Efficiency of Innovations in Mitigating Livestock Depredation in the Wildlife Dispersal Areas of Maasai Mara National Reserve-Kenya

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Abstract

Wildlife conservation and local communities suffer significantly from livestock depredation on a socio-economic level. Local communities frequently kill or harm predators as a result of actual or perceived dangers to livestock. This study assessed the effectiveness of solar flashlights, predator-proof kraals, and "eye" Mark painting innovation in mitigating livestock depredation in wildlife dispersal areas. Data was collected through questionnaires, Focus Group Discussions, interviews, day-to-day monitoring and secondary sources for one year. All 342 respondents interviewed through the questionnaire survey experienced livestock depredation. The study recorded a total of 144 livestock attack incidents involving 294 killings and 52 Injuries. Of the 144 livestock depredation cases recorded in the year under investigation, only 2.3% (4) cases occurred under Solar Flashlight Kraals, Predator Proof Kraals and "Eye" marks Painting innovations. The total number of livestock killed under the innovations was 3% (n=9), while only 2% (n=1) were injured. The distribution of livestock killed showed a significant difference across the three innovation types ($\chi 2=8.667$, $df=2$, $p=0.0131$), while for the livestock injured in the innovations, there was no significant difference ($\chi 2=2.000$, $df=2$, $p=0.3679$). In conclusion, the three innovative techniques were equally efficient in protecting livestock against predator attacks and injuries.

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Keywords: Human-Carnivore Conflict, Livestock Depredation, Maasai Mara, Carnivore, Predator, Local Community, Mitigation

Introduction

Livestock depredation is considered one of the most prevalent forms of Human-Wildlife Conflict (HWC) in areas adjacent to conservation areas globally (LeFlore et al., 2019). This occurs when carnivores attack, injure, or kill livestock. Most local communities residing in areas adjacent to conservation areas are nomads and predominantly rely on livestock as their main source of livelihood. This makes livestock protection a top priority. In that, when the community loses livestock to wildlife attacks, they retaliate by poisoning and spearing the predator involved (Beattie et al., 2020). As the human population increases and encroaches into wildlife habitats, carnivores and humans come into proximity, thus increasing closer interaction. Livestock begins to replace the carnivores' natural prey, fuelling Livestock Depredation in which carnivores are attacked by humans in retaliation or because of their perceived threat to human livelihood (Mbise et al., 2018). There are significant regional and national differences in the percentage of livestock depredation, Bear attacks on cattle, for instance, are 100% in the Spain-Pyrenees and 58.5% in Greece, while in the Cantabrian Mountains, they account for 66% (Morales-González et al., 2020). Livestock depredation cases are intense in locations where protected areas are small and intermingled with human settlements (Ngoprasert et al., 2007; Radhakrishnan, 2018). In India, for instance, leopards coexist alongside 1.3 billion people and occupy 68% of the country's land area (Gulati et al., 2021). Naha et al., 2020, reported increased incidences of leopard attacks on humans and livestock, escalating revengeful killings of leopards.

In Africa, jackals (*Canis mesomelas and Canis auereus*), hyenas (*Hyaena spp*.), wild dogs (*Lycaon pictus*) cheetahs (*Acinonyx jubatus*), Leopard (*Panthera pardus*) and lions (*Panthera leo*) have been reported as the most troublesome carnivores to livestock (Loveridge et al., 2017). The African drylands hosts spectacular wildlife species including the carnivore species. These areas also support pastoralism as the main land use with livestock as a key economic activity. Throughout Africa, wild carnivores have been shot and or poisoned by the local community for killing or maiming their livestock (Masenga et al., 2020).

Causes of Livestock Depredation

The drivers of livestock depredation include inadequate benefits from wildlife conservation (Mogomotsi, 2019; Samelius et al., 2021), inadequate and slow compensation processes for livestock loss (Bauer et al., 2022; Sanei et al., 2020), increasing livestock population and competitive exclusion by wild herbivores (Suratissa, 2021) and poor livestock husbandry (Naha et al., 2020).

Impacts of Livestock Depredation

Livestock depredation is a widespread crisis, especially in rural and semi-urban areas near forests (Suratissa, 2021). It significantly affects the social, economic, and ecological dimensions of communities. Socially, depredation leads to human injuries or deaths during livestock protection efforts, impacting the physical and mental well-being of individuals (Mekonen, 2020). In many rural societies, livestock represents not only income but also social status and wealth (LeFlore et al., 2019). The psychological toll includes anxiety, depression, and fear of recurring losses, leading to a reduced quality of life (Shotuyo et al., 2021). Economically, the loss of animals directly undermines livelihoods, pushing families into poverty especially where no compensation mechanisms exist (Blair & Meredith, 2018; Gemeda & Meles, 2018).

