Large carnivores, people and livestock in the Laikipia-Samburu ecosystem: a comparative study of livestock depredation across different land-uses

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Submitted for the MSc in Conservation Science
DECLARATION OF OWN WORK

I declare that this thesis, “Large carnivores, people and livestock in the Laikipia-Samburu ecosystem: a comparative study of livestock depredation across different land-uses”, is entirely my own work, and that where material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature

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Abstract

Globally, large carnivore populations outside protected areas are at threat from retaliatory killings triggered by livestock depredation. Monitoring livestock depredation in specific areas is essential to formulate conflict management strategies that can address the root causes of human-carnivore conflicts and promote large carnivore conservation.

Based on different data collection protocols, observed patterns of conflict reporting and livestock depredation were compared between community conservancies and commercial ranches in the Laikipia-Samburu ecosystem in northern Kenya. Conflict reports indicate that leopards (*Panthera pardus*) and hyaenas (*Crocuta crocuta*) are the most problematic livestock killers in conservancies, mostly attacking sheep and goats by day away from enclosures. In contrast, lions (*Panthera leo*) were reported to be the most troublesome in ranches, mostly killing cattle by night in enclosures.

The results were used to make suggestions over livestock husbandry, such as avoiding herding by children alone, using domestic dogs as deterrents for predators, and increasing human activity levels around livestock enclosures. If applied, these could contribute to addressing human-carnivore conflicts through reduction in livestock depredation in the study area.

Improvements and greater standardisation of conflict reporting systems could ease the identification and interpretation of reported livestock depredation patterns.

In the future, the effectiveness of conflict prevention measures should be evaluated, to ensure that methods applied to manage human-carnivore conflicts are delivering the intended outcomes and promoting large carnivore conservation outside Kenya's protected areas.

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1. INTRODUCTION

1.1. Problem statement
As the human population increases, large areas are being encroached for human settlements and food production, making less natural habitat available for wildlife (Sisk et al. 1993). Increased proximity between people and wildlife means they are bound to share the landscape, from which different forms of conflict can emerge (Woodroffe 2000). Human-wildlife conflicts (HWC) encompass a tremendous variety of species and arise through competition for the same resources, such as crops, game wildlife and livestock, disease transmission from wildlife to domesticated animals, attacks on humans and all associated costs incurred to people in attempts to minimize conflicts with wildlife to safeguard their lives and livelihoods (Dickman 2010). Because people feel threatened by the presence of wildlife, and often rightly so, they endeavour to suppress it (Thirgood et al. 2005), giving conservationists the duty to find approaches that can allow people and wildlife to coexist through conflict resolution, while meeting both goals of wildlife conservation and people’s life and livelihood security (Woodroffe et al. 2005a).

**Human-carnivore conflicts**
Particularly, human-carnivore conflicts (HCC) are a major component of HWC and constitute a source of great resentment from people towards carnivores, driving retaliation and threatening carnivore populations (Sillero-Zubiri & Laurenson 2001), thereby potentially leading to species extinctions (Woodroffe 2001). An important source of HCC involves large carnivores and rural communities where conflicts are triggered by livestock depredation by predators (Thirgood et al. 2005). As wide-ranging species, carnivores generally roam beyond protected area boundaries where they disperse into unprotected lands (Woodroffe & Ginsberg 1998), making them more vulnerable to anthropogenic threats linked to higher human densities (Woodroffe 2000), while being more likely to cause damage by coming into contact with livestock. Although carnivore diet is essentially based on wild prey species, it can be expanded to livestock species when wild prey availability is low (Patterson et al. 2004), and/or when a predator hunting success is limited (Cotterill 2013). Therefore, livestock depredation can be particularly frequent in areas where domesticated stock have replaced native
wildlife (Patterson et al. 2004) or where the ratio between livestock and wild prey abundances is low, although this does not necessarily lead to higher depredation rates (Woodroffe et al. 2005a).

**Conflict consequences**

Both people and carnivore populations undergo the consequences associated with HCC (Sillero-Zubiri et al. 2006). Indeed, depredation events incur costs to livestock keepers in terms of income through livestock losses and time and money spent in preventing depredation attacks (Mishra 1997; Patterson et al. 2004; Thirgood et al. 2005; Maclennan et al. 2009). Consequently, livestock keepers tend to hold negative attitudes towards carnivores that they consider a threat to human livelihoods (Thirgood et al. 2005; Linnell 2013), and may respond to conflicts by killing the culprits in retribution, through trapping, snaring, poisoning, shooting or spearing (Woodroffe et al. 2005b). Because of their life history traits of relatively low reproductive rates, which limit population resilience, and generally low densities at which they occur, large carnivores are particularly vulnerable to extinction (Woodroffe 2001; Treves & Naughton-Treves 2005). Although deliberate killing is not the only threat they face, in some areas it is certainly the greatest and can cause severe declines in large carnivore populations, with past population and species extinctions documented throughout the world (Woodroffe & Ginsberg 1998; Woodroffe 2001; Woodroffe et al. 2005b).

**Conflictual African large carnivores**

In Africa, large carnivore populations have been declining over the last decades, mainly because of conflicts with humans (Woodroffe et al. 2005b; Winterbach et al. 2013). In Kenya particularly, HCC are widespread across the country rangelands and threaten the viability of large carnivore populations, those ranging outside protected areas being most at risk from human-caused mortality (Woodroffe & Ginsberg 1998; Okech 2010). In the Laikipia-Samburu ecosystem in northern Kenya, pastoralist communities and commercial ranchers are regularly confronted with large carnivores that attack their livestock (Woodroffe et al. 2007; Ocholla et al. 2013). Among those feature species of conservation concern, namely leopards (*Panthera pardus*; near threatened), spotted hyaenas (*Crocuta crocuta*; near threatened), lions (*Panthera leo*; vulnerable), cheetahs (*Acinonyx jubatus*; vulnerable) and African wild dogs (*Lycaon pictus*; endangered), that
all have experienced local extinctions and contraction of their range in the last century (Woodroffe & Ginsberg 1998; Durant et al. 2008; Henschel et al. 2008). Lions are particularly vulnerable to retaliatory killing compared to other large carnivores, such as leopards that are considerably difficult to track down and kill, and are often more persecuted due to cultural practices and to the perception that they are responsible for most attacks on livestock, even when the majority of them is in fact attributable to other predators (Ogutu et al. 2005; Kissui 2008; Hazzah et al. 2009). Furthermore, the lion populations that roam across the Laikipia-Samburu ecosystem are critical for the connectivity of East African lion populations (Riggio & Pimm 2011). Therefore, lion conservation in the area raises the greatest concerns, consistent with their conservation status (vulnerable) that prioritises them over other species that also cause conflicts, such as leopards and hyaenas (both near threatened).

**Socio-economic implications**

From a socio-economic standpoint, conserving large carnivores in the Laikipia-Samburu ecosystem is relevant to supporting local development (Ating’a & Kimokoti 2012; Lalampaa 2012). As wildlife tourism is an important source of income that benefits local communities through employment and supplying of financial resources for infrastructural development (e.g. building schools and hospitals; NRT 2014), local declines or even extinctions in carnivore populations that reside in the region would have worrisome consequences upon local people, through potentially reduced tourism activities and associated benefits (Frank 1998; Ocholla et al. 2013). Nevertheless, as a considerable number of pastoralists in Samburu rely exclusively on livestock sales to meet basic household needs such as purchase of food and access to health services, even low levels of depredation on livestock can engender substantial hardship at the household level (Nowell & Jackson 1996; Esilaba et al. 2007). This highlights the requisite for combining carnivore conservation with livestock depredation reduction (Woodroffe et al. 2007).

**Studying human-carnivore conflicts**

In order to find effective conflict reduction strategies based on science, preliminary research must be conducted to investigate and understand how depredation events take place in specific areas (Quigley & Herrero 2005; Woodroffe et al. 2007). Decisions
regarding livestock management can then be taken in order to avert depredation incidents to the highest by considering the spatio-temporal characteristics of HCC, to ultimately enhance carnivore conservation through reduction in retaliatory killings (Ogada et al. 2003; Woodroffe et al. 2007; Dickman 2010).

1.2. Study aims and objectives
This research project aims to provide the scientific basis for understanding spatial, temporal and contextual patterns of reported livestock depredation within the Laikipia-Samburu ecosystem, from data collected on a continuous basis from livestock keepers in Samburu (pastoralist communities) and in Laikipia (commercial ranchers). Livestock management strategies will then be suggested to effectively reduce livestock depredation and hence HCC with local people across communally-owned and privately-owned areas.

The study aims will be achieved through the following objectives:

1. Construct a framework for understanding the processes which contribute to observed patterns in self-reported HCC data.
2. Compare reported patterns of HCC across two different land-use types (communally-owned community conservancies and privately-owned commercial ranches) and associated livestock keeping groups (pastoralists and commercial ranchers respectively).
3. Analyse relationships between conflict events and husbandry practices.
4. Investigate the current responses of pastoralists to carnivore conflict.
5. Make recommendations for improving the monitoring and management of HCC.
2. BACKGROUND

2.1. Why should HCC be studied?

2.1.1. Impacts of livestock depredation on people's livelihoods

Coexisting with large carnivores can incur substantial costs to people, particularly when livestock production stands as their main livelihood (Thirgood et al. 2005). While livestock losses might be negligible for wealthier households, those that own few livestock may lose a considerable part of their herd in a single depredation event (Nowell & Jackson 1996; Hazzah et al. 2009). Existing studies have essentially quantified the impacts of livestock depredation on people’s livelihoods through income losses inferred from livestock market value (Mishra 1997; Patterson et al. 2004). For example, economic losses to livestock depredation were valued $69,193 per year in a community-managed group ranch ranging across 1,229 km² in Kenya (Maclennan et al. 2009). Ultimately, the perceived cost of depredation will play a major role in determining people’s attitudes and behaviour towards carnivores (Hazzah et al. 2009).

2.1.2. Retaliatory killing and impacts on carnivores

Killing of large carnivores in reprisal for livestock depredation is a common response from livestock keepers that attempt to take action over HCC, either to seek vengeance or to reduce the prevalence of depredation in an area (Sillero-Zubiri et al. 2006). Livestock keepers may also retaliate to protest against inadequate HCC management systems (e.g. compensation schemes; Maclennan et al. 2009; Bowen-Jones 2012). Most studies have quantified retributive killing of carnivores in response to depredation on livestock (Frank 1998; Miquelle et al. 2005), or people’s propensity to retaliate (Hazzah et al. 2009; Romañach et al. 2010). However, the common use of direct questioning makes the true extent of such behaviour largely underestimated (Gavin et al. 2009).

From a legal perspective, the Wildlife Conservation and Management Act establishes the conditions in which killing problem animals may be authorised in Kenya (articles 48 and 77; KWS 2013). Any activity involving species protected under the Sixth Schedule of the Act, which includes African wild dogs, lions, cheetahs and leopards, requires permission from the Kenya Wildlife Service (KWS), the governmental body responsible for Kenya’s wildlife protection and management (KWS 2013). Therefore, killing large carnivores in retribution for livestock depredation as it is generally enacted, that is without the KWS
authorisation, is illegal.

Although retaliatory killings may specifically target individual livestock killers, people might as well kill any individual regardless of its actual involvement in an attack (Frank et al. 2005; Romañach et al. 2010; Ocholla et al. 2013). As some individuals repeatedly attack livestock, while being more likely to reiterate where they have had previous success, untargeted retributive killing will not remove problematic individuals from a population nor associated learnt livestock killing behaviour (Frank et al. 2005; Treves & Naughton-Treves 2005; Cotterill 2013).

However, targeted killing of individual livestock killers as a form a lethal control might be effective in mitigating HCC locally through reduced livestock depredation (Treves & Naughton-Treves 2005), by limiting the prevalence of livestock killing behaviour within a predator population, although this is not applicable to areas where potentially all individuals may kill livestock at some point (Frank et al. 2005).

Retaliatory killing can be highly detrimental to large carnivore populations because even localised declines potentially affect metapopulations over large areas, through social composition disruption and effects on population resilience, influenced by reproductive success and survival rates (Woodroffe 2000; Woodroffe et al. 2005b; Woodroffe & Frank 2005). Carnivore populations that include regions adjoining protected areas into their home ranges are particularly vulnerable (Woodroffe & Ginsberg 1998). On a landscape scale, preserving viable large carnivore populations across non-protected pastoral systems remains necessary for ensuring the dispersal of individuals and the connectivity between different populations (Ogutu et al. 2005; Mogensen et al. 2011; Riggio & Pimm 2011).

