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Research article

Promoting human–carnivore coexistence through outreach in Namibia's eastern communal conservancies

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Education and community outreach are fundamental to raising conservation awareness in rural communities for alleviating human–wildlife conflict (HWC). Evaluating the impacts of programs aimed at reducing HWC is necessary to justify the effectiveness of mitigation strategies, and to provide feedback for designing sustainable conservation initiatives at the community level. We examined the impacts of an outreach program in four eastern communal conservancies in Namibia using questionnaire surveys administered to outreach workshop participants. Most participants experienced livestock losses (91.7%), which were caused primarily by predators and droughts. Following workshop attendance, significant declines in livestock losses were observed and perceptions regarding the abundances of predators in the area reflected the reality on the ground more accurately. These results suggest that workshops can be effective in teaching communities about predator ecology and mitigating depredation losses of livestock. Therefore, workshops can be used as an important strategy to promote conservation and sustainable livelihoods.

Keywords: community workshop, depredation mitigation, human–wildlife conflict, livestock depredation, predators, rural education

Introduction

Human–predator conflict occurs due to real or perceived threats of livestock depredation, often resulting in farmers retaliating by killing predators (Woodroffe et al. 2005b, Rust and Marker 2014). As many carnivore species have experienced population declines and range contractions worldwide, human–predator conflict is one of the most pressing issues affecting modern biodiversity conservation (Marchini 2014, Ripple et al. 2014). Achieving harmonious coexistence between livestock farmers and predators is challenging because depredation can negatively affect the viability of rural livelihoods, resulting in predator persecution (Loveridge et al. 2010). Impacts are

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further intensified if livestock that are lost have cultural or emotional significance, in addition to financial value (Sillero-Zubiri and Laurenson 2001, Dickman 2010, Dickman et al. 2018a).

The development of effective mitigation strategies is key to reducing livestock losses to predators; therefore, understanding the human dimensions of human–predator conflict is necessary (Manfredo and Dayer 2004, Loveridge et al. 2010, König et al. 2020). Educational programs that promote positive attitudes and beliefs about wildlife can help foster increased acceptance of predators on rural lands and can reduce human–predator conflict (Ballantyne and Packer 2005, Lagendijk and Gusset 2008, Morehouse et al. 2020). For example, programs targeting communities whether in classrooms or in the field can yield greater tolerance, lower perceived risk from predators, and higher potential for coexistence (Skupien et al. 2016).

Where livestock losses to predators are experienced by communities, significant economic losses and persecution of predators often occur (Creel and Creel 2002, Woodroffe et al. 2005a, MET 2013, Verschueren et al. 2020, Wilkinson et al. 2020). In Namibia, small populations of endangered and vulnerable predators such as cheetahs *Acinonyx jubatus* and African wild dogs *Lycaon pictus* are found in the Eastern Communal Conservancies (Fig. 1), where pastoralism is the main land use. Communal conservancies are legally recognized, geographically defined areas that are formed and co-managed by land occupiers, who work to collaboratively use natural resources in a sustainable manner (Weaver and Petersen 2008, Shaw and Marker 2010). Therefore, communal conservancies can be important potential refuges for wildlife populations outside of nationally protected areas. Despite their potential, communal conservancies may sometimes hold less value for predator conservation than freehold lands (privately owned livestock and game farmlands) due to differences in land use practices, culture and economic activities (Selebatso et al. 2008). Communal conservancies typically have a higher human density who are dependent on a predominant subsistence farming system. Farmer training workshops may thereby provide the necessary framework to mitigate human–predator conflict and allow coexistence.

