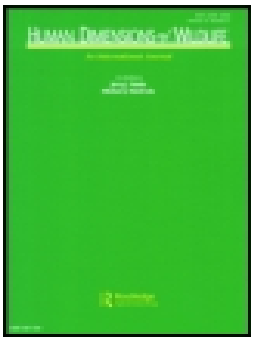

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Assessing human conflicts with carnivores in Namibia's eastern communal conservancies

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ABSTRACT
Livestock depredation has severe socio-economic impacts on local communities. Consequently, carnivores are often persecuted because of actual or perceived threats to livestock. Perceptions of threats are often shaped by underlying socio-cultural values, which make resolving human conflicts with carnivores complex. We conducted questionnaires with local farmers (*n* = 276) at workshops to assess annual livestock depredation rates in Namibia's eastern communal conservancies. On average, farmers lost 8% of total herd size to depredation, with high variability among respondents. The main predators were African wild dog and black-backed jackal. Depredation intensified with herd size and carnivore familiarity (i.e., better carnivore identification skills and more frequent carnivore encounters). We suggest that patterns of depredation are predicted by carnivore occurrence and we recommend spatial modeling of risk to prioritize mitigation efforts. Reported livestock husbandry practices used before workshops were apparently ineffective, which might be attributed to lack of knowledge and/or resources.

KEYWORDS
Carnivore conservation; co-existence; communal conservancy; human-wildlife conflict; livestock husbandry

Introduction

Livestock depredation is the principal source of human conflict with carnivores worldwide, which has been exacerbated by the expansion and growth of human populations (Baker et al., 2008; Thirgood et al., 2005; Woodroffe, 2000). In landscapes devoid of natural prey, carnivores opportunistically predate on livestock to supplement their dietary requirements (Khorozyan et al., 2015; Woodroffe et al., 2005). Domesticated livestock have retained little anti-predator behavior, so are easy prey (Thirgood et al., 2005). Across sub-Saharan Africa, losses to predators are typically only a small percentage of livestock numbers, often below 5% of the total herd size (Butler, 2000; Hemson et al., 2009; Holmern et al., 2007; Patterson et al., 2004; Schiess-Meier et al., 2007). Yet, the economic consequences of these losses may be significant in a local context and may result in retaliatory killings of carnivores (Graham et al., 2005; Treves & Karanth, 2003).

Perceptions of threats or risks from carnivores may differ from actual levels or probabilities of risk because they are shaped by social and cultural beliefs, economic pressures, knowledge about wildlife, and past depredation events (Delibes-Mateos et al., 2013; Dickman, 2010; Kansky et al., 2014). In Nepal, for example, Buddhists are generally tolerant of livestock depredation by snow leopards (*Panthera uncia*) because killing them is considered a sin (Ale, 1998). In contrast, many Maasai pastoralists in Tanzania despise spotted hyenas (*Crocuta*

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crocuta) because they are associated with gluttony, incompetence, and witchcraft (Maddox, 2003). Furthermore, communal farmers are typically less resilient to economic perturbations caused by livestock depredation and may have lower levels of tolerance compared to farmers on freehold (i.e., privately-owned) farmland (Butler, 2000; Kansky et al., 2014; Rust & Marker, 2013; Schiess-Meier et al., 2007).

Levels of tolerance and risk associated with conflict also appear to be related to knowledge about wildlife (Ericsson & Heberlein, 2003; Mkonyi et al., 2017). Previous research has demonstrated that misinformation and a lack of knowledge has been linked to higher human conflicts with wolves in southern Europe (Meriggi & Lovari, 1996) and more intense human conflicts with jaguars in Brazil (Conforti & De Azevedo, 2003). In such situations, conflicts may be mitigated by investing in conservation-based education (Conforti & De Azevedo, 2003; Kellert et al., 1996). However, around the Ruaha National Park in Tanzania, the intensity of reported conflicts between people and wildlife actually increased with people's level of knowledge about wildlife perhaps because traditional pastoralists (i.e., communal farmers) exhibited more knowledge, since they likely encounter wildlife more frequently (Dickman, 2008). Also, around Tarangire National Park in Tanzania, better identification skills of carnivores resulted in more smallstock losses (Msuha, 2009).