2.1.3. Addressing HCC

Long-term large carnivore conservation across human and livestock dominated landscapes largely depends upon finding solutions that can foster coexistence between people and predators, through prevention and mitigation of livestock depredation (Romañach et al. 2010).

Livestock husbandry in itself can prevent depredation to a certain extent through livestock herding, penning in enclosures and the use of guarding dogs (Breitenmoser et
al. 2005; Tumenta et al. 2013). While local economic costs often limit the quality of livestock husbandry practices, low-technology systems still can contribute to preventing depredation (Ogada et al. 2003).

Disruptive stimuli such as light- or sound-emitting devices might reduce livestock depredation for limited periods of time, however animals tend to become habituated and eventually ignore them (Shivik 2006).

A variety of management methods has been employed to mitigate HCC by improving livestock keepers' tolerance of large carnivores, mainly ranging from compensation schemes, problem animal translocations, lethal control, to zoning (Inskip & Zimmermann 2009).

Compensation for livestock lost to depredation can contribute to increase livestock keepers' tolerance of carnivores and hence avert retaliatory killings (Maclennan et al. 2009). However in practice, establishing a compensation scheme remains challenging, particularly in developing countries where institutional capacity might be inadequate for managing such scheme (Nyhus et al. 2005; Western & Waithaka 2005). It might as well disincentivise livestock owners to prevent depredation by improving husbandry practices associated with livestock security (Hazzah & Dolrenry 2007).

Translocations seem to be ineffective in reducing depredation, mostly because they simply displaces problematic individuals elsewhere, while causing high rates of post-translocation mortality, which go against conservation goals (Linnell et al. 1997; Treves & Karanth 2003).

Although lethal control may contribute to deterring retaliatory killing, it still might be ineffective in reducing depredation to levels livestock owners will tolerate (Breitenmoser et al. 2005; Treves & Naughton-Treves 2005).

Zoning contributes to addressing HCC through reducing “the spatial overlap between large carnivores and unmitigated sources of conflicts” (Linnell et al. 2005). By creating different management zones across the landscape in which either people or large carnivores are given the priority to various levels, the dual goal of conserving carnivores and reducing their impact on people's livelihoods may be met (Karanth & Gopal 2005;
However, zoning does not necessarily prevent livestock depredation where people and wildlife still share the landscape (Treves & Karanth 2003).

The effectiveness of the methods used to prevent and mitigate livestock depredation depend upon their social acceptability and technical feasibility (Karanth & Gopal 2005). The dynamism of human-livestock-predator systems dictates the need for determining the state of HCC, which monitoring can help to understand and explain (Dickman 2010). Ultimately, solutions to address HCC will be effectively targeted if spatial, temporal and contextual patterns of conflicts triggered by livestock depredation are explored in particular areas (Inskip & Zimmermann 2009).

2.1.4. The role of monitoring
Monitoring HCC is essential to finding effective solutions to conflicts, targeting conservation efforts and ensuring they are delivering the intended results (Treves et al. 2006; Inskip & Zimmermann 2009; Dickman 2010). An initial baseline must be established, followed by sustained effort aimed at evaluating changes in the system from that initial state, to make informed decisions over HCC management (Nichols & Williams 2006). This entails monitoring several dimensions within the multifaceted conservation issue that HCC represent, mostly ranging from livestock depredation to repercussions of livestock losses onto people's livelihoods, through to people's perceptions of, and attitudes towards, large carnivores, retributive killing, and impacts of retaliation on carnivore populations (Inskip & Zimmermann 2009).

In order to set a baseline against which to monitor HCC, monitoring livestock depredation fundamentally requires data on conflict occurrences to be collected and analysed (Treves et al. 2006). The different methods used to collect such data (e.g. self-reports of livestock keepers, structured surveys conducted using a formal sampling design) all have strengths and weaknesses. For example, while a formal survey requires more investment to collect data over a set period of time, self-reports can generate long-term data that are cheap and relatively easy to collect, although the bias inherent to self-reported data entails careful interpretation (Gavin et al. 2009).

Although HCC elements are inter-connected, most of them have virtually been studied separately (Dickman 2010; Fig. 2.1).
2.2. Studying and monitoring HCC

2.2.1. Main fields of interest within HCC

Livestock depredation

As a major form of HWC, livestock depredation by large carnivores is the subject of considerable interest among researchers. Existing studies have had either a site-specific or predator species-specific focus (Inskip & Zimmermann 2009) and have ranged from long-term monitoring (e.g. Dickman 2008; Treves et al. 2002) to ad hoc studies (e.g. Patterson et al. 2004; Kissui 2008; Tumenta et al. 2013) aimed at measuring and explaining patterns of depredation, as well as at understanding how to effectively address HCC. The topics encompass (i) the extent of livestock depredation (e.g. Kissui 2008), (ii) spatial and temporal patterns of depredation (e.g. Woodroffe et al. 2005c), (iii) context of attacks (e.g. Woodroffe et al. 2007), (iv) environmental factors affecting depredation (e.g. Kolowski & Holekamp 2006) and (v) livestock husbandry practices.
(i) Quantifying livestock depredation translates into the numbers of attacks on different livestock attributed to specific predators over a period of time. Relatively to total herd sizes, the impact of depredation on people's livelihoods can be estimated and put into context regarding other causes of livestock losses such as disease and theft (Frank et al. 2005; Kissui 2008). In order to give a spatially explicit picture of depredation, livestock depredation rates expressed as densities can be related to the size of survey sites (Ogada et al. 2003; Woodroffe et al. 2005c).

(ii) The spatial distribution of livestock depredation can inform on where to allocate conservation efforts for mitigating conflicts, and may also be associated with predator population distribution and space use (Kolowski & Holekamp 2006; Frank et al. 2010; Winterbach et al. 2013). The daily or monthly distributions of incidents can allow one to make suggestions over livestock management practices, by adapting husbandry to predation risk (Woodroffe et al. 2005c; Donikar et al. 2011).

(iii) Assessing predation risk in specific situations (i.e. at enclosures or in grazing fields) provides guidance to adapt livestock husbandry to specific conditions in which depredation may occur (Graham et al. 2005; Kissui 2008).

(iv) Understanding how environmental correlates (e.g. rain, wind, habitat type, terrain cover) affect livestock depredation can help to make informed decisions over livestock husbandry (Ogada et al. 2003; Patterson et al. 2004; Ogutu et al. 2005). For example, large carnivores are more likely to be encountered in areas with vegetation cover, where livestock herding should be avoided (Ogutu et al. 2005).

(v) Livestock husbandry practices range from the use of deterrents (e.g. presence of dogs, scarecrows, etc.), the type and quality of livestock enclosures, human activity alongside livestock, to how livestock keeping is managed on a daily basis (Ogada et al. 2003). Assessing which practices affect depredation can help to identify those that are effective in preventing livestock attacks in specific contexts considering species specific predatory behaviour (Woodroffe et al. 2007; Inskip & Zimmermann 2009). Certain practices assumed to be appropriate for averting livestock depredation may in fact be associated with an increased risk of depredation (Woodroffe et al. 2007).
In addition to the elements discussed above, some studies have focused on the ecology underlying livestock depredation, to assess whether livestock depredation is linked to wild prey depletion or carnivore population densities (Graham et al. 2005; Woodroffe et al. 2005c). The relationship between wild prey biomass and environmental factors associated with livestock depredation has also been explored (Ogutu et al. 2005). To evaluate where carnivores might be at risk from retaliation, livestock keepers’ responses to HCC have been studied (Dickman 2010).

Perceptions of conflict and attitudes towards carnivores
Understanding people’s perceptions of conflict and their attitudes towards large carnivores, which determine responses to depredation events, is essential for targeting conservation efforts (Treves et al. 2006; Dickman 2010). Livestock keepers’ perceptions and tolerance of large carnivores have been quantified through livestock losses and owners’ responses to depredation events (Marker et al. 2003), including propensity to kill large carnivores in retaliation (Hazzah et al. 2009). The number of livestock someone would tolerate losing to predators, limit above which that individual would attempt to retaliate, has also been used as a proxy for tolerance (Romañach et al. 2007). Differences between ranchers and community members have been found (Romañach et al. 2007). While perceived impacts of large carnivores on livelihoods drive negative attitudes, positive attitudes towards predators may potentially deteriorate over time if conflicts are not addressed, which could undermine the conservation efforts being operated in an area (Sillero-Zubiri et al. 2006; Groom & Harris 2008).

2.2.2. Biases in commonly used conflict monitoring data
Data on HCC have often been collected through structured (e.g. Romañach et al. 2010; Tumenta et al. 2013) or semi-structured interviews (e.g. Lindsey et al. 2005; Hazzah et al. 2009; Hemson et al. 2009). Longer term monitoring studies also frequently use records of claims submitted by livestock owners to organisations responsible for managing compensation funds (e.g. Treves et al. 2002; Maclellan et al. 2009; Donikar et al. 2011) or reports submitted spontaneously by livestock keepers to research project officers or land managers (e.g. Patterson et al. 2004; Woodroffe et al. 2005c; Dickman 2008; Kissui 2008) as a measure of conflict. The veracity of self-reported data have sometimes been verified through subsequent interviews (e.g. Woodroffe et al. 2005c;
Dickman 2008; Kissui 2008), but unvalidated self-reported data are subject to various sources of bias that should be considered in any analysis and interpretation.

**Reporting bias**

The nature of self-reporting implies that not all conflicts are systematically reported (Gavin et al. 2009), especially when livestock is only injured and not killed (Cotterill 2013). Therefore, “observed conflicts” often represent only a fraction of total conflict and are biased towards fatal incidents (Fig. 2.2). A parallel can be made between self-reported data and the presence-only data commonly used in species distribution models: both lack “absence” data, which in the case of livestock depredation would represent records from sites that did not experience depredation, and are therefore biased representations of reality (Pearce & Boyce 2006).

In the absence of a compensation scheme or other form of support, livestock keepers might have little incentive to report depredation incidents, thus increasing underestimation of the extent of depredation (Kissui 2008). Conversely, people may exaggerate losses in hope for any sort of support, while compensation might give people
an incentive to over-emphasise conflict events (Nyhus et al. 2005; Dickman 2008). Cautiousness in the interpretation of data analysis is therefore recommended (Pearce & Boyce 2006).

**Recall bias**

Individuals responsible for collecting conflict reports might create some delay in actually recording a depredation event once it has occurred, creating a time lag during which recall accuracy may decrease (Bradburn et al. 1987). Recall error can in fact reflect perceived losses and therefore inform on respondents’ perceptions of large carnivores and associated conflicts (Hazzah et al. 2009). Performing verification of attack events subsequently to reporting can improve data quality and accuracy (Woodroffe et al. 2005c; Kissui 2008). Alternatively, reports made after a certain period of time following incidents may be discarded (Cotterill 2013).

**Spatial and temporal coverage of monitoring effort**

Depending on how reports are collected, conflict data may suffer from geographic and effort bias, as accessing a site might limit report collection (Gavin et al. 2009). Thereby, the data might reflect monitoring effort more than the distribution of depredation events (Woodroffe et al. 2007).

Both continuous and *ad hoc* surveys used to monitor livestock depredation suffer from biased data, the main trade-offs in choosing one collection method over the other being cost-effectiveness and data quality, as long-term surveys are an inexpensive alternative yielding to self-reported, case data and associated biases, while both case and control data can be collected through *ad hoc*, systematic surveys at higher costs (Dickman 2010). Ultimately, conflict reports might be considered suitable for monitoring livestock depredation, as long as biases are acknowledged, alongside critical analyses of such data and subsequent interpretation (Ogada et al. 2003; Graham et al. 2005; Sutherland 2008).
2.3. Study area

2.3.1. The Laikipia-Samburu Ecosystem

Laikipia and Samburu are neighbouring counties within the Rift Valley Province in Kenya, with Laikipia (36°11’ - 37°24’ E and 0°18’ - 0°51’ N) located on the equator and bordering Samburu (36°20’ - 38°10’ E and 0°40’ - 2°50’ N) to the North (Fig. 2.3).

Figure 2.3. Map showing the location of Laikipia and Samburu Counties, Kenya.

Together Laikipia and Samburu Counties form the Laikipia-Samburu ecosystem and stand as key dispersal areas for wildlife from neighbouring protected areas (Esilaba et al. 2007; Georgiadis et al. 2007), and are crucial for the connectivity of East African wildlife populations (Riggio & Pimm 2011). As 80% of the country, arid and semi-arid rangelands of wooded savannah and open grasslands characterise Laikipia and Samburu, with annual average temperatures ranging from 16°C to 26°C and 24°C to 33°C respectively (Esilaba et al. 2007; Georgiadis et al. 2007; CRA 2014).