We examined the impacts of farmer training workshops implemented during 2015 and 2016, which were designed to equip communal farmers with tools to mitigate human–wildlife conflict, improve livestock management to prevent livestock losses, and raise community awareness towards wildlife conservation. Our broader goal was to understand the interaction between predators and rural communities, and to determine: 1) the extent of human–wildlife conflict in the Eastern Communal Conservancies, and 2) to determine if trainings given to community members improved knowledge in integrated livestock management, knowledge about predators, and reduce human–wildlife conflict over time. By comparing participants' responses pre- and post- workshops, we explored the effects of workshop participation on 1) correct predator identification, 2) perceptions regarding the abundance of local

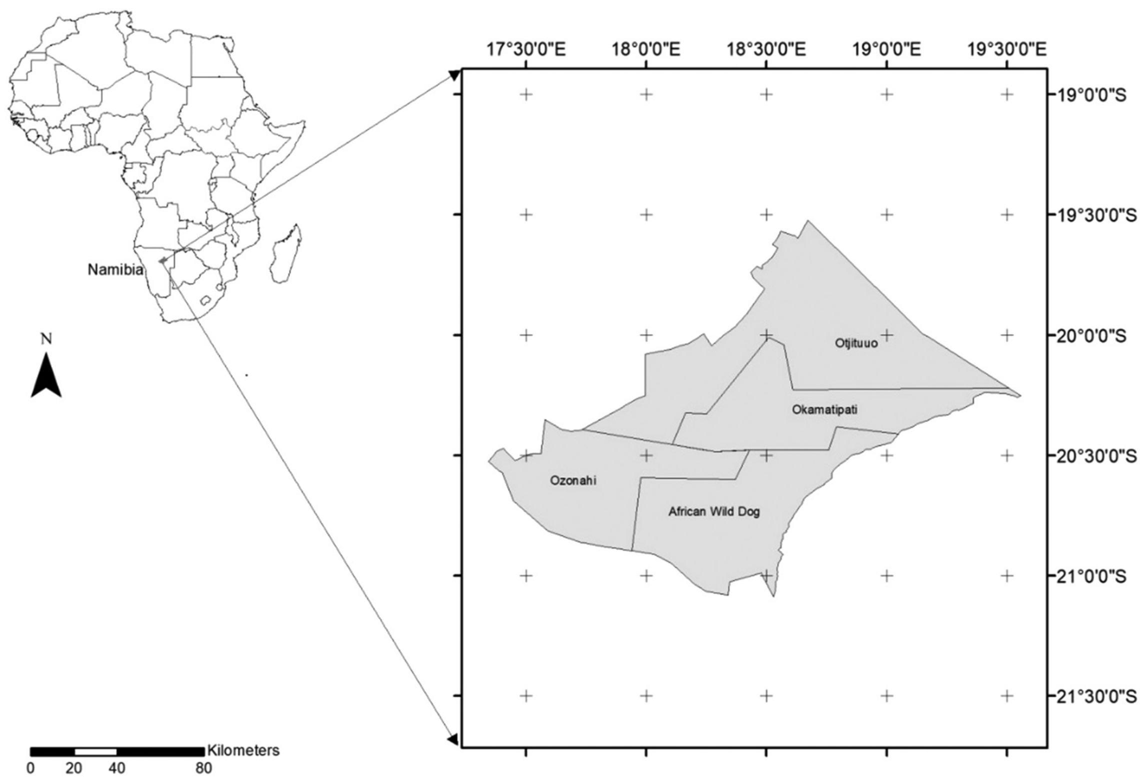

Figure 1. Location of the four Eastern Communal Conservancies in the Greater Waterberg Landscape of Namibia where farmer training workshops were conducted by the Cheetah Conservation Fund during 2015 and 2016.

predators, and 3) livestock losses and factors associated with livestock losses. Our approach provides information concerning human–wildlife conflict in Namibia's Eastern Communal Conservancies to assist in planning effective measures to reduce conflict and retaliation against predator species.