Farmers may also be more likely to rate predators as problematic if they see them more regularly on their property (Rust & Marker, 2013). For example, cheetahs (*Acinonyx jubatus*) are active during the day, they are extremely wide-ranging, and they may roam across multiple farms (Marker et al., 2003, 2008). This could mistakenly be taken as evidence for many cheetahs existing in the area and thus for increased perceived levels of threat. Perceived presence may result in negative attitudes and false accusations, even when no evidence of livestock is found in carnivore diets (Chase Grey et al., 2017).

Negative attitudes and low levels of tolerance can often result in lethal control of carnivores (Sillero-Zubiri & Laurenson, 2001). However, many non-lethal techniques exist that are effective in reducing livestock depredation (Breitenmoser et al., 2005; Woodroffe et al., 2007). Even simple and low-technology solutions can make substantial contributions to resolve human conflicts with carnivores (Ogada et al., 2003), which may be economically more advantageous compared to retaliatory killings (McManus et al., 2015). Such predator-friendly practices include nighttime confinement of livestock in traditional or fortified enclosures (hereafter named "kraals"; Ogada et al., 2003; Weise et al., 2018), shepherding (Ogada et al., 2003), controlled calving/lambing (Palmeira et al., 2008), and the use of guarding animals (Marker et al., 2005; Potgieter et al., 2016) and other predator deterrents, such as flashing lights (Lesilau et al., 2018; Ohrens et al., 2019) and human activity (Ogutu et al., 2005; Oriol-Cotterill et al., 2015).

Despite the numerous studies on human conflicts with carnivores and associated mitigation measures, the lack of resources and knowledge and/or the negligence of live-stock husbandry practices reduces the efficacy of these mitigation measures, and thus increases human conflicts with wildlife (Bauer et al., 2017). Furthermore, resolving conflict is not straightforward and requires more than technical solutions (Dickman, 2010; Shilongo et al., 2018). Therefore, it is necessary to consider the socio-economic dimen-sions of human conflict with carnivores, such as the different factors affecting attitudes and perceptions of people toward wildlife (as described above).

Conservancies are one way of supporting a more holistic view of these complexities. Conservancies are legally defined protected areas, co-managed by neighboring land occupiers (Lindsey et al., 2009). Conservancies often aim to mitigate human conflicts with wildlife by reversing wildlife declines in the area and by providing local communities with income from the use of wildlife (e.g., through tourism or trophy hunting; MET, 1995; Weaver & Skyer, 2003). Despite this approach, some communities receive little to no benefits from occupying land within a gazetted conservancy, which is typically due to low wildlife numbers stemming from bushmeat hunting and livestock grazing competition, and the lack of capacity to increase tourism or trophy hunting potential in the conservancy (MET/NACSO, 2018).

Here, we report the results of a study on livestock depredation in communal conservancies in northeast Namibia. Farmers in these conservancies have no income from wildlife-based land uses, and human conflict with carnivores appears to be a pertinent issue (Lines, 2008; MET/NACSO, 2018). Based on anecdotal reports, we suspect an increase in conflict within this area over the past decade. Limited data are available from an earlier study in the same area that focused on the highly persecuted population of African wild dogs (*Lycaon pictus*; Lines, 2008). The study found that livestock depredation caused 16% of all cattle losses, with leopard (*Panthera pardus*) and spotted hyena as the most common predators (>80%), whereas African wild dogs were responsible for 15% of cattle losses (Lines, 2008). Smallstock losses in our study area, and throughout southern Africa, were mainly caused by black-backed jackals (hereafter jackal, *Canis mesomelas*), which are known as opportunistic hunters (Gusset et al., 2009; Kaunda & Skinner, 2003; Rust & Marker, 2013).

