

Research Article

Nature and Extent of Livestock Depredation in Wildlife Dispersal Areas of Maasai Mara National Reserve - Kenya

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Abstract

The study in the wildlife dispersal areas of Maasai Mara National Reserve established the nature and extent of livestock depredation in terms of the types of livestock attacked, the specific carnivores responsible for depredation, the causes of depredation, as well as the timing and seasonality of these events. It also examines the locations and habitats where depredation occurred and identifies hotspot areas for livestock depredation. Qualitative and quantitative data collection methods were used through questionnaires, focus group discussions, interviews with key informants, observation and monitoring sheets. Data from the questionnaire survey were analyzed using frequencies and chi-square, while spatial-temporal data were analyzed through Kernel Density and Standard Deviation Ellipse. The results showed that all respondents interviewed experienced livestock depredation in the study area. Although lions, leopards, cheetahs and hyenas were identified as the problem animals, the most problematic carnivore involved in depredation was hyenas (98.8%, n=338), followed by lions (56.7%, n=194). The chi-square analysis showed that the type of carnivore involved in depredation was dependent on the location where depredation took place ($\chi^2=60.732$, df=4, p=0.001). The most vulnerable livestock to depredation were sheep (n=208, 71% killed and n=31, 62% injured), followed by goats (n=59, 20% killed and n=15, 30% injured). The cattle that had an "eye" mark on their hinds to scare predators were not attacked during the entire study period. The results revealed that there was no association between the type of livestock attacked and the habitat where the attack took place ($\chi^2=6.215$, df=3, p=0.400). The major cause of livestock depredation was the grazing of livestock on the conservancies (n=152, 44.2%). When the herders carry defensive equipment like knives, clubs, sticks, and spears, depredation cases are less experienced (n=173, 51%). In conclusion, the type of livestock significantly influences the rate of depredation, with sheep and goats being the most vulnerable to predator attacks. The absence of attacks on cattle with "eye-marked" signs highlights the potential effectiveness of this low-cost, simple deterrent method. The high incidence of injuries and fatalities among sheep and goats calls for targeted interventions to protect these more vulnerable livestock types. Given the high involvement of hyenas in depredation, the study recommends that specific strategies to mitigate livestock attacks should be prioritized.

Keywords

Maasai Mara, Livestock Depredation, Human-Carnivore Conflict, Carnivore, Livestock, Local Community

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1. Introduction

Human-carnivore Conflict in areas adjacent to conservation areas is a worldwide conservation issue and a serious threat to both the local communities and the carnivore species [1]. Globally, prevalent cases of human-carnivore conflict in terms of livestock depredation have been documented in different regions and involving various carnivore species. In Europe and Northern America; the lynx, wolf and bear have been documented as the most problematic carnivore species [2]. However, the proportion of livestock depredation varies greatly between countries and regions. For instance, bear attacks on livestock in Greece was reported as 58.5%, Spain-Pyrenees 100%, and Spain Cantabrian Mountains 66% [3]. The factors leading to livestock depredation in European countries include: distance of human settlement from a protected area [4].

In Asian countries, leopards (*Panthera pardus*), snow leopards (*Panthera uncia*), and tigers (*Panthera tigris*) have been as the most problematic carnivore species [5]. Livestock depredation is severe in areas where protected areas are small and interspersed with human settlements [6]. In India, for instance, leopards inhabit 68% of the country's land mass and co-occur with a population of 1.3 billion people [7].

In Africa, jackals (*Canis mesomelas* and *Canis aureus*), hyaenas (*Hyaena spp.*), wild dogs (*Lycaon pictus*) cheetahs (*Acinonyx jubatus*), leopard (*Panthera pardus*), and lions (*Panthera leo*) have been reported as the most troublesome [8]. The African dryland areas are also characterized by pastoralism as the main land use with livestock as a key economic activity. The interphase between wildlife species and local communities has intensified livestock depredation, resulting in severe socio-economic impacts. Predators are often killed or injured by the local communities because of actual or perceived threats to livestock [9]. Domestic animals have little anti-predatory behavior thus being an easy prey for predators [10]. In Botswana, local communities living adjacent to Moremi game reserve have been reported killing wild dogs illegally despite the presence of compensation scheme for livestock depredation cases [11].