Material and methods

Study area

Social science surveys were conducted in four adjacent communal conservancies (registered in 2005), of approximately 16 257 km[2]: Otjituuo, Okamatapati, African Wild Dog (AWD), and Ozonahi, within the Greater Waterberg Landscape (GWL), in the Otjozondjupa region of Namibia (Fig. 1). The climate is semi-arid with a mean annual rainfall of 418.2 mm (± 33.5SD) falling between January–April (Fick and Hijmans 2017, MEFT et al. 2022). There are three main seasons: hot-wet (January–April), cold-dry (May–August) and hot-dry (September–December), with the mean daily maxima of 31°C (± 0.2 SD) in January and 23°C (± 0.3 SD) in July. Elevation is 1298.5 m (± 45.7 SD) (Fick and Hijmans 2017) and vegetation is broadly classified as camelthorn *Vachellia erioloba* savannah, thorn bush savannah, tree savannah and woodlands (Erkkilä and Siiskonen 1992, Mendelsohn et al. 2003, MEFT et al. 2022).

The area has a population of approximately 23 952 people, with the majority relying on livestock farming (cattle, goats and sheep) as an economic mainstay (MET 2013). A pastoral and communal grazing system prevails in the area with poor or no rotational grazing. Livestock freely move across the entire farming landscape) with an unregulated stocking rate. Consequently, overgrazing and bush encroachment are prevalent, and most large wild mammals were extirpated due to high levels of sustained poaching prior to the development of conservancies (SAIEA 2016, Birch and Middleton 2017).

Data collection

During 2015 and 2016, day-long farmer training workshops were conducted each month at two central locations within each of the four conservancies (overall workshops: n = 100 (25 per conservancy)). Workshop modules were designed specifically to educate participants in better livestock husbandry and management practices, while also providing education in predator identification, ecology and conservation of wildlife and predators. We used farmer training material developed from previous workshops (Supporting information). Workshop attendance was voluntary, and permission to participate in this study was requested from the participants prior to conducting the survey.

Workshop participants were surveyed at the start of the workshops using a structured questionnaire that consisted of open- and close-ended questions (Supporting information). Data collected included: 1) household (a house and its occupants regarded as a unit) and settlement characteristics (i.e. household and population sizes); 2) demographic details per participant (sex, age, workshop attendance history); 3) livestock management practices applied to reduce livestock losses; 4) number of livestock owned; 5) number of livestock lost over the past 12 months per household and contributing factors of the losses; and 6) perceptions regarding the abundance of predators in the area. A total of four workshop facilitators assisted with data collection and interpretation into local languages, mainly Otjiherero and Afrikaans.

As the workshops were conducted over a 24-month period, it was possible some of the participants attended multiple workshops and had prior workshop attendance before being surveyed. These participants were defined as post-workshop participants, and no more than 24 months passed between their workshop attendance and them being surveyed. The participants with no prior workshop attendance were defined as pre-workshop participants.

Statistical analyses

We summarized the demographic data using descriptive statistics (mean, SD, sum, frequencies, and percentages) for households, settlements, sex, age, number of participants and frequencies of workshop attendance. We used generalized linear models (GLM) for count data (Quasi-Poisson) to separately compare the mean number of livestock owned and livestock lost across the four conservancies; post-hoc tests were completed using the general linear hypothesis function at a alpha = 0.05 level (R packages 'Mass' and 'multcomp') (Venables and Ripley 2002, Hothorn et al. 2008).

A quassi-Poisson GLM was also used to estimate the effect of different factors responsible for livestock losses while accounting for settlement size. The number of livestock losses during the 12 months prior to the survey was designated as the dependent variable. Factors responsible to losses included birthing problems, disease, drought, poisonous plants, predators, snakebite, and theft. Birthing problems was considered as the reference category in the modelling procedure.

We applied a quasi-Poisson GLM for over-dispersed data (Venables and Ripley 2002, Mehtatalo and Lappi 2020) using package 'Mass' to assess the effect of workshop attendance on livestock losses. We set the baseline condition (intercept) for the categorical covariate as no prior workshop attendance, thereby obtaining a regression estimate for confirmed attendance to a workshop. We modelled separately the various factors that we anticipated could cause livestock losses. A total of seven models were run for the following livestock loss factors: predators, drought, disease, poisonous plants, theft, birthing problems, and snake bites. In addition, an overall model for all livestock losses from all factors was run to estimate the effect of workshop exposure on losses. We again accounted for settlement size (centered) by including it as a covariate in all models. For meaningful interpretation, we centered settlement size (expressed as settlement size –19.2, where 19.2 is the average number of households in a settlement across all conservancies).