Laikipia County covers 9,500 km² North-West of Mount Kenya and borders the Ewaso Nyiro river to the North. Annual rainfall varies between 400mm and 750mm along a North-South gradient, the northern part of the county being more arid (Georgiadis et al. 2007; CRA 2014). No formally protected area is found in Laikipia, and areas that have been set aside for wildlife are located on private land (Georgiadis et al. 2007).
Samburu County occupies 21,022 km² and borders the Ewaso Nyiro river to the South. Annual rainfall varies between 250mm and 500mm (Esilaba et al. 2007). Samburu holds one IUCN category II protected area, Samburu National Reserve (SNR), and borders Shaba and Buffalo Springs National Reserves, administratively located in Isiolo, a neighbouring County (CRA 2014).

2.3.2. Local people and livelihoods

Across the Laikipia-Samburu ecosystem, livestock production stands as the main livelihood for pastoralists and commercial ranchers (Campbell et al. 2009). Over the years, overgrazing has degraded Kenya’s rangelands and led to soil erosion, which prevents rain waters from being captured into a soil already suffering from water scarcity (Campbell et al. 2009). This impoverished soil precludes the land from being cultivated, which greatly limits the economic activity across Kenya’s arid and semi-arid rangelands (Spencer 2004).

Within Laikipia, the human population numbers nearly 400,000 people of which 75.2% inhabit rural areas (CRA 2014). Throughout the landscape, large-scale commercial ranches that mostly keep cattle at moderate to low densities form “pro-wildlife” properties where competition between livestock and wildlife over water and pastures is minimised, while communally-owned group ranches managed by pastoralists are found in the North-Eastern part of the county (Georgiadis et al. 2007).

With a population of 224,000 of which 82.7% are rural communities, livestock production by semi-nomadic pastoralists stands as the main livelihood in Samburu (Spencer 2004; CRA 2014). As exclusively dependent on their livestock, pastoralist groups regularly move their herds in search for water and pasture (Spencer 2004).

Traditional livestock husbandry is still practised across Laikipia and Samburu (Ogada et al. 2003; Spencer 2004), which involves grazing livestock herds by day before penning them into traditional livestock enclosures (bomas) made from thorny Acacia branches, where livestock is kept throughout the night (Ocholla et al. 2013). Livestock herds include cattle, sheep, goats, donkeys and camels (Spencer 2004). Throughout their continuous journey, nomadic pastoralists build temporary dwellings called manyattas,
formed by family homesteads surrounding livestock bomas (Ocholla et al. 2013; Fig. 2.4).

![Image](image1.png)

Figure 2.4. Aerial view of a manyatta in Samburu. From www.samburutrust.org.

In Laikipia commercial ranches, boma construction is sturdier and more varied, mostly based on thornbush branches, wooden posts, or wire mesh (Frank 2011; Fig. 2.5).

![Image](image2.png)

Figure 2.5. (a) Cattle and (b) sheep bomas in commercial ranches in Laikipia.

### 2.3.3. Community conservancies

To protect wildlife across unfenced, communally-owned land in Laikipia and Samburu, the Northern Rangelands Trust (NRT) have established several community conservancies collectively managed by locals to benefit both wildlife and the local community through livestock management integrated to conservation (NRT 2014). West Gate Community Conservancy (West Gate hereafter) and part of Kalama Community Conservancy (Kalama hereafter) form the focal study area within Samburu (Fig. 2.6).
West Gate covers 40,350 ha of which 880 ha form the core conservation area, and is home to 5,000 people who belong to the Samburu tribe. Kalama expands over 46,100 ha East of West Gate, with a 3,150 ha core conservation area, and holds a population of 6,000 Samburu people (NRT 2014). Although the communities’ main livelihood is pastoralism, West Gate and Kalama also benefit from tourism through tourist lodges that allocate 60% of their revenues to community development projects and provide employment opportunities for community members (Lalampaa 2012; NRT 2014).

Livestock densities are much higher in conservancies than in commercial ranches (Georgiadis et al. 2007). All family members herd the livestock, and domestic dogs are widely used to deter predators from approaching herds or to signal their presence (Ogada et al. 2003). People mostly keep sheep and goats (85% of total livestock), but also cows (8%), donkeys (4%) and camels (3%; stock censuses in Appendix I, Table 1).

2.3.4. Commercial ranches
Although community conservancies are also established in Laikipia, the focal study area within Laikipia does not include any but exclusively comprises fenced, individually-owned, pro-wildlife commercial ranches (Fig. 2.7).
Wildlife occurs at much higher densities across commercial ranches than in community conservancies, alongside low livestock densities compared to those in pastoralist land (Georgiadis et al. 2007). Ranchers mostly keep cattle (70.4% of total livestock), but also sheep, goats, camels and donkeys (details in Appendix I, Table 2). Ranch herders are employed adult males, and domestic dogs are rarely used.

2.3.5. Wildlife

The Laikipia-Samburu ecosystem harbours a number of wild ungulate species such as Grevy’s zebra (*Equus grevyi*), Somali ostrich (*Struthio camelus molybdophanes*), beisa oryx (*Oryx beisa*), Grant’s gazelle (*Nanger granti*), gerenuk (*Litocranius walleri*) and reticulated giraffe (*Giraffa camelopardalis reticulata*). Laikipia holds the second greatest wildlife abundance in Kenya after the Masai Mara National Reserve, with lion densities estimated at 5 to 6 individuals per 100 km² and well established wild dog, leopard, spotted hyaena and cheetah populations (Frank 1998; Frank et al. 2005; Georgiadis et al. 2007). In West Gate and Kalama, most large carnivore population sizes are unknown. However 10 lions are estimated to impermanently use the conservancies as dispersal areas from the adjoining SNR, and West Gate may hold 3 to 5 cheetahs and 2 packs of wild dogs accounting for nearly 20 individuals in total (S. Bhalla, pers. comm.).
3. METHODS

3.1. Ewaso Lions & Samburu HCC data

Ewaso Lions is a Kenyan non-profit organisation based in West Gate, which employs Samburu community members to promote human-carnivore coexistence throughout the region, by monitoring carnivore movements and informing herders in order to avert potential encounters between predators and livestock (Ewaso Lions 2014). The organisation research activities involve collecting baseline data on HCC, through two Community Officers who collect reports of depredation events from pastoralists across the 1,466 km² study area (S. Bhalla, pers. comm.). They are informed by word-of-mouth from community members and warriors (male demographic spanning from adolescence to marriage) when a depredation incident occurs, and subsequently meet the livestock keeper to fill in a conflict report (S. Bhalla, pers. comm.).

Data from September 2007 to December 2013 was available, which contains information on time and location (name and GPS coordinates) of each livestock depredation event, carnivore species and number reported responsible for the attack, livestock type and number that was attacked, context of incident and associated details (e.g. number of people and dogs present, deterrents used, etc.), terrain type, and livestock owner’s response to attack (see conflict reporting sheet in Appendix II). A narrative report section is present but not systematically provided. GPS referenced locations might be inaccurate in a number of cases where reports are filled in away from the actual site where livestock was attacked (in the field while grazing or when was lost), except for lion attacks for which the GPS coordinates are systematically recorded at the attack site (S. Bhalla, pers. comm.).

3.2. Laikipia HCC data

Within the study area in Laikipia, livestock depredation data were collected by two trained scouts from May 2007 to September 2011 through the incident reporting system of the Living With Lions programme (see Appendix III) and as part of a piece of research that investigated lion behavioural responses to human-caused mortality risk (Cotterill 2013). This study focused on nine pro-wildlife cattle ranches covering 1,312 km², and each was visited weekly in order to minimise reporting and recall biases (Cotterill 2013).
The data contain most of the information stated in the above section 3.2 and therefore includes the same variables as Samburu HCC data. Hence it can be considered suitable for comparing livestock depredation between Samburu and Laikipia study areas. However, some of the information collected through HCC monitoring in conservancies is not available from the commercial ranch data, such as livestock owners’ responses to depredation events. Therefore, this information cannot be compared between the two study locations but can only be explored within community conservancies.

Narrative reports are available for all but 2 reports within the n=441 recorded livestock depredation incidents from Laikipia.

Patterns of livestock depredation were compared between community conservancies in Samburu and commercial ranches in Laikipia (Table 3.1).

Table 3.1. Key points of comparison between livestock depredation data available from Samburu and from Laikipia.

<table>
<thead>
<tr>
<th></th>
<th>Samburu data</th>
<th>Laikipia data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary land-use</td>
<td>Community conservancies</td>
<td>Commercial ranching</td>
</tr>
<tr>
<td>Main livestock owned</td>
<td>Sheep and goats</td>
<td>Cattle</td>
</tr>
<tr>
<td>Land tenure</td>
<td>Communally-owned</td>
<td>Privately-owned</td>
</tr>
<tr>
<td>Method of data collection</td>
<td>Opportunistic – spontaneous reporting – 2 Community Officers</td>
<td>Weekly visits of ranches – 2 Scouts</td>
</tr>
<tr>
<td>Area covered</td>
<td>1,466 km²</td>
<td>1,312 km²</td>
</tr>
<tr>
<td>Length of collection period</td>
<td>2007 to 2013</td>
<td>2007 to 2011</td>
</tr>
<tr>
<td>Sample size</td>
<td>453 reports</td>
<td>441 reports</td>
</tr>
</tbody>
</table>

3.3. Main variables

**Predator species**

Attacks are attributed to a predator species based on sight when someone directly witnesses the incident, or based on track identification at the incident site when an attack is undetected and livestock that is missing is only noticed later on.

**Livestock types**

In conflict reports, sheep and goats are considered together as “shoats” because they are herded together. When 2 livestock types were reported to be attacked over a single
depredation event, each was assigned a weight of 0.5 attack.

**Attack locations and associated terrain types**
Attack location refers to whether livestock was attacked while being enclosed in bomas or away from enclosures (grazing or lost in the field). At attack sites, terrain types (open or cover) are visually assessed by reporters, with open habitat being characterised by short grass (<50cm), open grassland or light bush (<50% of vegetation cover), while habitats with cover, in which large carnivores can hide or rest, include rocky terrain, tall grass (>50cm), thick bush (>50%) and luggas (sand-bed rivers that cross plains, generally bordered by thick bush).

**Time of attack**
Reported times of attack (24-hour system) were converted into 3-hour intervals.

**Deterrents used and predator behavioural response**
To avoid an attack from taking place or when they detect an attack, livestock keepers use various methods to deter the animal from approaching or scare it away, such as dogs, torches, scarecrows, spears, lighting fires, shouting, banging, and throwing projectiles. Intuitively, no reaction is triggered when no deterrent is used, although predators may run away instinctively when encountering a herder. Using deterrents does not necessarily induce a response from predators, but they may react by running away completely, running away and returning, or becoming more aggressive.

**3.4. Data entry and analysis**
The data from Samburu were entered manually into an Excel spreadsheet from paper format, numbering n=453 reports, and presented in the same format as the data from Laikipia made available by the author of the study mentioned above. Approximately half of Samburu HCC reports (53%, n=252) included a narrative report in which depredation incident details were highly useful in capturing additional data that were missing from the formal parts of the reports. Most variables were entered as categorical data, others being either numerical, binary, ordinal or count data (see Appendix IV).

Since control data were generally not available, only differences in the data within and
between community conservancies and commercial ranches could be statistically tested, as opposed to assessing the effect of a given variable on livestock depredation. All analysis sections are therefore based on comparing differences in the distribution of reported attacks on livestock among the different categories of given variable sets, to answer the research questions displayed in Table 3.2.

Table 3.2. Methods used to answer the research questions associated with the study objectives (stated in section 1.2).