In Kenya, approximately 70% of the country's wildlife lives on rangelands outside national parks and reserves, making private and community lands critically important for wildlife dispersal, migration, and key lifecycle stages [12]. In Amboseli ecosystem and Northern rangelands of Kenya, lions, hyaenas, cheetahs and leopards have been documented as the most problematic carnivores [13]. Livestock depredation in the Maasai Mara Ecosystem have been recorded, and the carnivores involved include jackal, Spotted hyaena, wild dog, leopard, cheetah, lion among others [14]. The Maasai community attaches high value to livestock keeping; the limiting factors to livestock keeping being diseases, cattle raiding and livestock depredation. In most cases, lions attack cows, inflicting high economic losses even with a single animal lost since most cows attacked are mature ones [15]. When carnivores kill livestock, the local community can resort to retali-

atory killing by poisoning baited prey and leftover carcasses, which not only kills targeted predators but also non-targeted species such as vultures. Large carnivores especially lions, leopards and hyaenas suffer most for killing livestock [10]. Hence, the future of carnivores' conservation lies in the hands of local communities living adjacent to conservation areas.

2. Materials and Methods

The study was conducted in Mara Siana, Isaaten, and Mara Ripoi Conservancies (30,922 Acres), which are in the dispersal areas of Maasai Mara National Reserve in Narok County, Kenya. The major land use activities in the study area are livestock keeping and wildlife tourism.

The study utilized the mixed research design in data collection and analysis, which incorporated elements of both qualitative and quantitative approaches. The quantitative aspect measured the extent of livestock depredation, while the qualitative aspect offered insights into local community attitudes, experiences, and perceptions on the issue.

The conservancies included in the study had a total of 3,402 landowners. The sample size for the questionnaire survey was determined using the formula proposed by [16] and 357 respondents were sampled.

A multi-stage sampling procedure was used whereby all cases of Livestock depredation in the study area were clustered into seasons of the year, time of the day, location, and the GPS coordinates. A systematic sampling procedure was used for the questionnaire survey. At every 5th landowner, a person was selected after randomly selecting the first as the starting point.

Data was collected through observation/daily monitoring, questionnaire survey, informant interviews, and focus group discussions with local community members, conservation officials, and other stakeholders. Secondary data was sourced from Kenya Wildlife Service reports, the Maasai Mara Wildlife Conservancy Association reports, books and journals.

Response frequencies were calculated, and chi-square tests were conducted where appropriate to analyze the data and ensure its representation of the real population. Spatial and temporal data was imported to Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS 10.2) software to create a point shapefile of livestock depredation and associated attribute data. Maps were developed linking livestock depredation with aspects like season, time and habitat. The Kernel Density and Standard Deviation Ellipses (SDE) were carried out for all cases of depredation recorded in the study area. The SDE and Kernel density were calculated based on the distance from Mara Bush Top Luxury Camp and Ngoso Primary facilities within the study area.

3. Results

Results showed that all respondents interviewed had experienced livestock depredation. The SDE showed that the mean center for all livestock depredation cases was about 3.9km from Mara Bush Top Luxury Camp and about 4.6 km from Ngoso Primary. The high density of livestock depredation occurred about 2.5km from the Mara Bush Top Luxury Camp.

3.1. Depredation Cases per Carnivore

The day-to-day monitoring of livestock depredation results indicated that lions, leopards, Spotted hyenas, and African wild dogs were involved in livestock depredation. The Spotted hyenas were the most notorious carnivore with 70 (48.6%) cases, followed by leopards with 41 (28.5%) cases, lions with 26 (18%) and African wild dogs with 4 (2.8%) cases. The findings indicate that lion attacks on livestock were high in grazing fields (85%, $n=22$), leopard high in the traditional Bomas (51%, $n=21$), and Spotted hyaena attacks were high in both grazing fields and traditional Bomas (47%, $n=33$). Chi-square test results showed that the type of carnivore in-

involved in depredation was dependent on the location ($\chi^2=60.732$, $df=4$, $p=0.001$).

Lions attacking livestock was high in open habitats (48%, $n=12$), leopard attacks were high in the grazing fields that had thickets of shrubs and forest (68%, $n=13$), Spotted hyaena depredation cases were highly recorded in open habitats (62%, $n=21$), while for the African wild dog, all the four cases recorded were in the open grazing field. Results further showed that there was a significant difference in the type of carnivores involved in the attack and the type of habitat where depredation took place ($\chi^2=22.205$, $df=3$, $p=0.035$).