Our first research objective was to provide new and more detailed information on the magnitude of human conflict with carnivores within these communal conservancies. We aimed to quantify livestock depredation as proportion of annual livestock losses and as proportion of total herd size. Additionally, we aimed to calculate the financial costs of livestock depredation and identified the predator most related with livestock depredation. Our second research objective was to analyze different predictors of predator attacks that relate with farmers' familiarity with carnivores, and the implementation of livestock husbandry practices. Specifically, we tested the following hypotheses: livestock depredation is expected to be higher when: (a) carnivore identification skills are good (Dickman, 2008; Msuha, 2009); (b) carnivore densities are perceived as high (Rust & Marker, 2013); and (c) livestock husbandry practices are lacking (Breitenmoser et al., 2005). Our findings provide important insights on how communal farmers perceive conflicts with carnivores and how sustainable co-existence could be facilitated.

Methods

Study Area

The Okakarara District Communal Area (ODCA) is part of the Greater Waterberg Landscape and is situated in northeast Namibia (Figure 1). The ODCA covers 18,951 km^2 and consists of four communal conservancies: African Wild Dog, Okamatapati, Otjituuo, and Ozonahi. These conservancies were gazetted by Namibia's Ministry of Environment and Tourism (MET) in 2005 as part of Namibia's Community-Based Natural Resource Management (CBNRM) program (MET/NACSO, 2018; Naidoo et al., 2011). The OCDA is mainly dominated by cattle and smallstock (sheep and goats) farming of the Ovaherero communities, with higher human population and lower wildlife

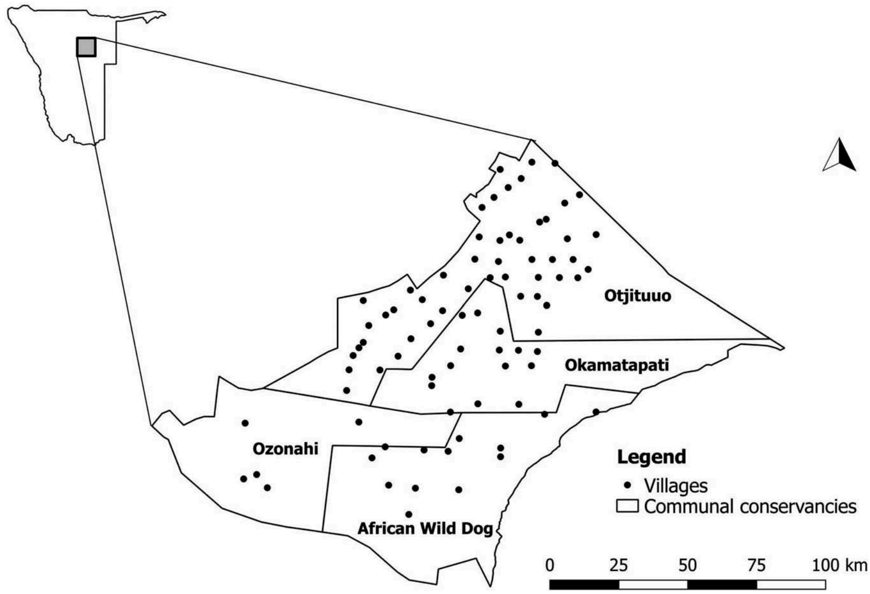

Figure 1. Location of villages where respondents lived in the Okakarara District Communal Area in northeast Namibia.

numbers compared to the surrounding freehold farmland (Kauffman et al., 2007) and other communal conservancies (Lines, 2008).