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Research questions</th>
<th>Variables used</th>
<th>Methods / Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How much depredation is reported?</td>
<td>Incident date</td>
<td>Descriptive</td>
</tr>
<tr>
<td></td>
<td>How are reported depredation events spatially distributed?</td>
<td>Attack location GPS coordinates</td>
<td>GIS mapping</td>
</tr>
<tr>
<td></td>
<td>How long after reports are made in community conservancies?</td>
<td>Incident and reporting dates</td>
<td>Descriptive</td>
</tr>
<tr>
<td></td>
<td>How are attack outcomes distributed within the data?</td>
<td>Attack outcome</td>
<td>Fisher’s exact test</td>
</tr>
<tr>
<td>2</td>
<td>What are the reported livestock depredation patterns?</td>
<td>- Predator species</td>
<td>Chi-squared tests/Fisher’s exact tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Number of predators</td>
<td>Wilcoxon rank sum tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Detection means</td>
<td>GLM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Livestock type and number attacked</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>In which locations and terrain types are conflicts reported to occur?</td>
<td>- Location (boma vs field)</td>
<td>Chi-squared tests GLM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Terrain type (open vs cover)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Predator species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Livestock type</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>What is the reported daily distribution of livestock attacks?</td>
<td>- Time of attack</td>
<td>GLM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Predator species</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Location</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Do human activity levels seem to affect depredation?</td>
<td>- Number of herders</td>
<td>Chi-squared test Wilcoxon rank sum tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Herder activity at time of attack</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Number of people present at bomas</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Does the use of deterrents affect predator behaviour?</td>
<td>- Number of dogs present</td>
<td>Wilcoxon rank sum tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Deterrents used</td>
<td>CLM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Predator response</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>How do Samburu pastoralists respond to carnivore attacks?</td>
<td>- Owner’s response to attack</td>
<td>Chi-squared tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Location</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Predator species</td>
<td></td>
</tr>
</tbody>
</table>
When more than two variables were used simultaneously, generalised linear models (GLMs) were adopted as a method to test whether differences in the data were statistically significant or not, by comparing fitted GLMs through likelihood ratio tests. Minimal adequate models were selected using a stepwise backwards selection procedure, removing one by one the variables or variable combinations for which differences were the least significant (highest p-value).

The distribution of non available data varied considerably within the different variables in the datasets, so slightly different subsets were used at the various stages of data analysis where the results statistical significance was tested.

For each result obtained, the model deviance from the more complex model, degrees of freedom (df) and p-value are provided. As the data consist of counts of attacks on livestock, GLMs were fitted with Poisson errors to account for non-normality.

Predator response to deterrents was the only variable for which control data were available. Indeed, conflict reports record whether or not deterrents were used to avoid or interrupt a predator attack, which ones, and how the animal responded to them as in an ordinal response ranging from running away and not returning to becoming more aggressive. The effect of deterrent use on predator behavioural response could therefore be tested, using a cumulative link model (CLM) suitable for modelling ordered categorical response variables, performed with the R package *ordinal* (Christensen 2013).

The data were analysed using R 3.1.0 software (R Core Team 2014). All statistical tests were considered significant at alpha=0.05.

Maps were created using ArcGIS 9.0 software, and GPS referenced locations were mapped using the UTM 37N coordinate projection system.
4. RESULTS

The results are presented in the following order. Firstly, the temporal and spatial characteristics of livestock depredation reporting are explored, to understand the processes which contribute to observed patterns in self-reported HCC data in Samburu compared to those in the data collected systematically in Laikipia (section 4.1). Secondly, to investigate how HCC differs between the different land-uses, reported patterns of livestock depredation are compared between Samburu community conservancies and Laikipia commercial ranches (section 4.2). Thirdly, husbandry practices associated with reported conflict events are explored (section 4.3). Lastly, the current responses of Samburu pastoralists to HCC are examined (section 4.4). The results will be used to formulate livestock management recommendations aimed at reducing HCC, tailored to the differential characteristics of depredation in the study area, and to make suggestions to improve HCC monitoring.

4.1. Patterns of HCC reporting

4.1.1. How much depredation is reported?

The number of attacks reported per year in Samburu and Laikipia has generally increased over time, although the data from Samburu show very low reporting in 2010 (n=2 reports), while that from Laikipia show a stable increase in annual reporting until a decrease in 2011 to n=59 reports (Fig. 4.1). However, the number of reported incidents in Laikipia is confounded with changes in monitoring over time, since commercial ranch data collection was initially based on a single ranch in 2007, and expanded to Laikipia study area’s eight other ranches from 2008 to 2011.

![Figure 4.1. Number of reports made per year in (a) community conservancies (2007 to 2013) and (b) commercial ranches (2007 to 2011).](image-url)
Within conservancies, the monthly distribution of reported attacks was highest in September (n=70) and lowest in December (n=12), averaging $36.3 \pm 16.5$ reports per month. In ranches, the monthly distribution of attacks reported shows less variation, with $36.8 \pm 10.2$ reports per month (Fig. 4.2).

![Number of attacks reported per month in community conservancies (dark line) and in commercial ranches (light line).](image)

**4.1.2. How are reported depredation events spatially distributed?**

Based on the GPS locations of the depredation incidents recorded in conservancies (n=416), most incidents were reported in West Gate (73.3%, n=326), while 9.4% were reported in Kalama (n=42; Fig. 4.3).

![Spatial distribution of reported attacks on livestock in the study area.](image)
Additionally, 10.8% (n=48) of the GPS coordinates recorded as attack locations were located in SNR where unauthorised livestock grazing occurs. West Gate reported 8.7 attacks/10 km² over the study period, averaging 1.75 ± 0.56 attacks/year/10 km². Data collection across community conservancies does not include the entirety of Kalama and SNR, because Ewaso Lions’ data collection efforts are concentrated in West Gate, therefore depredation rates across these areas were not calculated.

Commercial ranches reported on average 4 ± 2.8 attacks/10 km² over the study period (averaging 0.91 ± 0.58 attacks/year/10 km²). No linear relationship was found between the number of attacks reported and property sizes, although the smallest ranch (Kamogi, 13 km²) reported the highest depredation rate relative to its size (1.92 attacks/year/10 km²), and the lowest depredation rate was reported in the third largest ranch (Mpala, 195 km²) with 0.18 attacks/year/10 km² (Fig. 4.3).

4.1.3. How long after reports are made in community conservancies?

The process through which livestock depredation incidents are reported in community conservancies (section 3.1), is such that there is a time lag between occurrences of livestock depredation and their reporting by pastoralists. Fifty-one percent of attacks on livestock (n=211 out of 431 reports) were reported within 2 weeks after the incident occurred, with 3% of attacks reported on the same day (n=14), and a third reported after 1 month with a maximum of a 13-month delay (Fig. 4.4).

Figure 4.4. Time difference (weeks) between depredation incident and reporting dates in community conservancy data.

On average, incidents were reported 6 ± 10 weeks after they occurred. Reports with a 9-month delay (36 weeks) or above were excluded from further analysis (n=8) to minimise
the influence of recall error on data accuracy. This aspect of HCC data was only explored for community conservancies as the commercial ranch data were collected on a weekly basis and did not capture reporting dates, but only incident dates.

4.1.4. How are attack outcomes distributed within the data?
In conservancies, no report (out of n=403) acknowledged attacked but unharmed livestock, while in commercial ranches 25.6% of reports (n=113) stated livestock was unharmed over the attack (Table 4.1).

Table 4.1. Distribution of reported attack outcomes (killed, injured or unharmed) in the datasets from community conservancies and commercial ranches.

<table>
<thead>
<tr>
<th>Location</th>
<th>Attack outcome</th>
<th>Livestock killed</th>
<th>Livestock injured</th>
<th>Livestock unharmed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community conservancies</td>
<td></td>
<td>96.9 %</td>
<td>3.1 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Commercial ranches</td>
<td></td>
<td>60.5 %</td>
<td>12.2 %</td>
<td>25.6 %</td>
</tr>
</tbody>
</table>

The number of fatal attacks reported was significantly higher in conservancies than in ranches, and pastoralists reported significantly fewer attacks where livestock was only injured, but not killed, than ranchers (Table 4.1; Fisher's exact test: p<0.001).

4.2. Reported contextual, spatial and temporal patterns of depredation
4.2.1. What are the reported patterns of livestock depredation?

**Predator species**

On communally-owned land in Samburu (n=443), all but 6 attacks were attributed to a single predator species, with 5 incidents ascribed from track identification to both spotted hyaenas (hyaenas hereafter) and jackals and one attack ascribed to both leopards and hyaenas. Because the species that initiated the attack cannot be discerned, each was assigned a weight of 0.5 attack. All attacks in commercial ranches were attributed to a single species.

In community conservancies, the number of attacks attributed to leopards and hyaenas was not significantly different (Chi-squared test: $\chi^2=0.79$, df=1, p=0.37; Fig. 4.5). Each was attributed significantly more attacks (leopards: 34%, n=149.5; hyaenas: 30%, n=135) than any other predators (lions: 16%, n=69; cheetahs: 9%, n=41; wild dogs:...
2.5%, n=11; Fig. 4.5; for additional pairwise comparisons see Appendix V, Table 1). The remaining attacks were mostly ascribed to black-backed jackals *Canis mesomelas* (5%, n=21.5), followed by crocodiles *Crocodylus niloticus* (1.4%, n=6), baboons *Papio spp.* (0.9%, n=4), eagles (0.9%, n=4) and caracals *Caracal caracal* (0.4%, n=2).

In commercial ranches, lions were reported to be responsible for significantly more attacks (92.3%, n=407) than any other predator (leopards: 4.1%, n=18; hyaenas: 3.2%, n=14; cheetahs and wild dogs: each 0.2%, n=1; Fig. 4.5; for pairwise comparisons see Appendix V, Table 2).

![Figure 4.5. Proportion of reported livestock depredation incidents attributed to each large carnivore species in community conservancies and in commercial ranches.](image)

Leopards and hyaenas were attributed significantly more attacks in conservancies than in ranches (Chi-squared tests: leopards: \( \chi^2=103.71, \ df=1, \ p<0.001 \); hyaenas: \( \chi^2=98.26, \ df=1, \ p<0.001 \)), while lions were attributed significantly more attacks in ranches than in conservancies (Chi-squared test: \( \chi^2=240, \ df=1, \ p<0.001 \)). The number of attacks ascribed to cheetahs and wild dogs did not differ significantly either within or between conservancies and ranches (Fisher's exact test: p=0.4).

A significantly higher number of lions were reported to be involved on average per attack in commercial ranches than in community conservancies (3 ± 2.4 and 1.7 ± 1 individuals respectively; Wilcoxon rank sum test: \( W=18,183.5; \ p<0.001 \)). The same was true for hyaenas (5.1 ± 4 and 1.5 ± 1.5 reported individuals per attack in ranches and in conservancies respectively; Wilcoxon rank sum test: \( W=1,240, \ p<0.001 \)), and leopards (1.2 ± 0.7 and 1 ± 0.1 individuals respectively; Wilcoxon rank sum test: \( W=442.5, \ p<0.001 \)).
p=0.015). The comparison was not applicable to cheetahs and wild dogs because each was attributed a single attack in ranches. In conservancies, cheetah and wild dog attacks were reported to involve on average 1.5 ± 0.7 and 7.2 ± 3.6 individuals per attack respectively.

Although 41% of the data from community conservancies (n=166) and 3% of that from ranches (n=14) did not specify whether an attack was attributed to a predator species based on sight or track identification, predators were identified from sight more than from track identification where this information was available (Table 4.2).

Table 4.2. Percentages of attacks attributed to each carnivore species based on sight or track identification in community conservancies and commercial ranches. Percentages for each species do not necessarily match 100% because of non available data.

<table>
<thead>
<tr>
<th>Carnivore species</th>
<th>Community conservancies</th>
<th>Commercial ranches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sight</td>
<td>Tracks</td>
</tr>
<tr>
<td>Lions</td>
<td>23 %</td>
<td>17 %</td>
</tr>
<tr>
<td>Leopards</td>
<td>49 %</td>
<td>20 %</td>
</tr>
<tr>
<td>Hyaenas</td>
<td>42 %</td>
<td>20 %</td>
</tr>
<tr>
<td>Cheetahs</td>
<td>17 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Wild dogs</td>
<td>27 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

**Livestock types**

In community conservancies, shoats were reported to be the most commonly attacked livestock (79% of reported incidents, n=342), followed by donkeys (9%, n=39), camels (8%, n=36) and cattle (4%, n=17; Fig. 4.6).

In commercial ranches, most attack were reported on cattle (72%, n=236.5), followed by shoats (17%, n=54.5), camels (10%, n=34.5) and donkeys (1%, n=3.5; Fig. 4.6).
Attacks reported on shoats in conservancies were significantly more prevalent than in ranches and than attacks reported on the other livestock types within conservancies, and attacks reported on cattle in ranches were significantly more prevalent than in conservancies and than attacks reported on the other livestock types within ranches (Fisher's exact test: p<0.001).

Significantly more livestock were reported to be killed on average per attack event in community conservancies (1.6 ± 2.1 livestock killed on average per attack, ranging from 1 to 24) than in commercial ranches (1.2 ± 2.4 livestock killed on average per attack, ranging from 1 to 31; Wilcoxon rank sum test: W=70,953.5, p<0.001).

To investigate patterns of depredation by specific carnivore species on the different livestock types, only attacks involving the 5 large carnivore species were considered within the reports from community conservancies (n=396).