Lions mostly attacked when livestock was under the care of one adult male herder (65%, $n=15$), leopards attacks were high when livestock was under the care of more than one male herder (33%, $n=5$), Spotted hyaena attacked most when the livestock was under the care of one male adult herder (47%, $n=16$). There was a strong association between the type of carnivore involved in depredation and the type and number of herders present ($\chi^2=71.439$, $df=4$, $p=0.000$). The high density of lion, leopard and Spotted hyaena attacking livestock is shown in Figure 1.

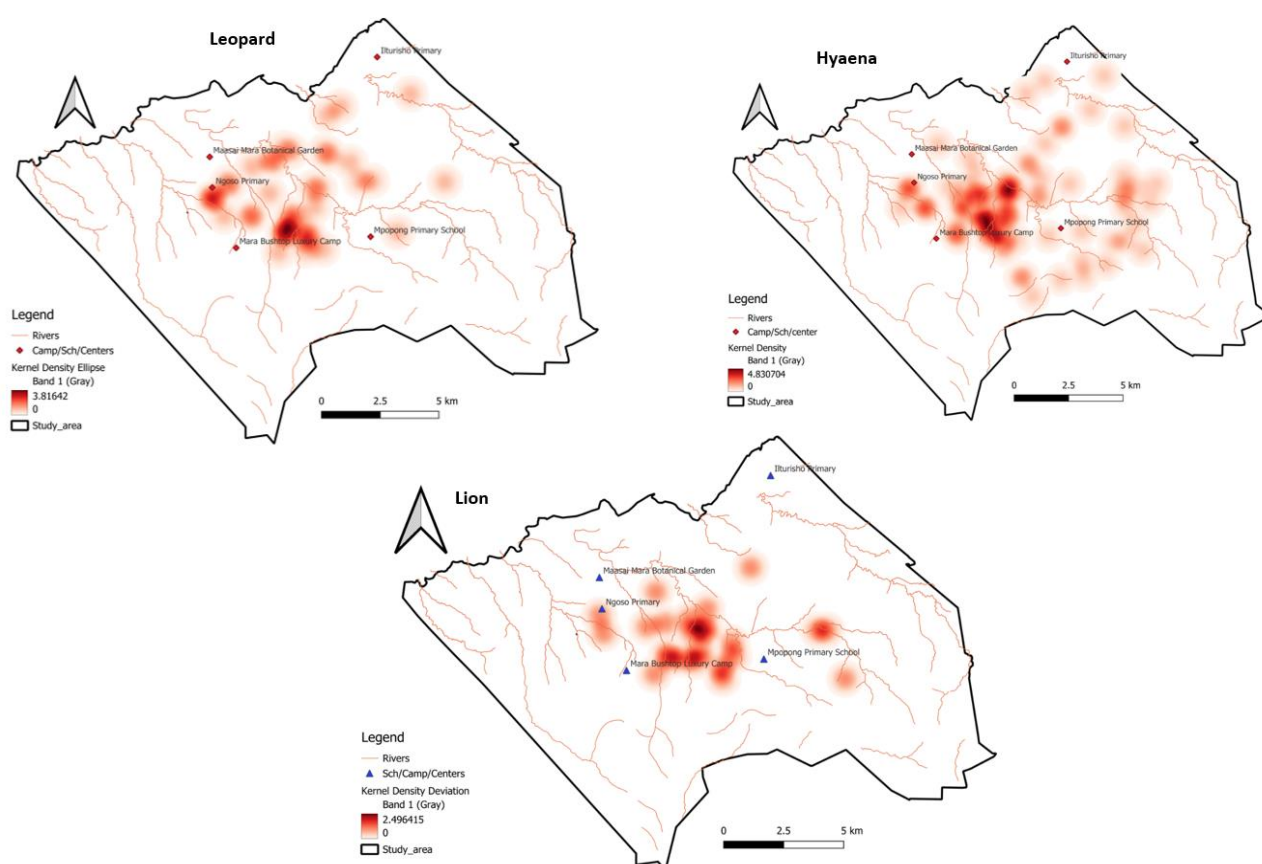


Figure 1. The Kernel Density for lion, leopard and hyaena.

3.2. Livestock Attacked and the Frequency of Attack

The daily monitoring results indicated that out of the 144 cases of livestock attacks recorded in one year, a total of 294 livestock were killed and 50 were injured by predators. Sheep were highly killed (71%, $n=208$), followed by goat (20%, $n=59$), Unmarked cattle (9%, $n=27$) and the least were cattle with “eye Marked” sign on their hinds with no case of killing or injury. For those that were injured, sheep were leading with 62% ($n=31$), followed by goats (30%, $n=15$) and the least injured were unmarked cattle with 8% ($n=4$). The hot spot area

of depredation on cattle, sheep and goats was as shown in Figure 2.