This region has hot-wet (January to April), cool-dry (May to August) and hot-dry (September to December) seasons (Mendelsohn et al., 2002). The climate is classified as semi-arid with an erratic annual rainfall of 325–450 mm, most of which falls between January and April (Mendelsohn et al., 2002). The average minimum temperature is 6°C during the cool-dry season, whereas the average maximum temperature is 31°C during the hot-dry season (Mendelsohn et al., 2002). The region falls within the Kalahari System Basin and the topography is generally flat, with plains incised by omuramba (i.e., shallow watercourse with no visible gradient) valleys (Strohbach & Kutuahuripa, 2014).

Wildlife populations around human settlements are low and estimated at <0.2 kg/ha (Lines, 2008). Of the larger antelope, the kudu (*Tragelaphus strepsiceros*) is the only species still resident in the area. Among the smaller antelope, steenbok (*Raphicerus campestris*) and duiker (*Sylvicapra grimmia*) are considered relatively common (Lines, 2008). Large carnivores, such as leopard, cheetah, and spotted hyena, are scarce throughout the area. A small population of wide-ranging, but endangered African wild dogs also inhabits the area, but are severely persecuted by farmers (Lines, 2008). Brown hyenas (*Hyaena brunnea*), as well as meso-carnivores, such as jackal and caracal (*Caracal caracal*), are well distributed.

Data Collection

We collected data during three survey periods in 2015, 2016, and 2018. We organized workshops that covered basic conservation training on sustainable wildlife utilization, the role and value of predators in the ecosystem, predator kill identification, and "predator-friendly" farming practices. Questionnaires were administered at the beginning of these workshops to assess farmer perceptions about wildlife and mitigation practices used prior to conservation-based education. A total of 276 unique respondents from the four communal conservancies participated, of which 73% were men and 27% were women. Age categories were 18 to 30 years (18%), 31 to 50 years (54%), and 50+ years (28%). Our sample represented 1% of Ovaherero households, but data were collected over the entire ODCA.

We designed questionnaires to obtain information on characteristics of livestock losses based on the 12 months prior to the survey. Additionally, we collected data on carnivore identification skills, perceptions of carnivore densities, and livestock husbandry practices. We assessed carnivore identification skills by asking the respondents to identify photographs of eight different carnivore species (African wild cat [*Felis lybica*], African wild dog, brown hyena, caracal, cheetah, jackal, leopard, serval [*Leptailurus serval*]). We considered respondents who correctly identified seven or eight carnivore species to have good identification skills, whereas those who correctly identified fewer than seven were considered to have poor identification skills. This was based on two potential difficulties with identification: (a) the possible confusion between cheetah and leopard (Dickman, 2008; Mkonyi et al., 2017), and (b) the rarity of serval in the study area (Edwards et al., 2018). The other species were rather easy to distinguish, or common in the area. We used an ordinal method to collect data on perceptions of carnivore densities by asking the respondents to report if they typically encounter the different carnivore species either every week or more, every month, every six months, every year, or never. We collected data on livestock husbandry practices by asking respondents if guarding dogs were present, if herders were present, how large the herd size was, how many households there were in the settlement, and if nighttime confinement of livestock in kraals was implemented.

Questionnaires were semi-structured to allow for a more detailed description whenever respondents reported experiencing livestock losses due to depredation. We conducted the questionnaires in English, Afrikaans, or Otjiherero, depending on the language spoken by the respondent. Questionnaires in Afrikaans and Otjiherero were translated by one of the conservancy committee members. All respondents agreed to be interviewed, providing verbal consent.

Data Analysis

To meet our first research objective, we analyzed compiled questionnaire data descriptively to characterize livestock losses. To test for differences between carnivore species associated with cattle and smallstock losses, we used the chi-square test.

To test our first hypothesis from our second research objective, we used the Wilcoxon rank sum test as a non-parametric alternative to determine differences in livestock losses between farmers with good and poor carnivore identification skills.