In both conservancies and ranches, lions were reported to attack all livestock types while cheetahs were only reported to attack shoats (Fig. 4.7). In conservancies, nearly half of attacks on shoats were attributed to leopards (Fig. 4.7-a), compared to less than a fifth on commercial ranches (Fig. 4.7-b). Hyaenas were reported to be responsible for most attacks on donkeys in conservancies, while in ranches all attacks on donkeys were attributed to lions (Fig. 4.7-b). In conservancies, all wild dog attacks were reported on shoats, while in ranches the single attack attributed to wild dogs involved cattle (Fig. 4.7).
Although the difference between conservancies and ranches was not significant (Likelihood ratio: $\chi^2=13.6$, df=12, p=0.33), the number of depredation events on the different livestock types differed significantly between the five predator species (Likelihood ratio: $\chi^2=211.2$, df=12, p<0.001).

### 4.2.2. Attack locations and associated terrain types

In conservancies, a significantly higher number of incidents were reported to have occurred away from enclosures in terrain featuring cover (76%, n=239) compared to open areas (24%, n=75; Chi-squared test: $\chi^2=26.8$, df=1, p<0.001).

In ranches, livestock was mainly reported to be attacked at bomas in open habitat (44.3%, n=136). Attacks reported to have occurred in these circumstances (at bomas in open terrain) were significantly more prevalent than attacks reported to have occurred either in the field in terrain with cover (Chi-squared test: $\chi^2=26.8$, df=1, p<0.001). The difference observed between conservancy attacks, being mostly reported as field attacks in terrain with cover, and ranch attacks, mainly reported as boma attacks in open terrain, was significant (Likelihood ratio: $\chi^2=9.8$, df=1, p=0.024).

Unlike reports from commercial ranches, those from community conservancies discriminate within attacks in the field between incidents that occurred while livestock was grazing or when it was lost. Most of them were reported to have occurred while livestock was grazing (72%, n=246), and 28% (n=94) when livestock was lost. This distinction was not considered here because it is often misunderstood by herders when
reporting an attack, as livestock is still grazing while being lost.

**Predator species focus**

The number of either field or boma attacks attributed to each predator species is consistent with the overall trend of conservancy attacks prevailing away from bomas (in terrain with cover) and ranch attacks prevailing at bomas (in open terrain; Fig. 4.8).

![Figure 4.8. Reported number of attacks by predator species and by attack location (at boma or in the field) in (a) community conservancies and (b) commercial ranches.](image)

Although species-specific attack locations were consistent with the general pattern observed, some additional cases are worth mentioning: in conservancies, the next most commonly reported terrain type in hyaena attacks was open terrain (n=51), and in ranches, the next most prevailing lion attack location was reported to be away from bomas, still in open terrain (n=86).

**Livestock type focus**

As the overall trend of attack locations, attacks reported away from boma accounted for most attacks on each livestock type in conservancies (Fig. 4.9-a), and in ranches most attacks were reported at bomas, except for camels that were reported to be mostly attacked in the field (Fig. 4.9-b).
Figure 4.9. Reported number of attacks by livestock type and by attack location (at boma or in the field) in (a) community conservancies and (b) commercial ranches.

4.2.3. What is the reported daily distribution of livestock attacks?

Twenty percent of the reports from ranches (n=89) and 13% of that from conservancies (n=56) did not specify the time of attack, although n=34 and n=44 respectively stated the incident took place at night. The reported timing of depredation incidents differed significantly between conservancies and ranches (Likelihood ratio: $\chi^2=125.5$, df=7, $p<0.001$). Thirty-four percent of conservancy attacks (n=117) were stated to have occurred by day between 3pm and 6pm, and 24.5% by night between 9pm and 3am (n=85; Fig. 4.10). In ranches 51% (n=180) were reported as night attacks (12am to 6am; Fig. 4.10).

Figure 4.10. Number of attacks reported by time of day in conservancies and in ranches.

No significant difference in the timing of attacks by the different predator species was found between conservancies and ranches (Likelihood ratio: $\chi^2=28.2$, df=28, $p=0.46$),

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although reported timing differed significantly between the different predator species independently from location (Likelihood ratio: $\chi^2=151.2$, df=28, p<0.001). In both conservancies and ranches, cheetahs and wild dogs were reported to attack during daytime (9am to 6pm), and leopards, hyaenas and lions at any time of the day, with lion attacks peaking at night (9pm to 6am).

4.3. Husbandry practices

4.3.1. Do human activity levels seem to affect depredation?

**Number of herders and activity during field attacks**

In conservancies, pastoralists reported that grazing herds were left completely unattended significantly more often than in ranches (conservancies: 21% of cases, n=56; ranches: 13%, n=11), and significantly more attacks in conservancies occurred while herders were resting, either with their livestock or separately, than in ranches (Chi-squared test: $\chi^2=62.3$, df=3, p<0.001). In ranches, in most cases herders reported being walking with their herds when the attack occurred (89%, n=81). The number of herders accompanying grazing herds was significantly lower in conservancies, where field attacks prevail, than in ranches where boma attacks prevail (conservancies: 1.1 ± 0.4 herders on average per incident, ranging from 1 to 4; ranches: 1.6 ± 1.5 herders on average per incident, ranging from 1 to 10; Wilcoxon rank sum test: W=14,877, p<0.001).

Herders were reported to be children in most reports in conservancies (62%, n=166), and almost always adult males in ranches (93%, n=74) but never children alone.

**Number of people present at bomas**

The number of people reported to be present when livestock was attacked at bomas was significantly higher in community conservancies than in commercial ranches (conservancies: 17.3 ± 10.4 people present on average per attack, ranging from 3 to 50; ranches: 4.6 ± 2.5 people present on average per attack, ranging from 1 to 15; Wilcoxon rank sum test: W=1643.5, p<0.001). While in conservancies only 1 boma attack was reported to have occurred without anybody being present, in commercial ranches 5% were reported as such (n=14).
4.3.2. Does the use of deterrents affect predator behaviour?

Narrative reports indicate that attacks at bomas are generally detected by people because dogs start barking on approach of a predator. Dogs were reported to be present more often in boma attacks in conservancies (86%, n=77) than in ranches (20%, n=55). In conservancies, significantly more dogs were reported to be present on average per attack (3.2 ± 2.8 dogs per attack, ranging from 1 to 20) than in ranches (2.1 ± 2 dogs per attack, ranging from 1 to 12; Wilcoxon rank sum test: W=3,428, p<0.001). Dogs were reported to be absent from most field attacks in conservancies (84%, n=286) and from all of those in ranches (n=165).

Although herders most commonly reported that predators ran away completely when an attack was detected (field attacks: 78%, n=74 in conservancies and 72%, n=41 in ranches; boma attack: 87%, n=61 in conservancies and 74%, n=156 in ranches), the use of deterrents did not significantly affect predator behaviour (Likelihood ratio: field attacks: $\chi^2=6.1$, df=4, p=0.19; boma attacks: $\chi^2=1.6$, df=5, p=0.9).

4.4. How do Samburu pastoralists respond to carnivore attacks?

Pastoralists' responses to conflicts (n=232) differed significantly according to whether livestock was attacked in the field or at bomas, in that leaving the situation as it is (28% of reports, n=65), avoiding the area where the attack took place (20.7%, n=48), changing herding practices (8.6%, n=20) and tracking the predator (5.6%, n=13) were stated more often as responses to field attacks. Improving boma quality (33%, n=77) and adding deterrents (4%, n=9) were stated more often as responses to boma attacks (Chi-squared test: $\chi^2=157.31$, df=4, p<0.001). In 6 cases the predator that had been tracked was a lion, in 3 cases a cheetah, and in 2 cases each a leopard and a hyaena. Within these, one narrative report acknowledged the predator was tracked in order to find lost livestock, while two reports indicated the livestock keeper's intention to retaliate by spearing a lion.

Some of the responses to conflicts reported by pastoralists differed significantly according to which carnivore attacked livestock, with willingness to improve boma quality mostly in response to hyaena and leopard attacks, and tracking the animal mostly in response to cheetah and lion attacks (Chi-squared test: $\chi^2=57.5$, df=20, p=0.013).
5. DISCUSSION

5.1. Patterns of reporting and biases

Although the total number of reports made in conservancies increased between 2007 and 2013, this increase may be partly explained by the expansion of the warriors network in West Gate, both numerically and geographically, that allowed more HCC data to be collected as more depredation incidents were notified to Ewaso Lions. The data are therefore biased in that monitoring effort increased throughout the study period. Although the prevalence of livestock depredation could have risen since 2007, this cannot be quantified, nor can be the actual extent of depredation in conservancies from the self-reported data alone. Nevertheless, the number of reports made per year reflects the minimum number of depredation incidents that occurred each year across conservancies in Samburu. The minimum of 2 reports available for 2010 is due to lack of collected data (technical issues), and does not reflect a decrease in depredation across community conservancies that year.

The number of incidents reported in Laikipia is confounded with changes in monitoring over time, since data collection was initially based on a single ranch in 2007, and expanded to Laikipia study area’s eight other ranches from 2008 to 2011. Nevertheless, with a more systematic data collection method in ranches than in conservancies, the overall increase in the number of reports since 2008 could also reflect an increase in depredation across ranches throughout the study period. However, the number of attacks reported dropped in 2011, with fewer incidents reported than in 2010 in all but one ranch, which could indicate that livestock depredation decreased between 2010 and 2011. Nonetheless, changes in monitoring effort and reporting by ranchers over the study period complicate the interpretation of observed trends in livestock depredation.

Other patterns also relate to differences in data collection between areas. For example, unsuccessful attacks (livestock unharmed) were recorded in Laikipia but not elsewhere. Samburu pastoralists probably did not report such attacks because no loss was incurred (Kissui 2008; Selebatso et al. 2008). The lower proportion of fatal attacks reported in ranches could also be due to ranch herders being more effective at detecting predators than pastoralists (Kolowski & Holekamp 2006), thus resulting in fewer livestock kills and more injuries reported. An interesting task for future HCC studies would be to
explore which factors influence attack success and if it differs between various land-uses.

In conservancies, the number of attacks reported increased during the dry season from July to September. However, this pattern is to be considered carefully as a number of reports testify that dates are occasionally misreported. There are several possible explanations to this observed pattern, each of which may play a role. Firstly, this period corresponds to when Samburu pastoralists move the most to find water and pastures for their livestock, building very temporary, low quality bomas and neglecting husbandry (Spencer 2004). Secondly, herds are grazed close to the reserves and adjoining wildlife corridors in this period, where predators are more abundant hence more likely to come into contact with livestock (Ogutu et al. 2005). Thirdly, in the dry season pastoralists go close to the Ewaso Nyiro river, the only water source available at that time, which harbours vegetation cover suitable for predators (Spencer 2004; Schuette et al. 2013). Lastly, pastures become so sparse that herds are driven up mountains and hills where predation risk is higher (Mogensen et al. 2011).

In Laikipia, the study period captured the end of a drought (2007) followed by several years of unseasonal rainfall resulting in a lack of distinct dry seasons (A. Cotterill, pers. comm.). This could explain why the monthly distribution of attacks reported across ranches does not show any particular pattern. Other studies have found higher depredation rates in the wet season where dispersed wild prey are more difficult to hunt than in the dry season, making livestock easier prey for carnivores (Patterson et al. 2004; Kolowski & Holekamp 2006; Kissui 2008). Hence we could have expected a rainy season peak in livestock depredation in ranches, in contrast with the monthly depredation pattern in conservancies where more incidents were reported in the dry season. Indeed in conservancies, seasonal movements of wild ungulates to find water sources and grazing fields in the dry months mean predators may have lower hunting success, and therefore shift to livestock during that period (Funston et al. 2001; Patterson et al. 2004; Georgiadis et al. 2007). Conversely, artificial water sources in ranches (e.g. constructed dams and water holes), replenished by rain, benefits wild ungulate dispersal in the wet season, likely to increase livestock depredation risk during this period (Kolowski & Holekamp 2006).
The observed spatial distribution of depredation incidents reported in conservancies, concentrated in West Gate, might reflect monitoring effort more than the actual distribution of conflicts (Pearce & Boyce 2006; Woodroffe et al. 2007). However, the extent of depredation might be highest close to SNR boundaries, where resident large carnivores and wild prey are more abundant than further away into community land (Ogutu et al. 2005; Western et al. 2009).

In ranches however, since the extent of depredation reported per ranch was not proportional to property area, ranches that experienced fewer incidents than others may have sturdier bomas, or more preventive herders (Ogada et al. 2003; Tumenta et al. 2013), while carnivore and livestock densities on their property may or may not have affected depredation rates (Frank et al. 2005; Kolowski & Holekamp 2006; Suryawanshi et al. 2013).

