6), 383–396.

Wall, J., Wittemyer, G., Klinkenberg, B., Lemay, V., & Douglas-Hamilton, I. (2013). Characterizing properties and drivers of long distance movements by elephants (*Loxodonta africana*) in the Gourma, Mali. *Biological Conservation*, *157*, 60–68. https://doi.org/10.1016/j.biocon.2012.07.019

Webber, A. D., Hill, C. M., & Reynolds, V. (2007). Assessing the failure of community-based human–wildlife conflict mitigation project in Budongo Forest reserve, Uganda. *Oryx*, *41*, 177–184.

Weise, F. J., Wessels, Q., Munro, S., & Solberg, M. (2014). Using artificial passageways to facilitate the movement of wildlife on Namibian farmland. *South African Journal of Wildlife Research*, *44*, 161–166.

Wishitemi, B. E. L., Momanyi, S. O., Ombati, B. G., & Okello, M. M. (2015). The link between poverty, environment and ecotourism development in areas adjacent to Maasai Mara and Amboseli protected areas, Kenya. *Tourism Management Perspectives*, *16*, 306–317. https://doi.org/10.1016/j.tmp.2015.07.003

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Dupuis-Desormeaux, M., Kaaria, T. N., Kinoti, J., Paul, A., Gilisho, S., Kobia, F., Onyango, R., Chege, G., Kimiti, D., Mwololo, M., Davidson, Z., & MacDonald, S. E. (2023). Human-wildlife conflicts in communities bordering a Savannah-Fenced wildlife conservancy. *African Journal of Ecology*, *61*, 628–635. https://doi.org/10.1111/aje.13151