Injured animals require costly medical treatment (Mekonen, 2020), and surviving herds often suffer stress-induced drops in productivity (Acha & Temesgen, 2015). Although mitigation strategies such as predator-proof enclosures, insurance, and conservation efforts exist, they are costly and require sustained support (LeFlore et al., 2019).

From a conservation standpoint, livestock losses often provoke retaliation from communities, including hunting, poisoning, or trapping of predators (Thondhlana et al., 2020), which can unintentionally affect non-target species and disrupt entire ecosystems (Baral et al., 2021). Retaliatory behaviour may also hinder community cooperation with conservation authorities, sometimes resulting in illegal activities like poaching and habitat destruction (LeFlore et al., 2020).

Ecologically, depredation-related conflicts contribute to reduced wildlife populations or local extinctions. In response, communities may poison predator carcasses or use spears and traps (Jablonski et al., 2020; van Eeden et al., 2018). Additionally, habitat modification such as deforestation and fencing used to protect livestock leads to ecosystem fragmentation and further threatens biodiversity (Khorozyan & Waltert, 2019).

The future of carnivores' conservation lies in the hands of local communities settled in areas adjacent to conservation areas, as an estimated 70% of the wildlife population resides outside Protected Areas (Morales-González et al., 2020). Some of the measures employed to mitigate LD include the use of guarding dogs, a community-based approach, carcass removal (Morehouse et al., 2020), enhanced law enforcement in conservation areas, compensation programs, insurance schemes to fund compensation and re-stocking of wild prey populations, among others. In the Maasai Mara dispersal areas, communities have employed the use of predator-proof Kraals, solar flashlights to keep predators away from livestock and the use of "eye" mark painting to scare off predators during the day, while in the grazing fields. However, no studies have been carried out to assess the efficiency of the three innovations. This study, therefore, evaluated the effectiveness of LED Flashlight Kraals, Predator Proof Kraals and "Eye" mark Painting interventions to mitigate livestock depredation.

Methods

The study was conducted in Mara Ripoi (13,500 acres), Mara Siana (11,000 acres) and Isaaten (6,422 acres) conservancies located in the dispersal areas of Maasai Mara National Reserve (Figure 1). The conservancies border the famous Maasai Mara National Reserve, thus considered key wildlife dispersal areas. The conservancies under investigation are located in Narok County located in the Southwest of Kenya. The County is rich and diverse in wildlife and wildlife-related activities. The main land uses include wildlife-based tourism, wildlife conservation, pastoralism and crop farming. Livestock keeping is the main livelihood source for the local Maasai community. The study conservancies were provided with an introductory letter and research permits indicating the need to carry out the research.

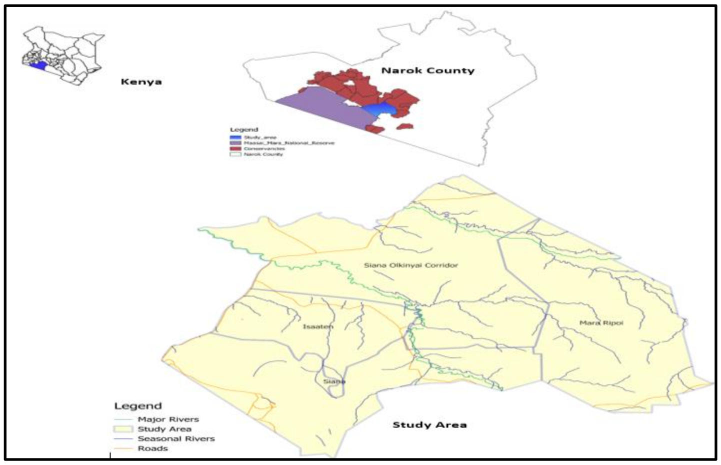

Figure 1: Study Area

Data Collection

The study carried out daily monitoring and recording of livestock depredation incidences for twelve months between April 2023 to March 2024. One Predator-proof Kraal and Solar flash Kraals were randomly sampled in each conservancy. One model Kraal was constructed for data collection, in cases where Predator proof Kraal (PPK) and Solar flash Kraals did not exist. The Predator-proof Kraal entailed upgraded traditional Maasai livestock Kraals by reinforcing with posts, rolls of chain-links and flattened oil drum doors while the traditional Maasai livestock Kraal installed solar lighting around it to deter carnivores. Three herds of cattle that have been experiencing depredation from secondary data were purposively selected from each Conservancy. Half of the cattle in the herd were painted with an artificial eyespot mark on the hind sides. Black and white paints were used, for pale-coloured livestock. Black paint was applied on the outer side of the eye while the white paint to the inner eye pattern, for dark livestock only white paint was applied to the inner eye pattern. Marking was repeated every two weeks since it faded over time. The unmarked half of the herd acted as the control herds. The control herd had the same exposure and environment as the treatment herds. Both control (unmarked) and treatment herds (marked) spent each night in the same Kraal and grazed in the same field under the same herder. The "eye" marking was done on 190 heads of cattle for one year.