To test our second hypothesis, we used the chi-square test to determine differences in frequency of encounter between different carnivore species. Additionally, we used the Wilcoxon rank sum test to determine if livestock depredation was higher when respondents reported seeing predators more frequently. We tested for differences in smallstock losses between farmers who encounter small carnivores (African wildcat, caracal, jackal, serval) once a week or more, and farmers who encounter small carnivores less than once a week. Similarly, we tested for differences in cattle losses between farmers who encounter large carnivores (African wild dog, brown hyena, cheetah, leopard) once a week or more, and farmers who encounter large carnivores less than once a week. We did not analyze smallstock losses in relation to encounter frequency with large carnivores, as large carnivores were rarely reported to be responsible for smallstock losses. Similarly, we did not analyze cattle losses in relation to encounter frequency with small carnivores.

To test our third hypothesis, we used a Poisson generalized linear mixed model, which accounted for overdispersion using the function *glmmPQL* from the package MASS (Venables & Ripley, 2002). We built two separate models to test for the effect of husbandry practices on livestock losses, one for cattle and one for smallstock. We included the following predictors: nighttime confinement in kraals, number of livestock owned, number of households in the settlement (human activity), presence of a livestock guarding dog, and presence of a herder. We did not include the predictor nighttime confinement in kraals in the model for smallstock because almost all respondents reported keeping smallstock in kraals at night. We included survey period as a random factor because different respondents were interviewed over the three survey periods and may induce variability. We did all statistical analysis in R version 3.4.3. A significance level of .05 was used and the data met assumptions of normality and heteroscedasticity if models required this.

To measure the impact of depredation, we estimated the economic value of cattle and smallstock at 352 USD per cattle and 53 USD per smallstock, regardless of animal age at the time of the loss, assuming all animals represent the same economic value at the time they would be sold. We obtained data about the value of livestock from two companies (Agra Ltd. and Blaauwberg Auctioneers CC) that record prices of auctioned livestock in the study area. These values provided would have fluctuated during the three-year survey period, although inter-annual price fluctuations are typically markedly smaller compared to monthly variations. Despite this, we recognize this is a limitation in our study.

Results

Characteristics of Livestock Depredation

Respondents reported annual cattle depredation rates that ranged between 0 and 35 head of stock (M = 6, SD = 9) per farmer, whereas annual smallstock depredation rates ranged between 0 and 100 head of stock (M = 14, SD = 21) per farmer. The number of cattle owned per respondent ranged between 0 and 400 head of stock (M = 86, SD = 85), whereas the number of smallstock owned per respondent ranged between 0 and 300 head of stock (M = 63, SD = 60). The total financial cost of depredation was 462,339 USD for all respondents for one year, or 2,848 USD (± 4,281 SD) per respondent. Depredation accounted for 57% of all reported livestock losses (6,972) and was 8% of the total herd size (44,217). Other causes of livestock losses included drought (18%), disease (11%), plant poisoning (8%), theft (3%), birthing problems (2%), and snakebites (1%).

The frequency of attacks by different carnivore species was significantly different between cattle and smallstock (χ^2 = 2650.8, df = 6, p < .01). For cattle lost to depredation (847), African wild dog was reported as the main predator (71%), followed by leopard (14%), unknown predators (10%), cheetah (4%), and brown hyena (1%). Smallstock losses

(3,123) were reported to be caused mainly by jackal (73%), followed by caracal (14%), African wild dog (6%), cheetah (3%), brown hyena (2%), and unknown predators (2%).

Carnivore Identification and Perceived Densities

The accuracy of correctly identifying the carnivore species was generally high for all species, except for serval (Table 1). Respondents with good identification skills suffered significantly more smallstock losses compared to respondents with poor identification skills ($Z = 4{,}404.5$, $p < .01$). This difference was not significant for cattle losses ($Z = 3{,}772$, $p = .16$).