The results from the questionnaire survey were almost similar to the day to day monitoring. Most respondents, 99.4% ($n=340$), indicated that sheep were attacked most, followed by goats at 89.8% ($n=307$). For a low extent, donkeys were the highest at 63.5% ($n=217$). The unmarked cattle and goats were highly attacked in the grazing field while sheep were highly attacked inside traditional Bomas. The eye-marked cattle were not attacked in all the cited locations. Chi-square test results showed that the type of livestock attacked depended on the location ($\chi^2=37.297$, $df=4$, $p=0.001$).

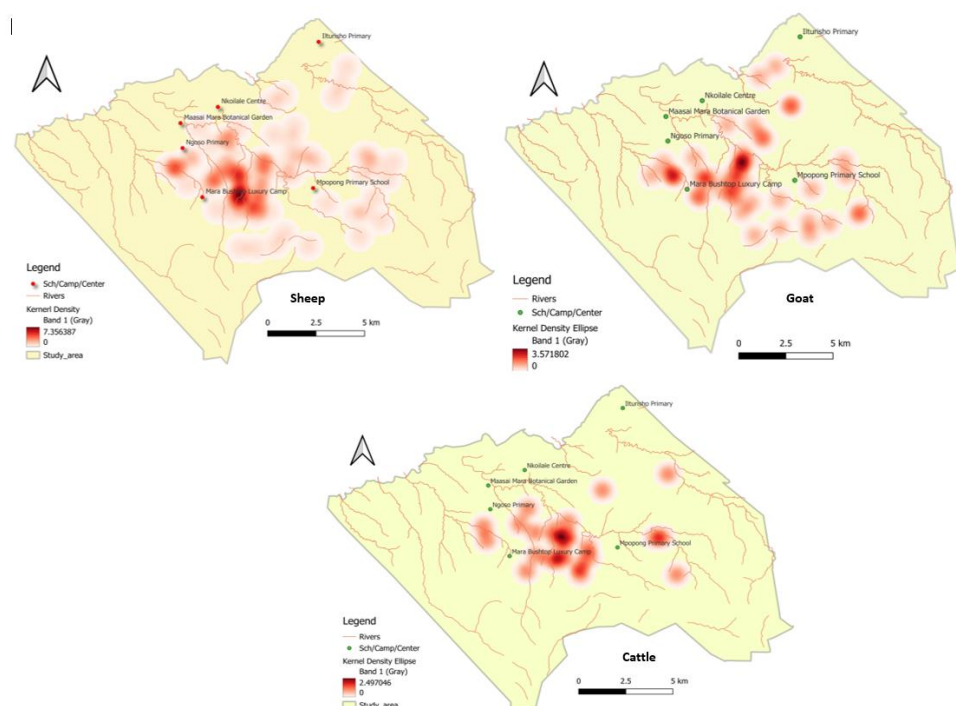


Figure 2. The Kernel Density depredation on Unmarked cattle, sheep and goat.

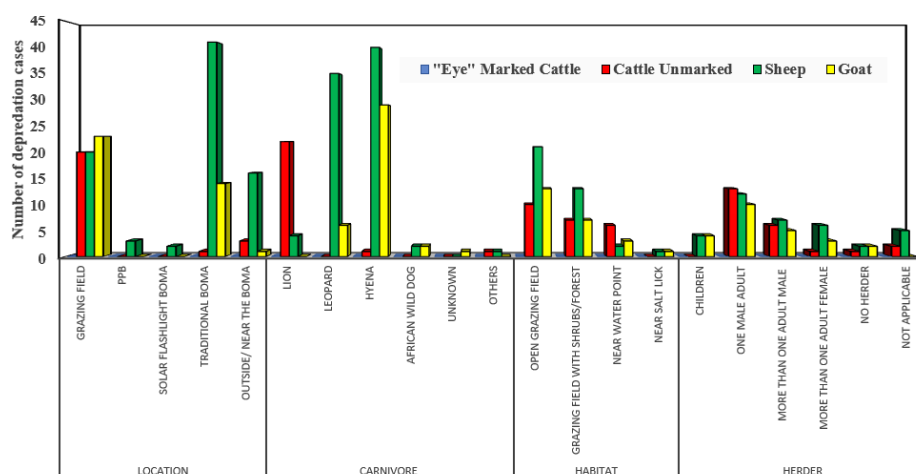


Figure 3. Livestock attacked in relation to the location, carnivore, habitat and herder.