As nearly 20% of the reports from conservancies were made 2 months after an attack, recall bias might have influenced the data in various ways (Eisenhower et al. 1991). Firstly, conflict incidents might have been erroneously attributed to predator species (Maddox 2003). For example, one leopard attack was inaccurately reported as the narrative section described a hyaena attack. However, the strong cultural, social and economic value of livestock to pastoralists means they surely accurately remember which of their livestock was attacked (Spencer 2004). Secondly, the time of attack might not be recalled or recorded accurately, especially when people are not familiar with the 24-hour system (Sorokin & Merton 1937). Thirdly, the terrain type at the attack site might be inaccurately categorised, or, in cases of attacks on lost livestock, correspond to the site where livestock was found rather than where it was attacked. In addition, the number of people and dogs present when an incident occurred, as well as the deterrents that were used, may have been inaccurately reported. Hence all the patterns of livestock depredation identified from the conflict reports are partly influenced by the biases associated with the data collection methods used in this study.

5.2. Reported patterns of livestock depredation

5.2.1. Large carnivores and livestock

The proportion of attacks attributed to each large carnivore species in conservancies
reflects each predators’ relative abundance in Samburu. Indeed, leopards and hyaenas appeared to be the most troublesome species, as Kolowski & Holekamp (2006) and Woodroffe et al. (2007) found, and are more abundant than any other large carnivores in the area. However in ranches, the fact that most attacks were attributed to lions, as in other studies (Ogada et al. 2003; Patterson et al. 2004), might be related to their higher abundance and that of their natural prey across pro-wildlife ranches compared to conservancies (Frank et al. 2005). Also, as boma construction influences predation risk, ranch bomas’ sturdiness may contribute to prevent most depredation incidents from any carnivore but lions (Ogada et al. 2003; Frank et al. 2005; Woodroffe et al. 2007; Hemson et al. 2009).

The variation in the observed timing of depredation by the different carnivore species is similar to that found in other studies of livestock depredation. Cheetahs and wild dogs, as diurnal, typically attack grazing herds by day and hardly ever livestock enclosed at bomas (Ogada et al. 2003; Frank et al. 2005; Woodroffe et al. 2007). Leopards, hyaenas and lions, however, may attack livestock at any time of the day, either in the field or at bomas (Patterson et al. 2004; Woodroffe et al. 2007), although other studies found that hyaena and leopard attacks prevail at night at bomas (Woodroffe et al. 2007; Kissui 2008).

The predominance of attacks reported on shoats in conservancies and on cattle in ranches over other livestock reflects livestock ownership trends in the study area, as pastoralists mostly keep shoats and ranchers mostly cattle (Spencer 2004; Georgiadis et al. 2007). In both conservancies and ranches, the prevalence of leopard and cheetah attacks on shoats, and lion attacks on camels and cattle is consistent with the findings of other studies (Kolowski & Holekamp 2006; Woodroffe et al. 2007; Kissui 2008). While hyaenas have been found to preferably prey on shoats elsewhere (Kolowski & Holekamp 2006; Kissui 2008), here hyaena attacks were reported on all livestock type. This might be related to their opportunistic foraging behaviour, as opposed to other large carnivores that may be more selective or have better hunting success on particular livestock types (Kolowski & Holekamp 2006; Ogara et al. 2010). Grazing camel herds are generally left unattended, which might explain why most reported camel attacks occurred away from bomas, in both conservancies and ranches (Ogada et al. 2003; Hemson et al. 2009).
The greater number of livestock reported to be killed on average per attack in conservancies may be related to the higher densities of livestock there than in ranches (Georgiadis et al. 2007). Additionally, in conservancies most attacks involved small stock (shoats), which have a lower biomass than the large stock taken in ranches (cattle), hence predators may take more small stock to meet their energy requirements (Sinclair et al. 2003). Small stock are also easier to kill compared to cattle, making predators more likely to take several of them in a single attack (Sinclair et al. 2003).

Wildlife in general, including large carnivores, are more abundant across ranches, which may explain why lions, leopards and hyaenas were reported to be more numerous on average per attack in ranches than in conservancies (Georgiadis et al. 2007). Moreover, the lions that roam across West Gate and Kalama are often solitary or in very small groups, whereas in Laikipia they form large prides, which is reflected in the higher number of lions reported on average per attack in ranches (Cotterill 2013).

5.2.2. Livestock husbandry and spatio-temporal context of attacks
The prevalence of daytime field attacks in conservancies and night time boma attacks in ranches might be related to livestock husbandry practices. Indeed, higher human activity levels around bomas at night in conservancies might generally prevent predators from approaching, unlike in ranches where low human activity levels around bomas may increase the likelihood of a carnivore attack (Ogada et al. 2003; Woodroffe et al. 2007). In addition, predator group sizes (larger in ranches) may affect the likelihood of an attack occurring at boma, as larger groups may be more likely to approach enclosures (Funston et al. 2001).

In community land, shoats and camels are mostly herded by children, sometimes with women or elders, while warriors usually herd larger stock like cattle (Spencer 2004). Field attacks in conservancies were mostly reported to have occurred with children herding, who generally run away when they encounter predators, whereas warriors chase them away and therefore probably avoid attacks on livestock most of the time (Maddox 2003). Although herder age class does not necessarily affect predation risk on livestock, cattle herds driven by children rather than adults may be exposed to higher predation risk (Ikanda & Packer 2008). Children might also be less vigilant than adults
(Kolowski & Holekamp 2006), as depicted in the following narrative report of a depredation incident in Samburu, experienced and narrated by a child:

“I was grazing our cows in dense bush. I was informed that one donkey was killed there by a lion so to be careful when grazing. It was just like a story and I didn’t bother to drive our cows away from there. Cows were grazing and I left them and went to drink water in the river. [...] I ran towards the bush and a juvenile cow was lying and the lion was over it. [...] I chased our cows away and quickly drove them towards home. I called my father [...] We went back home and I was told «don’t graze our livestock there again because it is home for predators».”

Commercial ranches employ only experienced, adult, male herders who are likely to be better at herding than children (Kolowski & Holekamp 2006; Tumenta et al. 2013). Experienced adult men may also be better at avoiding areas where large carnivore are found (e.g. thick bushes, denning sites) and chasing away predators if they are encountered (Kolowski & Holekamp 2006; Hemson et al. 2009).

Although more field attacks in conservancies than in ranches were reported to have occurred while herders were resting or when herds were unattended, it is unlikely that commercial ranch herders always admit negligent husbandry at the risk of losing their job (Kolowski & Holekamp 2006).

The prevalence of field attacks reported to have occurred in terrain with cover in conservancies may reflect the abundance of densely vegetated habitats in Samburu (Bussmann 2002), as well as the type of areas where Samburu herders most frequently graze their livestock in. Likewise, commercial ranch bomas are built in open terrain to reduce predation risk, and employed herders usually avoid densely vegetated areas because they know they would risk encountering predators (Kolowski & Holekamp 2006; Frank et al. 2010).

The common presence of domestic dogs around bomas in conservancies, unlike in ranches, could explain why fewer attacks at bomas were reported in conservancies. Likewise, most field attacks in conservancies were reported to have occurred when no dogs were accompanying herds, which may be associated with the reported prevalence
of incidents in grazing fields. Indeed, the presence of dogs can reduce predation risk both at bomas and in grazing fields (Ogada et al. 2003; Woodroffe et al. 2007), although mostly affecting depredation by lions and not necessarily reducing the probability of leopard and hyaena attacks (Ogada et al. 2003; Frank et al. 2005; Kolowski & Holekamp 2006).

### 5.2.3. Use of deterrents and predator behavioural response

Failure to detect any effect of using deterrents on predator behaviour may be due to the small sample size available, as only a portion of the datasets from conservancies and ranches contained this information. Alternatively, predator response may be triggered by human interference only, regardless of the deterrent used. Indeed, frightening stimuli aimed at interrupting predator attacks have been shown to be only effective in the short term, which may explain why no effect was found (Breitenmoser et al. 2005; Shivik 2006).

### 5.2.4. Pastoralists' responses to HCC

Willingness to improve boma quality was reported to be the main response of pastoralists to leopard and hyaena attacks, which suggests they are aware that poor quality bomas are a problem. Whilst the actual effect of boma quality on predation risk could not be tested, a willingness to change this rather than to remove carnivores is hopeful for conservation (Romañach et al. 2010). In practice, low cost husbandry solutions may be the only effective alternative for pastoralists to prevent depredation (Ogada et al. 2003). However, the quality of enclosures does not necessarily reduce depredation risk in pastoral lands (Ogada et al. 2003; Kolowski & Holekamp 2006), probably because other factors affect depredation to a greater extent (Graham et al. 2005).

Tracking the predator was stated as a response to conflicts in very few reports, but the considerable amount of non available data in this regard prevents the true extent of this response from being recognised. Tracking the animal was mostly mentioned in response to cheetah and lion attacks, but whether the purpose was to find the livestock or kill the predator was only acknowledged in some of the narrative reports. Nonetheless, this finding highlights the vulnerability of lions to be killed in retaliation for livestock
depredation (Hazzah et al. 2009). Whilst the reported data indicate that they were not as problematic as leopards and hyaenas, people still seem more prone to track them down following livestock depredation than any other large carnivore (Kissui 2008).

The following incident narrated by a warrior illustrates how Samburu herders might experience and respond to conflicts:

“I heard a strange sound coming towards me. It was the groaning of a dead camel [...] I ran towards the camel and the lion sitting on the dead camel was staring at me [...]. Tears of sweat streamed all over my body. Without hesitation I ran away and chased the rest of the herd to the home [...]. The horn was blown to call other warriors [...]. In a single file warriors headed to where the lion killed the camel. On arrival the lion had eaten half of the camel and when it heard the noise of people approaching it ran away, and because it was getting dark warriors did not bother to track the lion. They slaughtered the camel, ate meat, and returned home in the middle of the night.”

Nevertheless, West Gate pastoralists and Laikipia commercial ranchers are much more tolerant towards large carnivores than other pastoral groups within Samburu and Laikipia, thus giving positive prospects for the future of large carnivores in the area (Romañach et al. 2010; Gurd 2012).

5.3. Recommendations over livestock husbandry

Community-based HCC management methods are already being implemented in Samburu conservancies by Ewaso Lions, and in Laikipia ranches by the Living With Lions programme. These include mainly improving livestock enclosures, introducing disruptive stimuli (e.g. flashing light bulbs), and monitoring carnivore movements. In addition, education and awareness raising activities are being undertaken to improve attitudes towards large carnivores and engage local people in conservation.

Based on the results of this study, the following recommendations over livestock husbandry might, if implemented, contribute to reduce livestock depredation across the study area:
In community conservancies:

- Avoid herding by children alone,
- When herding, avoid densely vegetated areas and stay close to livestock,
- Do not let livestock graze unattended,
- Use domestic dogs to accompany grazing herds.

In commercial ranches:

- Introduce domestic dogs both at bomas and when herding livestock in the field,
- Increase human activity levels around bomas,
- Alternatively, increase perceived human activity levels by using devices such as flashing lights that can give the impression of higher human activity, even if actual activity levels remain unchanged.

Preventing livestock depredation across community conservancies in Samburu is a challenge that may escalate in the near future. Indeed, with regard to HWC and their consequences on both human livelihoods and wildlife conservation, a county-level compensation scheme is being implemented by the KWS to compensate livestock owners for wildlife-caused property damage, including livestock kills and injuries (KWS 2013). While this new act could be considered an improvement towards large carnivore conservation, compensation schemes do not address the root causes of conflicts (Sillero-Zubiri et al. 2006), and might not be as effective in addressing HCC as reducing livestock depredation (Breitenmoser et al. 2005). The establishment of a compensation scheme in Kenya as a HWC management method has already failed in the past because of high administrative costs and submission of false claims by livestock keepers (Western & Waithaka 2005; Bowen-Jones 2012). In addition, livestock is so abundant in Samburu that it is unlikely that sufficient funding would offset actual livestock losses (Nyhus et al. 2005). People also tend to neglect livestock husbandry because compensation payments remove incentives for applying depredation prevention measures (Treves et al. 2006; Hazzah & Dolrenry 2007). Because the county compensation committee responsible for disbursing the payments claimed is not formed to date in Samburu, people informed of the new bill are already showing discontent as they do not perceive the compensation they expect (S. Bhalla, pers. comm.). Moreover, livestock owners’ dissatisfaction driven by inadequate management of compensation schemes can instigate retaliation as a form
of protest rather than a direct response to livestock depredation (Bowen-Jones 2012).