Frequency of encounter was significantly different between predator species ($\chi^2 = 680.49$, df = 28, $p < .001$). Jackals were reported as the most frequently encountered species, whereas larger carnivore species were reported to be seen approximately every six months (Table 2). Cattle losses were higher if respondents reported seeing large carnivores more frequently such as once a week or more ($Z = 3\,011$, $p < .01$). This was not significant for smallstock losses when small carnivores were seen more frequently ($Z = 2\,206$, $p = .80$).

Livestock Husbandry

Ninety-six percent ($n = 265$) of respondents kept smallstock in kraals at night and 60% ($n = 166$) reported keeping cattle in kraals at night. Livestock guarding dogs were reported to be present by 66% ($n = 182$) of respondents for cattle, and by 74% ($n = 204$) for smallstock. The presence of a herder was reported by 37% ($n = 102$) of respondents for cattle, and 44% ($n = 121$) for smallstock.

Table 1. Percentage of respondents living in the Okakarara District Communal Area, Namibia, who identified the following carnivore species as correct or incorrect.

Species	% Correct	% Incorrect
Jackal	99	1
African wild dog	94	6
Cheetah	94	6
Leopard	93	7
Brown hyena	91	9
Caracal	89	11
African wild cat	77	23
Serval	14	86

Table 2. Percentage of respondents reporting how frequent they encounter different carnivore species around their settlements.

Species	Every week	Every month	Every 6 months	Every year	Never
Jackal	87	13	0	0	0
African wild cat	25	36	28	5	6
Caracal	13	29	44	10	4
Brown hyena	12	24	45	11	8
African wild dog	10	28	44	11	7
Leopard	5	15	45	18	17
Cheetah	4	13	49	19	15
Serval	3	6	12	3	76

Table 3. Generalized linear mixed model summaries predicting effectiveness of livestock husbandry practices against livestock depredation in the Okakarara District Communal Area, Namibia, between 2015 and 2018.

Model	Fixed effects	β	Std.Error	exp(β)	*p*
Cattle	(Intercept)	1.49	.37	4.1	<.001***
	Kraal at night	− 0.08	.25	0.93	.76
	Number of households	− 0.01	.01	0.99	.29
	Number owned	0.01	.001	1.01	<.001***
	Presence of dog	− 0.52	.23	0.6	<.05*
	Presence of herder	− 0.53	.31	0.59	.09
	Random effects:		Survey		
		(Intercept)	Residual		
	SD:	0.36	2.1		
Smallstock	(Intercept)	1.72	.4	5.58	<.001***
	Number of households	− 0.004	.005	0.996	.35
	Number owned	0.004	.001	1.004	<.001***
	Presence of dog	0.4	.16	1.49	<.05*
	Presence of herder	− 0.02	.16	0.98	.91
	Random effects:		Survey		
		(Intercept)	Residual		
	SD:	0.6	2.9		

The results of the generalized linear mixed model analyses are shown in Table 3. A unit increase in having livestock related to a significant increase in livestock lost by 1% for cattle and < 1% for smallstock. Having a livestock guarding dog was related to a significant decline in livestock lost by 40% for cattle, but was related to a significant increase in livestock lost by 49% for smallstock. Other parameter estimates were not significant. The random effects accounted for variability in livestock losses between the different surveys for both models.

Discussion

Characteristics of Livestock Depredation

Livestock depredation was the main cause (57%) of livestock losses in the ODCA and is well above the 16% found by Lines (2008) in the same area. Livestock depredation as a proportion of total herd size was relatively high (8%) compared to other areas across sub-Saharan Africa (Butler, 2000; Hemson et al., 2009; Holmern et al., 2007; Patterson et al., 2004; Schiess-Meier et al., 2007). We suggest that human pressures on the landscape and depletion of wild prey are the main causes for this conflict (Khorozyan et al., 2015; Woodroffe, 2000).

We also found high variability in livestock losses among respondents. Five percent of farmers lost more than 50 head of stock to predators in one year, accounting for almost 35% of all livestock losses in one year. On the other hand, more than 20% of respondents did not lose livestock at all to predators in the past year. This suggests nonrandom patterns of livestock depredation shaped by underlying drivers.