We analyzed whether perceptions of predator abundance were related to past livestock losses or exposure to workshops using a multinomial logistic regression (package 'nnet') (Venables and Ripley 2002). We used three different perception outcomes (decrease, no change, increase) as levels in the dependent variable. Covariates included workshop attendance (yes/no) and the number of livestock losses experienced. We ran eight models that were predator species-specific: brown hyena *Hyaena brunnea*, cheetah, leopard *Panthera pardus*, African wild dog, African wild cat *Felis silvestris lybica*, caracal *Caracal caracal*, black-backed jackal *Canis mesomelas*, and serval *Leptailurus serval*.

All analyses were carried out using R ver. 4.0.4 (www.r-project.org).

Results

Demography of survey participants

A total of 217 surveys were completed in four conservancies with 71% (n = 154) male and 29% (n = 63) female participants (Table 1). Fifty seven percent (n = 124) of the participants were between 31 and 50 years of age. Survey participants were from 69 different settlements, with an average of 19.2 (±18.4 SD) households per settlement, and 10.9 (± 9.7 SD) individuals per household (Table 1). Over half (62.7%; n = 136) of the participants indicated that they had previously participated in an integrated livestock and predator management training workshop before participating in this study, and they were assigned to the post-workshop sample group.

Livestock management techniques, losses and related factors

Survey participants were asked to provide information regarding the total number of livestock owned per household in the 12 months before the survey. A total of 31 240 head of livestock were owned, comprising mainly cattle, goats and sheep, with smaller number of horses and donkeys (Table 1). Most farmers (98.6%, n = 214) branded and ear tagged their animals, vaccinated them (98.6%, n = 214), added supplement feed (98.2%, n = 213), and enclosed livestock in kraals (97.7%, n = 212). Compared to the aforementioned techniques, fewer farmers used guard dogs (75.6%, n = 164) or herders (54.4%, n = 118). Only one individual indicated they did not apply any of the common livestock management techniques.

The majority of farmers (91.7%, n = 199) had experienced livestock losses within the previous 12-months before attending a workshop, amounting to 13.7% (n = 4290) animals of the total livestock owned (Table 1). Livestock losses were significantly different between Ozonahi–Okamatapati (p = 0.002) and Ozonahi–AWD (p = 0.010) (Table 2). Losses were lower in Ozonahi compared to AWD conservancy as the reference category in the modelling procedure (Table 2).

Predators, drought, diseases and poisonous plants incurred more losses than birthing problems, whereas snakebite accounted for lowest number of losses (Table 3–4). Smaller settlements experienced on average greater losses than larger settlements (Table 3).

Effects of workshop attendance on carnivore perceptions

Perceptions of the different predator population abundances are presented in Table 5. Attending a training workshop may have contributed to these indices. Workshop attendance was associated with a significant reduction in the participants' perception that predator populations were increasing for brown hyena ($p < 0.001$) and African wild dogs ($p < 0.001$) (Table 5). Also, attending a workshop caused a significant

Table 1. Demographic features of the respondents, their settlement and household size, number of livestock (owned and loss within 12 months prior to survey) and workshop attendance in the study area. Numbers in brackets represent percentages.