Data was recorded using monitoring sheets in the Survey123 App on the phones. The daily monitoring sheets captured: the date and time of the attack (Night or Daytime), GPS Coordinates, attack site whether inside PPK or Outside PPK**,** Grazing field, type of carnivore involved (Lion, Leopard, Hyena, African Wild Dog, Unknown or Others; Status of the predator **(**Speared, Poisoned, Escaped or Unknown; type of livestock attacked (Cattle "Eye Marked", Cattle Unmarked, Sheep, Goat or Others); the number of livestock dead; the number of livestock injured among other information. Data collection for eye mark painting recorded: The herd name, date of marking, date of depredation, Sex of cattle, GPS coordinates, and coat colour. Questionnaire survey to sample 342 landowners who have contributed their parcels of land towards the establishment of conservancies was also conducted.

Spatial data was analyzed using ArcGIS 10.2) software to create a point shapefile of LD and associated attribute data. Kernel density analyses were performed to identify areas within the study area that recorded high LD density. The respondents' opinions and daily monitoring data were subjected to the chi-square test whereby a 0.05 level of significance was used to determine the relationship existing between data categories and conclude the study.

Results

Efficiency of the Innovations in Mitigating Livestock Depredation

A total of 144 livestock depredation incidences were reported in a single year under investigation. Of these, 63 (44%) cases occurred in open grazing fields, 56(30%) inside traditional Kraals, 20(2.3%) outside traditional kraals, but just next to the Kraal, 20(14%), inside Predator Proof Kraals 3(2%) while 2(1%) inside the solar flashlight Kraal.

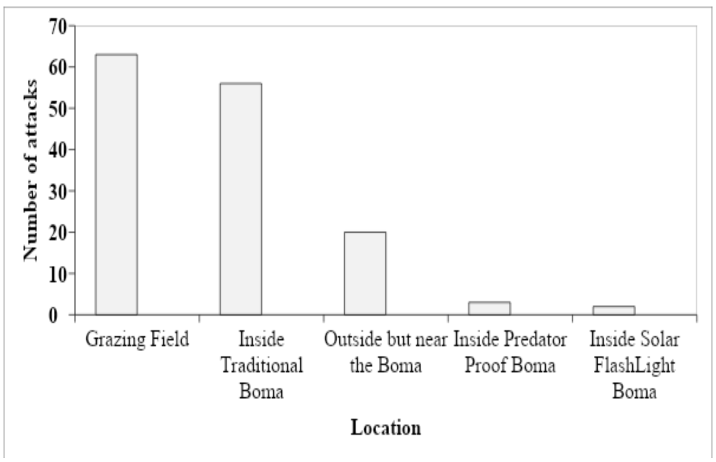

Figure 2: Location of livestock depredation

For the two incidents recorded inside the solar flashlight Kraals, hyenas and leopard were the carnivores involved and livestock attacked were sheep. For the three cases that occurred inside predator-proof kraals, 7 sheep were attacked and killed while 1 was injured. The carnivores involved were six (6) leopards and two (2) hyenas. There was no killing or injury recorded on the "eye" marked cattle during the entire monitoring period. However, out of the 27 unmarked cattle attacked and killed during the entire monitoring period, 29.6% (n=8) of cattle were from the control herds that were under the same environmental conditions as the marked ones.

Table 1: Comparison of Innovations

Innovation	Solar Flashlight Kraals	Predator Proof Kraals	Eye marked Cattle	Chi-square	p-value
No. of attack cases	2	3	0	2.000	0.3679
No. livestock killed	2	7	0	8.667	0.0131
No. livestock injured	0	1	0	2.000	0.3679

A comparison of livestock attacked and killed by predators across the different innovative intervention measures using the chi-square test for goodness of fit, assuming equal distribution across the innovation types based on the following null and alternative hypothesis: H_0*: The distribution of livestock killed did not vary significantly across the innovation types.* H_1*: The distribution of livestock killed varied significantly across the innovation types.* The test conducted at 95% confidence level showed that there was sufficient evidence to show that the distribution of livestock killed was significantly different across the different innovation types (χ^2=8.667, df=2, p=0.0131). The "eye marking" recorded 0 killings while predator-proof Kraals recorded 7 killings while solar flashlight recorded 2 killings.