The average annual expenditure of Ovaherero people is estimated at approximately 1,708 USD per capita (NSA, 2018) and therefore, livestock depredation may have disastrous financial impacts on individual farmers (average cost per farmer estimated to be 2,848 USD), resulting in a significant economic loss for the Ovaherero community. Reducing livestock losses through effective livestock management may greatly increase the livelihoods of the local people and aid in developing effective and functioning communal conservancies.

Livestock depredation was mainly caused by jackal for smallstock and African wild dog for cattle. Jackals were reported to be the most frequently encountered species, as they have the tendency to frequent human settlements in search for food (Gusset et al., 2009; Kaunda & Skinner, 2003; Van der Weyde et al., 2018). On the other hand, African wild dogs are less common and extremely wide-ranging across the landscape (Lines, 2008). However when they have pups, they may hunt intensively within a smaller area around their den (Creel & Creel, 2002). African wild dogs largely subsist on wild prey when available, but when the natural prey base is depleted, they shift their diet toward livestock as an alternative (Gusset et al., 2009; Rasmussen, 1999; Woodroffe et al., 2005). Their impact locally may be severe and we recognize the conflict with African wild dogs in this region as the most pertinent issue to address, both for the wellbeing of the local community and for the survival of this understudied African wild dog population. Furthermore, we suggest that natural prey depletion over time and low abundance of other large carnivores in the area (unpubl. data, Cheetah Conservation Fund) explain our contrasting findings compared to the study by Lines (2008).

It is important to mention that perceived livestock depredation might overestimate actual losses due to low tolerance (Chase Grey et al., 2017; Lines, 2008; Rasmussen, 1999). This may induce bias in our estimates of livestock losses and financial costs. However, previous studies have shown that reliable depredation data can be obtained from questionnaires (Madsen & Broekhuis, 2018; Woodroffe et al., 2005). Furthermore, these questionnaires still indicate how local communities perceive the magnitude of human conflict with carnivores (Li et al., 2015).

Carnivore Identification and Perceived Densities

These communal farmers generally were good in identifying the different carnivore species in the area. Only the success rate of serval identification was low and therefore serval attacks may be attributed, perhaps incorrectly, to other small carnivores, such as jackal and caracal. However, this is likely to be neglected because of the rarity of serval in the area (Edwards et al., 2018). Furthermore, serval rarely predate on smallstock as they prefer birds and small mammals (Ramesh & Downs, 2015). Perceived densities of other small carnivores were high, in particular for jackal, which shows their ability to survive well in human-dominated landscapes (Gusset et al., 2009). African wild dog was reported as the most common large carnivore and therefore, this species may be perceived as the most problematic (Marker et al., 2003; Rust & Marker, 2013).

Our results suggested that livestock depredation intensified with increased carnivore familiarity. High perceived densities may increase depredation risk and may result in better identification skills. Also in the Pendjari Biosphere Reserve in Benin, and around the Kruger National Park in South Africa, commonality of carnivore species around villages was related to a higher livestock depredation risk (Lagendijk & Gusset, 2008; Sogbohossou et al., 2011). Additionally, farmers around Ruaha and Tarangire National Parks in Tanzania suffered more livestock losses when they had better identification skills (Dickman, 2008; Msuha, 2009).

However, the outcome of our analyses of livestock depredation in relation to carnivore identification and perceived densities was not uniform for all reported livestock losses. The overall high identification success of species that mostly predate on cattle (i.e., large carnivores) indicates that familiarity with large carnivores is high throughout the Ovaherero community, even if farmers did not lose cattle, or do not encounter large carnivores frequently. On the other hand, farmers may only become more familiar with smaller carnivores when they predate frequently on their smallstock, even if they are reported to be common throughout the study area.