Measured variables		Conservancy				Total
		African Wild Dog	Okamatapati	Otjituuo	Ozonahi	
No. of respondents (%)		52 (24)	33 (15.2)	65 (30)	67 (31)	217
Sex (%)	M	36 (23.4)	30 (19.5)	46 (29.9)	42 (27.3)	154 (71)
	F	16 (25.4)	3 (4.8)	19 (30.2)	25 (39.7)	63 (29)
Age (%)	0–20	2 (50)	1 (25)	–	1 (25)	4 (1.8)
	21–30	7 (25)	4 (14.3)	9 (32.1)	8 (28.6)	28 (12.9)
	31–40	20 (32.3)	10 (16.1)	15 (24.2)	17 (27.4)	62 (28.6)
	41–50	9 (14.5)	5 (8.1)	21 (33.9)	27 (43.6)	62 (28.6)
	51–60	8 (25)	6 (18.8)	11 (34.4)	7 (21.9)	32 (14.8)
	60 +	5 (20)	6 (24)	8 (32)	6 (24)	25 (11.5)
	Unk	1 (25)	1 (25)	1 (25)	1 (25)	4 (1.8)
Ave. (± SD) no. households in settlement		15.9 (±10.7)	6.9 (±4.7)	12.9 (±12.8)	33.8 (±22.7)	19.2 (±18.4)
Ave. (± SD) no. people in a household		12.4 (±7.5)	9.3 (±7.5)	9.2 (±10.8)	12.3 (±10.9)	10.9 (±9.7)
Total no. of livestock owned (%)		6466 (20.7)	5610 (18)	10307 (33)	8857 (28.4)	31240
Ave. (± SD) no. livestock owned per farmer		24.9 (±49.3)	34 (±51.3)	31.7 (±50.2)	26.4 (±51.3)	28.8 (±51.3)
Total no. of livestock lost (%)		1303 (20)	977 (17)	1186 (12)	824 (9)	4290 (13.7)
Ave. (± SD) livestock lost per respondent		5.1 (±26.2)	29.6 (±36.8)	18.3 (±21.7)	12.3 (±13.6)	19.8 (±24.7)
No. respondents at workshop (%)	Yes	29 (55.8)	12 (36.4)	49 (75.4)	46 (68.7)	136 (62.7)
	No	23 (44.2)	21 (63.6)	16 (24.6)	21 (31.3)	81 (37.3)

Table 2. Generalized linear model (GLM) output to compare the average number of livestock owned and livestock loss across the four conservancies (OK = Okamatapati, OT = Otjituuo, OZ = Ozonahi, and AWD = African Wild Dog). The Intercept represents the baseline conditions for livestock loss, in reference to the mean number of livestock losses in the AWD conservancy.

	Parameter	Estimate	SE	t-value	p-value (>|t|)
Livestock owned	(Intercept)	4.823	0.123	39.198	$< 2 \times 10^{-16}$***
	Conservancy: OK	0.313	0.181	1.732	0.0847
	Conservancy: OT	0.243	0.157	1.549	0.1229
	Conservancy: OZ	0.061	0.162	0.378	0.7057
	OK-AWD	0.313	0.181	1.732	0.305
	OT-AWD	0.243	0.157	1.549	0.406
	OZ-AWD	0.061	0.162	0.378	0.981
	OT-OK	−0.070	0.164	−0.424	0.974
	OZ-OK	−0.252	0.169	−1.490	0.442
	OZ-OT	−0.182	0.143	−1.269	0.581
Livestock loss	(Intercept)	3.221	0.143	22.528	$< 2 \times 10^{-16}$***
	Conservancy: OK	0.167	0.218	0.764	0.446
	Conservancy: OT	−0.317	0.207	−1.531	0.127
	Conservancy: OZ	−0.712	0.230	−3.098	0.002**
	OK-AWD	0.167	0.218	0.764	0.870
	OT-AWD	−0.317	0.207	−1.531	0.418
	OZ-AWD	−0.712	0.230	−3.098	0.010*
	OT-OK	−0.484	0.223	−2.171	0.131
	OZ-OK	−0.879	0.244	−3.599	0.002**
	OZ-OT	−0.395	0.234	−1.685	0.331

increase in perceiving that African wild cat ($p < 0.001$) and caracal ($p < 0.001$) abundances were declining and not increasing. No significant impacts were observed in perceptions of other animal types, following workshop attendance.

An increase in the number of livestock losses had a positive (and statically significant) relationship with the perception that brown hyena ($p = 0.005$) and serval ($p = 0.013$) populations were increasing, and African wild cat ($p = 0.029$) and jackal ($p = 0.034$) populations remain constant. The effect of the increase in the number of livestock losses in relation with the perception that jackals were increasing was high, although not significant. Livestock losses had no statistically significant relationship with the perceptions regarding the abundances of other animal species in the study area (Table 5).