Cattle were highly attacked by lions, while sheep and goats were highly attacked by Spotted hyaenas. There was a strong association between the type of livestock attacked and the type of carnivore involved ($\chi^2=123.535$, $df=5$, $p=0.001$). Most livestock were attacked while in the open grazing field. There was no association between the type of livestock attacked and the habitat where the attack took place ($\chi^2=6.215$, $df=3$, $p=0.400$). Lastly, results on the type of herders in charge of livestock during the attack incidences showed that most attacks happened when livestock were under the care of one adult male herder. The Chi-square test results, however, indicated that there was no significant association between the type of livestock attacked and the herder taking care of the herd ($\chi^2=12.362$, $df=5$, $p=0.417$) as shown [Figure 3](#).

3.3. Causes of Livestock Depredation

Findings on the causes of livestock depredation from the questionnaire survey indicated that grazing of livestock on the conservancies was the major cause (44.2%, $n=152$), followed by livestock being easy prey to wild animals as they are vulnerable and lack anti-predatory behavior (33%, $n=114$), lack of enough natural prey for predators in the conservancies (8.7%, $n=30$), increase in carnivore population in the con-

servancies (7.6%, $n=26$), lack of good livestock herding techniques like poor herders or children herding (4.1%, $n=14$) and the least was lack of predator-proof bomas (1.7%, $n=6$).

3.4. Time and Season of Attack

During the monitoring period (April 2023- March 2024), the dry seasons in the study area covered the months of March, April, May, November and December, while the rainy seasons were the months of January, February, June, July, August, September and October. Most cases of depredation were reported during the rainy season (60%, $n=86$) while only 58 (40%) cases were recorded during the dry season. In a period of twelve months, 220 of livestock were killed and 45 were injured by the carnivores during the rainy season.

The season of livestock depredation in relation to the location where the attack took place, the type of carnivore involved in the attack, the type of livestock attacked, the habitat and time of attack was as presented in [Table 1](#). It was also observed that most livestock attack incidences occurred during the night (53%, $n=77$), while 67 (47%) cases occurred during the day. Over the entire duration of daily monitoring, 196 livestock were killed and 34 injured at night, while 98 were killed and 16 injured during the day.

Table 1. Daily monitoring of seasonal variation in depredation.

The location where the attack took Place	Dry Season		Rainy Season		Pearson Chi-Square
	Freq	%	Freq	%	
Grazing Field	29	50	34	40	$\chi^2=6.993$, $df=4$, $p=0.136$
Inside Predator-Proof Boma	2	3	1	1	
Inside Solar Flashlight Boma	2	3	0	0	
Inside Traditional Boma	17	29	39	45	
Outside but near the Boma	8	14	12	14	
Type of Carnivore involved in the attack					$\chi^2=28.158$, $df=5$, $p=0.001$
Lion	17	29	9	10	
Leopard	22	38	19	22	
Hyaena	15	26	55	64	
African Wild dog	4	7	0	0	
Unknown	0	0	1	1	
Others	0	0	2	2	$\chi^2=11.808$, $df=3$, $p=0.003$
Livestock attacked					
Eye Marked Cattle	0	0	0	0	
Cattle Unmarked	17	29	7	8	
Sheep	30	52	52	60	

The location where the attack took Place	Dry Season		Rainy Season		Pearson Chi-Square
	Freq	%	Freq	%	
Goat	11	19	27	31	$\chi^2=2.519$, df=3, p=0.472
Habitat					
Open Grazing field	19	51	25	53	
Grazing field with Shrubs/Forest	14	38	13	28	
Near Water Point	4	11	7	15	
Near Salt lick	0	0	2	4	$\chi^2=0.000$, df=1, p=0.996
Time of attack					
Daytime	31	53	46	53	
Night	27	47	40	47	

3.5. Location of Livestock Attack

From the questionnaire survey, results showed that a high number of attacks was evident in the traditional livestock

bomas at night (94%), followed by in the grazing fields during the day (67%), at salt lick points, near water points (51%), in predator-proof bomas (10%) and finally Solar flashlight bomas at night (6%) as shown in the [Table 2](#).