On the other hand, the establishment of a compensation scheme might give livestock owners an incentive to report depredation incidents (Kissui 2008), which could ease HCC monitoring in the future. In addition, verification of claims by the county compensation committee could reduce reporting bias (Maclennan et al. 2009).

5.4. Recommendations for improving HCC monitoring
Several sources of bias in HCC reports have been highlighted throughout this study, each affecting observed patterns in livestock depredation in various ways (Gavin et al. 2009). Reducing these biases could improve the quality of reported HCC data and hence future HCC monitoring.

Recall bias
In HCC reports, people’s perceptions of conflicts influence the accuracy of the data collected (Dickman 2010). Therefore, minimising the delay between incidents and their reporting could prevent the data from being biased towards perceptions of conflicts rather than actual damage (Eisenhower et al. 1991; Dickman 2010). Livestock keepers should be encouraged to report depredation incidents promptly after they occur (Eisenhower et al. 1991). Narrative reports should be systematically provided and verified with the reporter to optimise the accuracy of the information provided (Woodroffe et al. 2005c).

Reporting bias
Random interviews across the study area could allow the extent of unreported conflict to be estimated (Selebatso et al. 2008). Systematically providing narrative reports could help identify discrepancies in the data reported. Unfamiliarity with the 24-hour system is likely to have influenced the data accuracy, so specifying “day” or “night” in addition to the time provided could help verify that times are accurately reported (Eisenhower et al. 1991). Likewise, dates are sometimes inaccurately reported, so using important events as references (e.g. natural or cultural reference points) could reduce this bias (Eisenhower et al. 1991; Maddox 2003).

Some of the information requested in conflict reports should be clarified with the
incident reporter to avoid misunderstandings (e.g. livestock attacked while grazing or when being lost, section 4.2.2).

Data collectors should inform reporters that the information they provide regarding livestock husbandry will not have consequences (e.g. will not be reported to ranch owners if herders admit negligent herd attendance), to encourage truthful reporting especially when it comes to herder activity at time of attack and responses to conflicts (Gavin et al. 2009).

**Monitoring bias**

Monitoring bias in terms of spatio-temporal coverage of data collection effort complicated the interpretation of observed spatial and temporal patterns of reported livestock depredation. This bias was highlighted in both cases of opportunistic (data from conservancies) and more systematic reporting methods (data from ranches), indicating that HCC reporting systems might take time before being established and fully operative (Woodroffe et al. 2005c). Whilst certain elements of monitoring bias can be accounted for when acknowledged (e.g. when and where monitoring started), others remain undetermined (e.g. monthly monitoring effort) and therefore confound the observed patterns of depredation.

Monitoring bias is also likely to be reflected in the spatial distribution of reported incidents (Woodroffe et al. 2005c; Pearce & Boyce 2006). Encouraging data collectors to cover as much of the study area as possible would partly contribute to overcome this. Systematically visiting actual attack sites, when possible, and acknowledging when this is not feasible could ease the interpretation of observed patterns in HCC, by distinguishing actual patterns of livestock depredation from monitoring effort (Woodroffe et al. 2005c).

Major differences in observed patterns of livestock depredation between Samburu pastoralists and commercial ranchers have been found through this comparative study. However, the absence of control data from sites that did not experience depredation prevented the effect of husbandry practices on livestock depredation from being explored. Indeed, major aspects of livestock husbandry would be useful to examine, such
as, for example, the effect of enclosure quality, or the effect of the presence of dogs, on depredation risk (Ogada et al. 2003; Woodroffe et al. 2007). Collecting control data from sites that did not experience depredation incidents should therefore allow more aspects of HCC in the study area to be explored. In addition, the effectiveness of livestock depredation prevention measures could be assessed in the future, to be able to best adapt to variations in HCC (Inskip & Zimmermann 2009).

This study highlighted the limitations of monitoring HCC and identifying patterns in livestock depredation based on different data collection protocols. Improvements in HCC monitoring methods and greater standardisation in reporting systems could address this issue, and allow a more systematic approach to be taken for monitoring conflicts (Graham et al. 2005; Inskip & Zimmermann 2009). Nonetheless, marked differences in observed patterns of livestock depredation have been found between community conservancies and commercial ranches. These findings provided a basis for making recommendations over livestock husbandry, which could, if applied, contribute to addressing HCC through reduction in livestock depredation in the study area (Ogada et al. 2003; Woodroffe et al. 2007). In order to ensure HCC management methods are delivering the intended outcomes and promoting large carnivore conservation outside Kenya's protected areas, the effectiveness of conflict prevention measures should be evaluated in the future (Ogutu et al. 2005; Sillero-Zubiri et al. 2006; Inskip & Zimmermann 2009).
REFERENCES


## Appendix I

Number of livestock in the study area

Table 1. Censuses of livestock in West Gate between 2012 and 2014.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sheep and goats</th>
<th>Cattle</th>
<th>Donkeys</th>
<th>Camels</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>34,380</td>
<td>2,272</td>
<td>1,279</td>
<td>974</td>
<td>38,905</td>
</tr>
<tr>
<td>2013</td>
<td>27,906</td>
<td>1,664</td>
<td>1,233</td>
<td>1,618</td>
<td>32,421</td>
</tr>
<tr>
<td>2014</td>
<td>33,000</td>
<td>4,875</td>
<td>1,943</td>
<td>978</td>
<td>40,796</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep and goats</td>
<td>31,762</td>
<td>3,410</td>
<td>85%</td>
</tr>
<tr>
<td>Cattle</td>
<td>2,937</td>
<td>1,706</td>
<td>8%</td>
</tr>
<tr>
<td>Donkeys</td>
<td>1,485</td>
<td>340</td>
<td>4%</td>
</tr>
<tr>
<td>Camels</td>
<td>1,190</td>
<td>371</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>37,374</td>
<td>4,392</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Average number of livestock owned per ranch in the study commercial ranches.

<table>
<thead>
<tr>
<th>Livestock</th>
<th>Sheep and goats</th>
<th>Cattle</th>
<th>Donkeys</th>
<th>Camels</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean per ranch</td>
<td>47</td>
<td>126</td>
<td>NA</td>
<td>6</td>
<td>179</td>
</tr>
<tr>
<td>SD</td>
<td>39</td>
<td>37</td>
<td>NA</td>
<td>7</td>
<td>94</td>
</tr>
<tr>
<td>Percentage of total</td>
<td>26.3%</td>
<td>70.3%</td>
<td>NA</td>
<td>3.4%</td>
<td>-</td>
</tr>
</tbody>
</table>
Appendix II
Conflict reporting sheets used by Ewaso Lions in Samburu

INJURY / DEPREDATION ON LIVESTOCK
© EWASO LIONS 2011

A) GENERAL INFORMATION

<table>
<thead>
<tr>
<th>Incident Number</th>
<th>Recorder’s Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Recording (d/m/y)</td>
<td>Time of Recording</td>
</tr>
<tr>
<td>Livestock Owner’s Name</td>
<td>Reporter’s Name</td>
</tr>
<tr>
<td>Date of Incident (d/m/y)</td>
<td>Time of Incident</td>
</tr>
<tr>
<td>Area and Location Name</td>
<td>GPS of Location (X, Y)</td>
</tr>
</tbody>
</table>

B) TYPE OF INCIDENT – circle or tick the answer

1. Predator Attack
   - Livestock killed
   - Livestock not killed
   - Livestock mauled

2. Where was livestock?
   - Grazing in herd
   - Lost
   - Enclosed in boma
   - Stamped out
   - Unknown

3. Did the predator attack a person?
   - Yes
   - No
   If yes:
   - Victim name:
   - Victim contact:

C) PREDATOR INFORMATION

1. How were the predators detected at the time of the incident? Circle or tick the answer.

<table>
<thead>
<tr>
<th>Sight</th>
<th>Tracks</th>
<th>Heard predator calls</th>
<th>Found dead livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Livestock response to predators</td>
<td>Dogs response to predators</td>
<td>Found randomly</td>
<td>Other (specify)</td>
</tr>
</tbody>
</table>

2. Type of predator and how many. Fill in chart below.

<table>
<thead>
<tr>
<th>Species</th>
<th>Adult male</th>
<th>Adult female</th>
<th>Adult unknown</th>
<th>Cubs/ Pups</th>
<th>Sub-adult male</th>
<th>Sub-adult female</th>
<th>Sub-adult unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Species = Lion, leopard, spotted hyena, striped hyena, cheetah, wild dog, silver-backed jackal

3. From what direction did the predator approach the livestock? Circle or tick the answer
<table>
<thead>
<tr>
<th>Upwind from livestock</th>
<th>Downwind from livestock</th>
<th>Unknown</th>
</tr>
</thead>
</table>

4. Did predator use calls to panic the livestock?  | Yes | No | Unknown |

5. Was it a chance encounter or an intentional encounter?  |

6. Was the predator wearing a collar?  | Yes | No | Unknown |

D) RESPONSE

1. If people were present during the attack, did they use deterrents to scare away the predator? Yes or No

   If yes, fill in the table below:

<table>
<thead>
<tr>
<th>Deterrent type</th>
<th>Used? Yes, No or Unknown</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shouting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gunshot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dogs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. What was the response of the predators to deterrents. Circle or tick the answer.

<table>
<thead>
<tr>
<th>Increased aggression</th>
<th>No change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ran away and returned</td>
<td>Ran away completely</td>
</tr>
</tbody>
</table>

3. What did the owner do AFTER the incident? Circle or tick the answer

<table>
<thead>
<tr>
<th>Nothing</th>
<th>Track Predator</th>
<th>Avoid Area</th>
<th>Change Herding Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make boma improvements</td>
<td>Add Deterrents (examples: guard dog, bells, fire)</td>
<td>Other (describe)</td>
<td></td>
</tr>
</tbody>
</table>

4. Why did the owner respond in this way?

   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

E) CONDITIONS – circle the answer

1. Rain during attack  | None | Light | Heavy | Unknown |

2. Wind during attack  | None | Light | Heavy | Unknown |

3. What is the type of terrain?  | Rocky | Thick bush | Lugga | Tall grass | Open |

F) CASE Livestock Details
## 1. CATTLE

<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Cows</th>
<th>Calves</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured/Mauled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 3. CAMELS

<table>
<thead>
<tr>
<th></th>
<th>Male camels</th>
<th>Female cows</th>
<th>Calves</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured/Mauled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 4. SHOATS

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Kids</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured/Mauled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## 5. DONKEYS

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Females</th>
<th>Young</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured/Mauled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### G) CONTROL Livestock Details

<table>
<thead>
<tr>
<th></th>
<th>Total number present in either control boma 1 or control herd 1</th>
<th>Total number present in either control boma 2 or control herd 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donkeys</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### H) If incident occurred when livestock was INSIDE MANYATTA/BOMA

1. Where was livestock attacked?
Inside boma or manyatta | Stampeded out of manyatta, then attacked | Other (explain)

2. What is the quality of the MANYATTA wall? Circle the answer.

| Very poor | Poor | Medium | Good | Very Good |

3. How many days or weeks or months since the MANYATTA wall was repaired?

4. What is the type of MANYATTA wall? Circle the answer.

| Thornbush | Solid (wood/metal) | Wire | Open | Stone | Other |

5. Type of entrances/gates in MANYATTA wall and how many? Circle the answer.

| Open | Thornbush | Wooden solid | Metal solid |

6. What is the quality of the BOMA wall? Circle the answer.

| Very poor | Poor | Medium | Good | Very Good |

7. How many days or weeks or months since the BOMA wall was repaired?

8. What is the type of BOMA wall? Circle the answer.

| Thornbush | Solid (wood/metal) | Wire | Open | Stone | Other |

9. Type of entrances/gates in BOMA wall and how many? Circle the answer.

| Open | Thornbush | Wooden solid | Metal solid |

10. Manyatta details

| a. Number of bomas | b. Number of houses |
| c. Number of total people | d. Number of askaris on duty |
| e. Number of dogs | f. Number of fires lit |
| g. Number of scarecrows | h. Other deterrents present |

11. Are there big trees or rocks next to manyatta? Describe.

I) If livestock was GRAZING IN HERD when incident occurred

1. Herder details

| a. Number of herders | b. Number of adult men |
| c. Number of adult women | d. Number of children under 10 yrs |
| e. Number of children 10-18 yrs | f. Number of warriors |
| g. Number of dogs when herd attacked | h. Other deterrents carried such as guns, bows, spears, knives, other |