Carnivore familiarity, stemming from good identification skills and/or frequent carnivore encounters, should not be mistaken for good knowledge of carnivores and their value within the ecosystem. Conservation-based education may impart such knowledge, but might not be sufficient to solve current conflicts on its own, as experience with past predation events often affects conservation attitudes more than general knowledge (Conforti & De Azevedo, 2003; Ericsson & Heberlein, 2003).

Livestock Husbandry

Livestock depredation increased with herd size, which was also found in other regions (Hemson et al., 2009; Li et al., 2015; Van Bommel et al., 2007). Large herd size increases vulnerability to carnivores as it becomes more difficult to effectively implement anti-predator practices (Li et al., 2015). Therefore, we recommend managing smaller herds with good husbandry practices to optimize cost-benefits.

Despite evidence from the literature on the effectiveness of livestock husbandry (Breitenmoser et al., 2005; Ogada et al., 2003; Woodroffe et al., 2007), we found that depredation was largely unaffected by these practices prior to our workshops (i.e., conservation-based education). Only the presence of guarding dogs was efficient in reducing cattle depredation, but their presence with smallstock increased smallstock losses. Reported guarding dogs used for smallstock may be small, poorly trained, and not bred to guard livestock, whereas on the other hand, guarding dogs used for cattle may be larger, have a more threatening bark, and may show more protective behavior toward the livestock (Marker et al., 2005). Therefore, we may explain these unexpected results of the apparent ineffectiveness of most livestock husbandry practices by the lack of knowledge and/or resources of farmers to successfully implement the reported livestock husbandry practices (Bauer et al., 2017). As described above, dogs may lack guarding behavior (Marker et al., 2005; Marker-Kraus et al., 1996), but kraals may also be in disrepair (Weise et al., 2018) or herders may lack vigilance (Kolowski & Holekamp, 2006). Additionally, respondents may give answers to please the interviewers rather than to give truthful answers (i.e., social-desirability bias; Leggett et al., 2003).

An alternative hypothesis may be that spatial variation in livestock attacks is predicted by patterns of carnivore occupancy (Treves et al., 2011; Zarco-González et al., 2013). The implementation of livestock husbandry practices in high-risk areas may not be sufficient to reduce livestock depredation rates to those found in low-risk areas. Additionally, farmers in low-risk areas may still implement livestock husbandry practices because of their perceived effectiveness.

Conservation Implications

Human conflict with carnivores intensified with herd size and carnivore familiarity. Conversely, the implementation of livestock husbandry practices appeared to be ineffective prior to our workshops, or at least, not sufficient to significantly reduce reported depredation rates. Familiarity with carnivore species because of frequent livestock attacks may yield low levels of tolerance. Educating local people about the importance of carnivores within the ecosystem, as well as better rangeland management and effective livestock husbandry practices, may alter their perceptions and reduce livestock losses (Hughes et al., 2018; Marker et al., 2003). However, a thorough and holistic approach may be needed, as changing conservation perceptions is often difficult and rooted within past experiences and socio-cultural values (Jacobson et al., 2006). Conservation perceptions are most likely to change when educational programs include enrollment into activities where they could obtain economic profits from wildlife conservation (Conforti & De Azevedo, 2003). For example, ecotourism-based initiatives encourage more positive perceptions toward carnivores, at least when it benefits the entire community (Conforti & De Azevedo, 2003; Vannelli et al., 2019).

Based on our findings, we recommend spatial modeling of predation risk to identify high risk areas, where mitigation efforts should be prioritized (Durant et al., 2017; Miller, 2015). However, external support and improved communication and collaboration among stakeholders (e.g., local communities, governmental institutions, non-governmental organizations, conservancy committees) may be needed to successfully implement these efforts, which should be part of an integrative management plan (Fraser-Celin et al., 2018). Currently, the high financial costs from livestock depredation, the low wildlife numbers in this region, and the lack of capacity within the community are preventing these conservancies from developing toward their desired outcomes.

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