There was no sufficient evidence to show that the distribution of livestock injured by the predators was significantly different across the different innovation types (χ^2=2.000, df=2, p=0.3679). This shows that the innovation types equally protect the livestock against injury by the predators.

Comparing the number of livestock attack cases by the predators across the innovation types the chi-square test for goodness of fit at 95% confidence level, the results showed that there was no sufficient evidence to show that the distribution of livestock attacks by the predators was significantly different across the different innovation types (χ^2=2.000, df=2, p=0.3679). This shows that the innovation types equally protect the livestock against predator attacks.

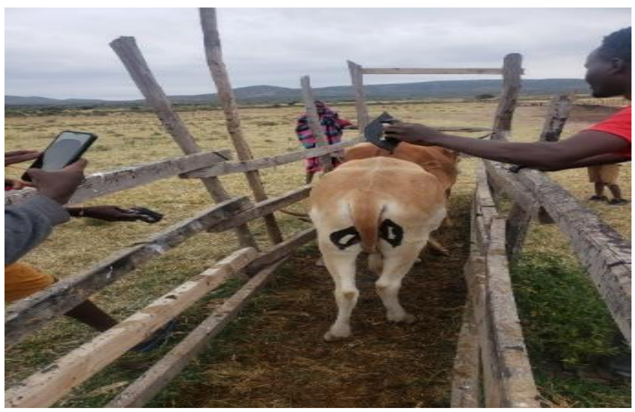

Figure 3: "Eye" mark on pale-colored cattle

Lastly, the study compared the number of livestock attack cases by the predators near the innovation sites across the innovation types using the chi-square test for goodness of fit at 95% confidence level based on the null: H_0*: The distribution of livestock attacks near the innovation sites was equal across the innovation types.* The results showed that there was insufficient evidence to show that the distribution of livestock attacks near the innovation sites by the predators was significantly different across the different innovation types χ^2=1.000, df=2, p=0.606.

Other Supplementary Mitigation Measures in Place to Curb Depredation

Besides the aforementioned livestock protection measures, community traditionally utilized the following measures to curb depredation: Employing more herders 28% (n=97), night guarding 19% (n=65), Improving livestock Kraals to more secure ones by adding chain-link wire and iron sheets 12% (n=41), Using lights self-bought solar lights and torches to scare away wild animals at night 11.1% (n=38), Use dogs to scare away the carnivores and raising alert in case of any danger 9.9% (n=34), fencing homesteads 7.6% (n=26), Use adult herders only as opposed to children 6.7% (n=23) and lastly not grazing livestock within conservancies 5.3% (n=18).

Spatial Distribution of Livestock Depredation Incidents

The general location included the grazing field, inside traditional Kraals, inside solar flashlight Kraals, PPK and outside but near the livestock Kraals where depredation occurred in the study area. The mean center of the grazing field was about 3.7 km from Mara Bush Top Luxury Camp and 4.7km from Ngoso Primary School. The Standard Deviation Ellipse showed that the mean center for depredation inside traditional Kraals was about 5km from Mara Bush Top Luxury Camp and 5.1km from Ngoso Primary School. The mean center of livestock depredation occurring outside but near Kraals was about 4.3km from Mara Bush Top Luxury Camp and 4.2km from Ngoso Primary School (Figure 4 and 5).