Effects of workshop attendance in reducing livestock losses

Results from the GLM analysis on the number of reported livestock losses experienced are shown in Table 6. The overall Model (1) showed that the average number of livestock losses amongst participants with no workshop exposure was 27 during the previous 12-month period. Attending a workshop was associated with a statistically significant decline ($p = 0.0001$) in livestock losses by 56.7%, with an average of 15 livestock losses per participant post workshop attendance (Fig. 2).

The average livestock losses due to predators in Model 2 (Table 6), per participant with no workshop exposure, was 12. Those attending a workshop showed a statistically significant decline ($p = 0.0001$) in livestock losses by 49.3%, and an average annual loss of six livestock per participant (Table 6). For livestock losses due to drought (Model 3), livestock losses per participant with no workshop exposure averaged eight per year. Attending a workshop was associated with a statistically significant decline ($p = 0.013$) of 42.7% in livestock losses, and an average loss of three livestock per participant.

For livestock losses to poisonous plants per participant with no workshop exposure (Model 4), averaged four per year. Participants who attended a workshop showed a statistically significant decline ($p = 0.001$) of 27% of livestock losses, and an average loss of one livestock per participant per year.

Table 3. Model coefficients for factors responsible for causing livestock losses experienced by workshop participants. Settlement size was included as a covariate to explain household effects on losses. The Intercept represents the number of livestock losses due to birthing problems per settlement.

Variable	Parameter	Estimate	SE	t-value	p-value (>|t|)
Intercept	β_0	−0.364	0.304	−1.195	0.232
Disease	β_1	1.368	0.340	4.025	0.000***
Drought	β_2	2.005	0.323	6.205	0.000***
Poisonous plants	β_3	1.151	0.348	3.308	0.001***
Predators	β_4	2.462	0.316	7.792	0.000***
Snakebite	β_5	−1.308	0.658	−1.990	0.047*
Theft	β_6	0.326	0.398	0.819	0.413
Settlement size	β_7	−0.019	0.004	−4.487	0.000***

Table 4. The predicted mean number of livestock losses by different factors per household before the survey. The Intercept represents the predicted mean number of livestock losses due to birthing problems per settlement.

			Estimated mean losses	95% Confidence level	
Variable	Parameter	Sum (β)	Exp (sum(β))	Lower	Upper
(Intercept)	β_0	−0.36	0.7	0.36	1.2
Disease	$\beta_0+\beta_1$	1	2.73	0.75	9.62
Drought	$\beta_0+\beta_2$	1.64	5.16	1.48	17.73
Poisonous plants	$\beta_0+\beta_3$	0.79	2.2	0.59	7.85
Predators	$\beta_0+\beta_4$	2.1	8.15	2.38	27.7
Snakebite	$\beta_0+\beta_5$	−1.67	0.19	0.02	1.05
Theft	$\beta_0+\beta_6$	−0.04	0.96	0.23	3.71

There was no significant impact of workshop attendance observed on the number of livestock losses due to disease, theft, birthing problems, and snake bite models in relation to participant workshop attendance. Despite the reported number of livestock losses experienced, 88.5% (n = 192) of the participants indicated that they did not kill predators.

Discussion

The majority (91.7%) of the participants in this survey experienced livestock losses in the previous 12 months before attending a workshop. Livestock loss has major implications for these communities, as pastoralism is the most common form of land use in the northeastern regions of Namibia. In these regions, communities rely heavily on livestock (cattle, goats, sheep, horses and donkeys) instead of on rainfall fed crop farming (Mendelsohn et al. 2003). Livestock have cultural, religious and economic value (i.e. source of income, ceremonial uses) while horses and donkeys are used for transportation and recreational activities (Barnes and de Jager 1996, Davies et al. 2019, Marker and Nghikembua pers. obs.). Therefore, the loss of any livestock has cultural, religious, and economic implications.