Table 2. Location and Extent of Depredation.

Location of attack	High		Medium		Low	
	Frequency	%	Frequency	%	Frequency	%
Grazing fields	229	67	113	33	0	0.0
Traditional Livestock Bomas	323	94	15	4	4	1.2
Near water points	172	50	158	46	12	3.5
Salt lick points	174	51	148	43	20	5.8
Predator-Proof Bomas	33	10	99	29	210	61.4
Flashlight bomas	21	6	125	37	196	57.3

3.6. Habitat Where Depredation Occurred

Results on incidences of livestock depredation in different grazing habitats indicated that: the open grazing field (52%, n=44) was leading in most cases of depredation, followed by forest and shrub grazing areas (32%, n=27), near livestock watering point (13%, n=11), and lastly near salt lick points with 2% (n=2). Results on the type of habitat where depredation took place based on the presence of a herder, their gender, age, and number taking care of livestock showed that: Dep-

redation reported cases were high in the open grazing field (52%, n=23) under the care of one male adult. In habitats with shrubs, forest, and thickets depredation was high when livestock were under the care of more than one adult male (26%, n=7). Near the livestock watering point, results showed that cases of livestock attack by carnivores were high when the livestock were under the care of one male adult (45%, n=5), while the 2 depredation cases that occurred near salt lick points occurred when livestock were under the care of one male adult ([Table 3](#)).

Table 3. Habitat of depredation in relation to herders.

Herder	Habitat								Pearson Chi-Square
	Open Grazing field		Shrubs or Forest		Near Water Point		Near Salt lick		
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	
Children	3	7	4	15	2	18	0	0	$\chi^2=26.851$, df=5, p=0.030
One Male Adult	23	52	5	19	5	45	2	100	
More than one male adult	9	20	7	26	2	18	0	0	
More than one Adult Female	5	11	4	15	1	9	0	0	
No Herder	4	9	0	0	1	9	0	0	
Not Applicable	0	0	7	26	0	0	0	0	

3.7. Livestock Herder and Herding Conditions When Attacks Occurred

Findings from day-to-day monitoring on the incidences of depredation and the presence of the herder during the day were as follows, 46.2% (n=36) were incidences of livestock attack occurred when livestock were under the care of one male, followed by 23.1% (18) when livestock were under care of one adult male, 12.8% (n=10) under the care of adult females, children 10.2% (n=8) and the least were 7.6% (n=6) cases where livestock did not have a herder.

Results from the questionnaire survey indicated that most respondents agreed that depredation cases were high when

livestock were under the care of children (51%, n=175), 161 (47%) strongly agreed, and the least was neutral and disagreed, which had 3 (1%) each. When livestock is under the care of female herders, most respondents agreed that depredation cases are high (49%, n=169), followed by strongly agree (42%, n=142) and the least (25%, n=7) strongly disagreed. Results also indicated that most respondents (65%, n=222) agreed that livestock depredation is high when livestock is under the care of one male herder. Further, most respondents agreed that when herders carry defensive equipment like knives, clubs, sticks, and spears, depredation cases are less experienced; and depredation cases are less at night in homesteads with dogs, and also less in the grazing field when herders have domestic dogs as shown in Table 4.

Table 4. Rating of livestock herding conditions under which livestock attacks take place.

Livestock attack	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
High under the care of children herders	161	47	175	51	3	1	3	1	0	0
High under the care of female herders	142	42	169	49	8	2	16	5	7	2
High under the care of one Male herder	69	20	222	65	13	4	34	10	4	1
Less when the herders carry defensive equipment	17	5	173	51	44	13	39	11	69	20
Less in homesteads with domestic dogs at night	34	10	236	69	60	18	12	4	0	0
Less when the herders have domestic dogs in the field	22	6	237	69	60	18	18	5	5	2

The Chi-square results showed that there was a significant association between the presence of the herder and the loca-

tion of depredation ($\chi^2=35.723$, df=2, p=0.000), while for the presence of the herder and the season when depredation took

place, there was no association ($\chi^2=10.694$, $df=1$, $p=0.058$).