2. Herder activity at time of incident. Circle the answer.

| Walking ahead of the herd | Walking behind the herd | Walking in the middle of herd |
| Resting together | Resting separately | Not with herd at all | Other (specify) |

J) If incident occurred when livestock was LOST

57
1. When did livestock become lost? Circle or tick the answer.

| While grazing | Escaped from manyatta or boma | Unknown |

2. Was entire herd lost or only some? How many were lost?

3. If livestock escaped from manyatta/boma how did it escape?

4. What is the distance from incident to nearest manyatta?

K) Report

Write a full narrative report explaining the incident with details.
Appendix III
Conflict reporting sheets used in the Living With Lions programme in Laikipia

PROPERTY: ________________________________

1. Date and Time of incident: (dd-mm-yy):______________ Time (24 hh:mm):________ ☐daylight ☐dark
2. Date and Time form filled in (dd-mm-yy):______________ Time (24 hh:mm):______________
3. Recorder’s Full Name (if not primary witness then also fill in sect 4.) ________________________________
4. Reporter’s Name(s) and role(s) (note if not primary witness to incident) ____________________________

5. Type of incident: ☐Calls heard ☐Tracks seen ☐Predators seen (but did not attempt to attack livestock/people) ☐Predators attack livestock/people but are chased off without harm ☐Predators attack and kill/maul livestock/people
6. Was this incident verified? ☐Yes ☐No If yes, verification number:___________________________
7. If a predator attacked a person; Person/witness name and contact details:__________________________

8. Rain ☐none ☐light ☐heavy     Wind: ☐none ☐slight ☐strong
9. Phase of the moon: ☐none ☐quarter ☐half ☐full     Cloud ☐none ☐partial ☐full
10. Predator Details:
Species: ☐Lion ☐Hyena ☐Leopard ☐Cheetah ☐Wild Dog ☐Other

<table>
<thead>
<tr>
<th>Total Predators</th>
<th>Cubs/Pups</th>
<th>Sub-adult</th>
<th>Sub-adult</th>
<th>Sub-adult</th>
<th>Adult</th>
<th>Adult</th>
<th>Adult</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracks found</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predators with collars seen? ☐Yes ☐No If yes, how many? _____Male _____Female _____ Unknown
ID’s of collared lions, if known ________________________________

Direction of predator’s approach: ☐upwind from livestock ☐downwind from livestock ☐other
☐unknown

Did predator use calls to panic livestock ☐Yes ☐No

Was attack ☐actively initiated by predator ☐due to livestock stumbling upon predators ☐unknown

Did one animal instigate the attack ☐Yes ☐No If yes was it ☐male adult ☐female adult ☐sub-adult
11. Location of incident: □ At a boma (don't complete section 14) □ Away from boma (don't complete section 12)

Incident GPS: East 37° 0' 0" North 00° 0' 0"

12a. Case Boma Details (if incident was at a boma):

Boma ID__________________________________________ Boma strength: □ Poor □ Average □ Good

Boma: □ Thorn □ Stone □ Ol Pejeta □ Chainlink □ w/ net? □ Post and rail □ Other________________________

Wall height: □ <1m □ 1m–1.5m □ >1.5m Wall strength: □ poor (gaps) □ average (some small gaps)

□ good (no gaps)

Type of gates: □ Thorn branch □ Post + rail □ Wooden solid □ Metal solid □ Metal gate Number of external

exits ________

Number of internal rooms ________ Outer boma? □ Yes □ No If yes, outer boma □ partial □ complete

No. herders/askaris on duty (awake): ____________ No. other people at the boma: ____________

No. of working torches: __ No. of dogs: ____ No. of fires lit: ______________________

Sketch of boma:

Comments: ____________________________________________________________________________________

___________________________________________________________________________________________

___________________________________________________________________________________________

13a. Case Habitat Details (within 50m of incident site/boma):

Length of Grass: □ <20cm □ 20-49cm □ 50-100cm □ >100cm

Bush Cover: □ 0% (open grassland) □ <25% (open grassland with some bushes) □ 25-49% (open areas and bush
cover roughly equal) □ 50-74% (more bush than open area) □ 75-100% (thick bush with no open areas)

Estimate distance to nearest: Boma Kopje/rocky escarpment Lugga Water Source Thick Bush

Less than 50 meters □ □ □ □ □

50-99 meters □ □ □ □ □

100-149 meters □ □ □ □ □

>150 meters □ □ □ □ □

Boma/incident site topographic position: □ in valley □ on ridgeline/ sharp hilltop □ on slope of hill

□ flat ground

14a. Case Daytime Herders; No. of herders with herd: adults _____ teenage children _____ children younger

than 13 ______________________________

No. dogs ________ No. firearms carried ________ Was there a herder walking ahead of the herd? □ Yes □ No

Herder activity at time of incident: □ walking together □ walking separately □ resting together □ resting separately
Other deterrents carried:  ◐ bow ◐ spear ◐ sword ◐ rungu ◐ fimbo ◐ other

15a. Case Livestock Details:  Was livestock involved?:  □ Yes □ No  (If no, go straight to section 16)
Was livestock lost or left behind?:  □ Yes □ No   Was livestock left out at night?:  □ Yes □ No
If in boma, was livestock controlled or did they stampede?:  □ Controlled □ stampeded

<table>
<thead>
<tr>
<th></th>
<th>Present at incident</th>
<th>Killed</th>
<th>Mauled</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Cattle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present at incident</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mauled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Present at incident</th>
<th>Killed</th>
<th>Mauled</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B. Camels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present at incident</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed</td>
<td></td>
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<th>Missing</th>
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<td><strong>C. Shoats</strong></td>
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<tr>
<td>Goats and Sheep</td>
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<tr>
<td></td>
<td>Total No. Shoats</td>
<td>No. Females</td>
<td>No. Kids</td>
<td>No. Males</td>
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<tr>
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</table>

12b. Control Boma Details (closest boma not attacked): Distance from case boma: ________________ km.
Boma ID ___________________________ Boma strength:  □ Poor □ Average □ Good
Type of boma:  □ Thorn □ Stone □ Ol Pejeta □ Post and rail □ Other __________________________
Wall height:  □ <1m □ 1m–1.5m □ >1.5m Wall strength:  □ poor (gaps) □ average (some small gaps) □ good (no gaps)
Type of gates:  □ Thorn branch □ Post + rail □ Wooden solid □ Metal solid □ Metal gate
Number of external exits ___________
Number of internal rooms ___________ Outer boma? □ Yes □ No   If yes, outer boma □ partial □ complete
No. herders/askaris on duty (awake): ________________ No. other people at the boma: ___________
No. of working torches: _ _ _ No. of dogs: ___ No. of fires lit: __________

Sketch of boma:

Comments: ___________________________________________________________
                        ___________________________________________________________
                        ___________________________________________________________

13b. Control Habitat Details (within 50m of control site/boma):

Length of Grass: □<20cm □ 20-49cm □ 50-100cm □ >100cm
Bush Cover: □ 0% (open grassland) □ <25% (open grassland with some bushes) □ 25-49% (open areas and bush
cover roughly equal) □ 50-74% (more bush than open area) □ 75-100% (thick bush with no open areas)

Estimate distance to nearest:

<table>
<thead>
<tr>
<th>Distance</th>
<th>Boma</th>
<th>Kopje/rocky escarpment</th>
<th>Lugga</th>
<th>Water Source</th>
<th>Thick Bush</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 50 meters</td>
<td>□</td>
<td>□</td>
<td>□</td>
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<tr>
<td>50-99 meters</td>
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<td>□</td>
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<tr>
<td>100-149 meters</td>
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<tr>
<td>&gt;150 meters</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

Boma/incident site topographic position: □ in valley □ on ridgeline/ sharp hilltop □ on slope of hill
□ flat ground

14b. Control Daytime Herders; No. of herders with herd: adults _____ teenage children _____children younger
than 13 ______________

No. dogs _______ No. firearms carried _______ Does a herder walk ahead of the herd? □ Yes □ No

Other deterrents carried: □ bow □ spear □ sword □ rungu □ fimbo □ other

15b. Control Livestock Details:

A. Cattle □ Yes □ No

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<tr>
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<td>Mauled</td>
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</table>

B. Camels □ Yes □ No
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</thead>
<tbody>
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<tr>
<td>Missing</td>
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</tbody>
</table>

C. Shoats □ Yes □ No

<table>
<thead>
<tr>
<th>Goats and Sheep</th>
<th>Total No. Shoats</th>
<th>No. Females</th>
<th>No. Kids</th>
<th>No. Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present at incident</td>
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<tr>
<td>Killed</td>
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<tr>
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<tr>
<td>Missing</td>
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</tr>
</tbody>
</table>

16. Deterrent measures: Deterrent used? □ Yes □ No (If no, go straight to section 18)
Type used: □ Torches □ Shouting □ Bangers □ Other____________________________
Comments:________________________________________________________________________

17. Response of predator to deterrents: □ Increased aggression □ No change □ Ran away but then came back □ Ran away and did not return □ Other____________________________

18. How were predators detected at the time of the incident (check all that apply):
□ Sight of predator
□ Sound of predator
□ Tracks of predator
□ Dog's response to predator
□ Livestock's response to predator
□ Other ________________________________________________________________

Narrative report and additional comments:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Appendix IV

Data entry: summary of the types of variables entered

<table>
<thead>
<tr>
<th>Type of variable</th>
<th>Variable</th>
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<tbody>
<tr>
<td>Numerical</td>
<td>Date and time of incident and reporting</td>
</tr>
<tr>
<td></td>
<td>GPS coordinates of attack site</td>
</tr>
<tr>
<td>Categorical</td>
<td>Attack outcome</td>
</tr>
<tr>
<td></td>
<td>Attack location</td>
</tr>
<tr>
<td></td>
<td>Predators species</td>
</tr>
<tr>
<td></td>
<td>Livestock type attacked</td>
</tr>
<tr>
<td></td>
<td>Terrain type</td>
</tr>
<tr>
<td></td>
<td>Herder activity at time of attack</td>
</tr>
<tr>
<td></td>
<td>Owner response to conflict</td>
</tr>
<tr>
<td>Count</td>
<td>Number of predators</td>
</tr>
<tr>
<td></td>
<td>Number of livestock attacked</td>
</tr>
<tr>
<td></td>
<td>Number of herders present</td>
</tr>
<tr>
<td></td>
<td>Number of dogs</td>
</tr>
<tr>
<td>Binary</td>
<td>Deterrents used</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Predator response to deterrents</td>
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Appendix V

Statistics of pairwise comparisons of the number of attacks on livestock attributed to the different carnivore species

Table 1. Statistics of pairwise comparisons between the number of attacks attributed to either leopards or hyaenas and to the other predator species in Samburu community conservancies (Chi-squared tests). Significant results are shown by an asterisk (*).

<table>
<thead>
<tr>
<th>Predator species</th>
<th>Leopards</th>
<th>Hyaenas</th>
<th>Lions</th>
<th>Cheetahs</th>
<th>Wild dogs</th>
</tr>
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<tbody>
<tr>
<td><strong>Leopards</strong></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>χ² = 0.79</td>
<td>df = 1</td>
<td>χ² = 62.2</td>
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<tr>
<td></td>
<td></td>
<td>p = 0.37</td>
<td></td>
<td>p &lt; 0.001*</td>
<td>p &lt; 0.001*</td>
</tr>
<tr>
<td><strong>Hyaenas</strong></td>
<td>χ² = 0.79</td>
<td>NA</td>
<td>χ² = 21.35</td>
<td>χ² = 50.2</td>
<td>χ² = 105.32</td>
</tr>
<tr>
<td></td>
<td>df = 1</td>
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<td>df = 1</td>
<td>df = 1</td>
</tr>
<tr>
<td></td>
<td>p = 0.37</td>
<td></td>
<td>p &lt; 0.001*</td>
<td>p &lt; 0.001*</td>
<td>p &lt; 0.001*</td>
</tr>
</tbody>
</table>

Table 2. Statistics of pairwise comparisons between the number of attacks attributed to lions and to the other predator species in Laikipia commercial ranches (Chi-squared tests). Significant results are shown by an asterisk (*).

<table>
<thead>
<tr>
<th>Predator species</th>
<th>Leopards</th>
<th>Hyaenas</th>
<th>Lions</th>
<th>Cheetahs &amp; Wild dogs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lions</strong></td>
<td>χ² = 356.05</td>
<td>χ² = 366.86</td>
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<td>χ² = 404</td>
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<td></td>
<td>df = 1</td>
<td>df = 1</td>
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<td>df = 1</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001*</td>
<td>p &lt; 0.001*</td>
<td></td>
<td>p &lt; 0.001*</td>
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</tbody>
</table>