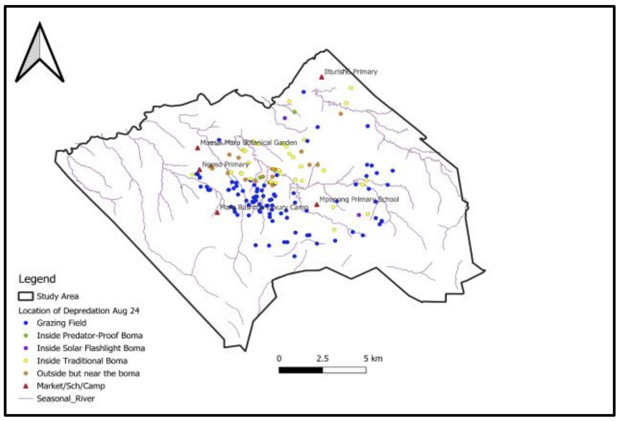

Figure 4: Locations where depredation cases took place

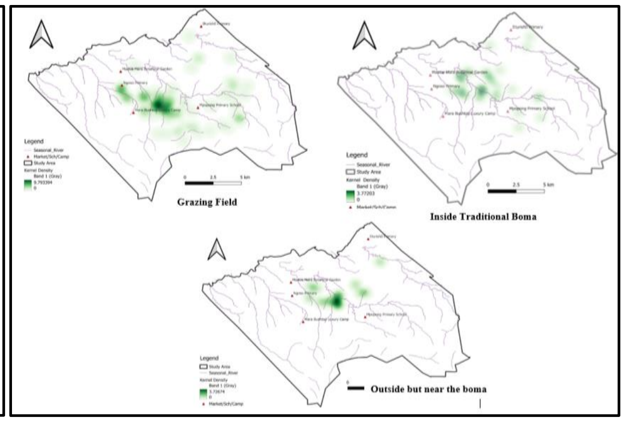

Figure 5: The Kernel Density for the locations of depredation

Discussion

Efficiency of the Innovations in Mitigating Livestock Depredation

There was a clear pattern in the extent and location where depredation took place. Livestock depredation cases in traditional Kraals were the highest with most incidents taking place at night. Suggesting that traditional Kraals are highly vulnerable to predator attacks, likely due its conditions predisposing livestock to predators, whereas grazing fields during the day ranked as the second most common site of attacks (Acha & Temesgen, 2015; LeFlore et al., 2019). Predators might take advantage of the open and less secure nature of these fields, making it easier to target livestock. This could also have been attributed to lack of physical barriers or enclosures making it easier for predators to access livestock. Further, lack of continuous herder supervision especially in expansive grazing fields with large herds of livestock exposed livestock to attacks. However, the extent of depredation cases in predator-proof Kraals was low indicating that these Kraals were effective in protecting livestock herds and thus reducing the frequency of depredation. The predator-proof Kraals have enhanced physical barriers and are designed to withstand predator attempts to intrude. Similarly, Solar Flashlight Kraals reported a low extent of attacks further confirming the effectiveness of these deterrent methods. The presence of lights at night deterred predators.

Generally, the very low percentage of depredation cases occurring inside solar flashlight Kraals, Predator Proof Kraals and the "eye" marked cattle innovations indicates that these measures are highly effective in reducing predator attacks on livestock. This implies that solar flashlight Kraals and Predator Proof Kraals are valuable in protecting livestock, particularly sheep, against nocturnal predator attacks such as hyenas and leopards, the findings conform with that of LED flashlight techniques in reducing depredation by lions. These findings support the study by Sutton et al., 2017 on the effectiveness of fortified Kraals in reducing livestock depredation

The fact that no eye-marked cattle were killed or injured by carnivores during the entire monitoring period suggests that eye-marking is an effective deterrent against predator attacks during the day. This indicates that predators might perceive the eye marks as a threat or a sign of vigilance, thus avoiding attacking the marked cattle. However, the deaths of 27 unmarked cattle, with 29.6% (8) from control herds in similar environmental conditions as the marked ones, underline the difference in predation risk between marked and unmarked cattle. This disparity highlights the potential protective benefits of eye marking and suggests that environmental conditions alone do not account for the difference in attack rates. Eye marking appears to play a crucial role in reducing livestock vulnerability to predators. The higher predation rate on control herds (unmarked cattle) reinforces the hypothesis that eye marking significantly deters predators.

At least one of the innovation types was better at controlling livestock killings than the rest. "Eye Mark" was better at controlling livestock killings than solar flashlights and predator-proof Kraals. However, the limitation of "eye mark" is that it was applicable during the day when livestock are in grazing fields, it is also not clear if this innovation could work on sheep and goats.

The incidents occurring near but outside the solar flashlight Kraals and predator-proof Kraals indicate that while the innovations are effective in a confined area, they do not provide absolute protection and that proximity to protected areas does not eliminate the risk. Predators may still pose a threat in the unprotected surrounding vicinity. This suggests the need for additional measures to extend protection beyond the immediate area of the solar flashlight Kraals, such as increased patrolling or combining different protective strategies. Sheep were the primary livestock attacked within and near Predator Proof Kraals indicating their vulnerability to predation.

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Authorship Contribution Statement

All the Authors contributed to the research and development of this article; Elizabeth Wakoli worked on conceptualization, methodology, formal analysis, original report preparation, original draft preparation and writing the review. Prof. Gilbert Obwoyere, Dr, Bernard Kirui, and Dr. Dickson Makanji they were the supervisors of the project and also worked on writing the review and editing of the final article. Dr. Dorothy Syallow helped in original draft preparation, writing the review, and fund acquisition to ensure that the objectives are achieved; All authors have read and agreed to the published version of the manuscript.

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