4. Discussion

4.1. Nature and Extent of Livestock Depredation

Livestock depredation is a very serious issue for the local community living in areas adjacent to conservation areas [17]. In this study, all the respondents interviewed through a questionnaire survey and focus group discussions had suffered livestock loss to depredation. Respondents interviewed live next to wildlife conservancies and, most of the time, graze inside or next to these conservancies. The level of livestock depredation depends on the distance from the protected area [18]. The local community survey indicated that cases of livestock depredation are on the rise. This finding conforms with the study in the Central and Eastern Part of Bale Mountains National Park, Ethiopia, where the study recorded an increasing trend of livestock depredation [19].

4.2. Causes of Livestock Depredation

The primary cause of livestock depredation, based on the survey, was grazing inside conservancies, thus attracting predators that see livestock as easy prey. Livestock lack instinctive anti-predatory behavior, making them vulnerable, especially during the day when most attacks occur. This concurs with the highest recorded cases of depredation occurring during the day during the monitoring period. Competition among predators for limited prey can lead to increased livestock attacks as predators seek alternative prey. The main cause of livestock depredation is an increase in human population as they have more herds and encroach into wildlife habitats [20]. Poor herding techniques for instance, children herding livestock might lack the skills and physical capability to deter predators. The increase in livestock herds increases the cases of depredation [21].

4.3. Carnivores Involved in Depredation

Lions, leopards, Spotted hyaenas, African wild dogs, cheetahs, and serval cats were involved in depredation, and this concurs with the findings on large carnivores being the problem animals in livestock depredation [22]. Lion cases were high in the open grazing fields, and this could be attributed to the fact that lions choose healthy livestock and therefore during the day they can choose the best. Leopard attacks were high at night in the traditional bomas, since leopards can climb and access the traditional bomas as they are built using twigs and posts, their nocturnal habits could also increase the cases of depredation at night [23]. In cases where the leopard attacked livestock during the day, it was in the grazing fields that had thickets of shrubs and forest, human-leopard conflicts mostly occurred in areas with thick vegetation [20]. The Spotted hyaenas' attack was high in the

grazing fields and the traditional bomas. Lions, leopards, wild African dogs, cheetahs, and serval cats were identified as problem animals, but Spotted hyaenas were the most problematic, followed by lions. This could be because Spotted hyaenas are highly adaptable and opportunistic predators that can thrive in various environments, including those close to human settlements, while lions hunt large prey like cattle [24]. Depredation cases by Spotted hyaenas were especially high in traditional bomas and open grazing fields, highlighting their opportunistic nature.

4.4. Livestock Attacked by Wildlife

Predators primarily attacked cattle, sheep, goats, and donkeys, with sheep being the most vulnerable, which contradicts the study in Zimbabwe where cattle were the most frequently attacked [25]. Goats followed sheep closely in vulnerability to depredation, and this could be attributed to goats grazing in rugged terrain where predators can easily ambush them, or the tendency to roam widely, increasing their exposure to predators.

Non-marked cattle were frequently attacked by lions, likely due to their size, while cattle with an "eye-marked" sign had no attacks, possibly scaring predators. However, this contradicts the findings of a study which indicated that hyaenas mainly targeted cattle at night in bomas [19]. Sheep and goats were highly attacked by Spotted hyaenas, often killing more than they could eat. There was a strong link between the type of livestock attacked and the carnivore responsible. The extent of the attack on donkeys was low, which is due to their defensive capabilities being very minimal and, in most cases, they do not join the main herd in the grazing fields. They graze near homesteads as they are used to fetch water, firewood, and carry luggage to nearby shopping centers. Livestock killed by carnivores were more compared to those injured, although the number could be higher as the survival rate of those injured is not guaranteed.

4.5. Spatial-temporal Distribution of Depredation

4.5.1. Time of Livestock Depredation

Livestock depredation was high as reported in both the questionnaire survey and focus group discussions, and this corresponds with the day-to-day monitoring. The highest number of livestock attacked and injured/killed was recorded during the night as in a single attack, a Spotted hyaena could kill about 30 shoats [18]. At night darkness provides natural concealment, which could encourage predators and make detection and intervention more difficult. There is also reduced surveillance at night making it easier for predators to attack livestock without being easily detected especially in homesteads without dogs. At night response time to attacks could be slower due to reduced visibility and fewer people being alert, especially if it is during the rainy season. Live-

stock being stationary in their bomas at night could also make it easier to target predators as they are less likely to run away [21]. At night depredation cases are high inside the traditional bomas as these bomas are not predator-proof. High depredation at night are also related to poor husbandry method [18]. Spotted hyaenas were leading in attacks at night as they accessed the traditional bomas easily and killed large numbers of shoats. Compared to the night-time, during the day, depredation cases were low, although most cases occurred in the grazing field as livestock had left homesteads to graze. This can be attributed to the increased visibility of livestock thus making them vulnerable in the grazing fields, some carnivores could have mastered the movement patterns of livestock during the day, as some depredation cases occurred near the bomas in the evening as animals moved back into the bomas.

4.5.2. Season of Livestock Depredation

Depredation was high during the rainy season. The higher frequency of attacks in the rainy season might be attributed to reduced visibility during the day, or seeking help by the local community members. During the rainy seasons, cases of livestock depredation are very high because wild animals move close to human settlements, while during the night when it is raining it is hard to hear the dogs barking and the attack, this is also related to the daily monitoring where during the rainy season attacks are high at night and inside the traditional bomas [22]. However, other studies indicated that there is no difference in the level of predation between the wet and dry seasons [26].

During the rainy season, cattle get healthier and lions like healthy cattle, hence the cattle are strong and able to reach the bomas in the evening during the rainy season and lions follow them to the boma, similar seasonal patterns have been observed [25]. This finding concurred with results of the questionnaire survey which showed that depredation cases were high during the rainy season.

4.6. Location and Habitat of Livestock Depredation

There was a clear pattern in the extent and location where depredation took place. The depredation cases in the traditional bomas were the highest with incidences occurring at night. Traditional bomas are highly vulnerable to predator attacks after dark, which is likely due to materials used in construction leading to insufficient protection against predators, while in the grazing fields during the day this was the second most common site of attack [21]. 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 the lack of physical barriers or enclosures making it easier for predators to access livestock or the lack of continuous herder supervision especially in expansive grazing fields with large herds of livestock.

Depredation at salt lick points occurred as livestock con-

gregated at these points, which might attract predators looking for easy prey. Watering points are critical for both livestock and wildlife, and this makes them hot spot areas for livestock attack. Depredation also occurred in forests and shrub grazing areas, dense vegetation provide cover for predators, allowing them to ambush livestock. Forest and shrubby areas, watering, and salt lick points had a medium extent of attack, they are significant locations though not as risky as the open grazing fields and the traditional bomas. There were also cases of depredation near/just outside the bomas in the evenings which indicates transitional vulnerability as livestock moved into bomas from the grazing fields and predators may take advantage of predictable movement patterns. However, the extent of depredation cases in the predator-proof Bomas was low indicating that these bomas are effective in reducing the frequency of depredation. The bomas have enhanced physical barriers and are designed to withstand predator attempts. Similarly, Solar Flashlight Bomas reported a low extent of attacks further confirming the effectiveness of these deterrent methods. The presence of lights at night deters predator.

4.7. Livestock Herder and the Herding Condition

Local communities near conservation areas invest heavily in guarding their livestock against depredation. Large herds require multiple herders, who play a crucial role in reducing depredation by actively monitoring livestock. Their presence deters predators, as they can recognize early warning signs and respond quickly [27]. Livestock herds that are not guarded in grazing fields are more vulnerable to predation [28].

The effectiveness of herders in preventing depredation depends on their age, gender, and experience [29]. Skilled herders are more adept at understanding predator behaviour and using protective measures like scare tactics or guard animals [19]. This study shows that lions and Spotted hyaenas mostly attack livestock under the care of a single adult male, while leopard attacks are higher when multiple male herders are present, likely due to dense vegetation in those areas. Surprisingly, female herders are highly effective at preventing attacks. Women tend to use non-violent deterrents like shouting and waving, which may be more effective in certain situations. However, livestock under the care of children face the highest depredation rates as they lack the necessary skills and strength to fend off predators.

Carrying defensive equipment like knives, clubs, and spears reduces livestock attacks. Many communities also rely on dogs for protection, particularly at night, where attacks are less frequent [27]. However, herders and dogs alone are insufficient deterrents, as some predators are undeterred or even kill dogs, highlighting the need for additional protective measures [1]. The study concludes that, the fact that sheep and goats were far more likely to be killed or injured than cattle

and that cattle with the "eye mark" sign experienced no attacks highlights the varying effectiveness of different livestock protection methods. Therefore, while all types of livestock are at risk, the implementation of specific protective measures like the "eye mark" technique can significantly reduce these risks.

Abbreviations

SDE	Standard Deviation Ellipses
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System

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Author Contributions

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Data Availability Statement

The data that support the findings of this study are available upon reasonable request from the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

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