The main factors causing livestock losses were predators and droughts. These findings were consistent with Verschueren et al. (2020) who also found that livestock losses in the region were mainly due to depredation and droughts, accounting for 57 and 18% of all reported livestock losses, respectively. The majority (88.5%) of participants in our study indicated they did not kill predators despite incurring high levels of livestock loss, which is similar to communities from Laikipia, Kenya which tolerate some level of livestock loss (Frank et al. 2005). However, people may not report the true extent of predator killing, for fear of being reported to legal authorities, which can lead to underreporting of HWC. For livestock loss, incidents could potentially be over reported in order to elevate the level of conflict, so as to highlight the issue of HWC being experienced (Dickman 2008). There were significantly more livestock losses in AWD conservancy compared to the Ozonahi conservancy. This finding may be influenced by the distribution of predators across these conservancies. Previous studies have shown African wild dogs, brown hyena, jackal, and leopard, to be the main species causing HWC across the conservancies (MET 2013, Verschueren et al. 2020).

Livestock losses and settlement size

Our data suggests that smaller settlements were associated with higher predator presence and experienced more predator related livestock losses. High human density found in larger settlements contributes to the loss of suitable wildlife habitat, increased poaching and direct persecution which leads to the loss of prey and low occurrence of predators (Gosselin and Callois 2018). However, loss of wild prey can increase livestock kills by predators especially if livestock are not protected/managed (Woodroffe et al. 2005a). Karanth et al. (2012) has suggested that the most effective way to prevent predator related livestock losses is to keep the livestock behind a physical barrier, although this is not possible in our study area, as livestock leave the kraal to graze during the day. The use of herders and guarding dogs can be effective at preventing livestock losses (Smith et al. 2000, Ogada et al. 2003, Potgieter et al. 2013, Marker et al. 2021), but the use of guarding dogs was not as common as other management techniques used by farmers in this study. During the farmer's training workshops, the use of livestock guarding dogs was discussed. By educating farmers about correctly using a livestock guardian dog, livestock losses due to predators can be reduced by as high as 90% (Marker et al. 2021). The most popular (used by over 95% of the participants) livestock management techniques reported in our study involved vaccinations, feed supplementation, branding, and kraaling which are primarily used to maintain animal health, ownership identification and safeguard livestock at night in protective enclosures.

We also found that smaller settlements experienced more livestock losses from stock theft, drought, poisonous plants, birthing problems, and snake bites. Smaller settlement sizes may experience more livestock loss due to the geographic location of the settlement and the distribution of poisonous plants. For example, the common geigeria *Geigeria ornativa* and silverbush *Mundulea cericea* are mostly found within the central parts of Namibia, in overgrazed and disturbed area types which are commonly found in smaller settlements (Schubert 2006). A possible explanation for high livestock losses due to droughts may be due to the degraded rangeland conditions found locally and economic factors like inadequate resources to afford feeds/supplements, or to keep herders that could help prevent further losses (Kauffman et al. 2007, MET 2013, Birch and Middleton 2017).

Table 5. Farmer perceptions of predator abundance in the study area before and after workshop attendance. The Intercept represents farmer perceptions before attending the workshop.

Predator size	Species	Trend	Intercept			Attended workshop			Livestock loss		
			β_0	SE	p-value	β_1	SE	p-value	β_2	SE	p-value
Large predator	Brown hyena	Decreased	−2.501	1.042	0.016	1.715	1.127	0.128	0.001	0.004	0.78
		No change	1.236	0.328	0	−0.517	0.437	0.237	0.005	0.003	0.11
		Increased	0.446	0.364	0.22	−3.075	0.713	0	0.01	0.004	0.005
	Cheetah	Decreased	−1.4	0.558	0.012	1.029	0.734	0.161	−0.009	0.007	0.193
		No change	1.042	0.276	0	0.037	0.414	0.929	0.002	0.003	0.382
		Increased	−1.573	0.555	0.005	1.227	0.675	0.069	0.004	0.003	0.168
	Leopard	Decreased	−2.959	1.029	0.004	1.682	1.128	0.136	0.005	0.005	0.215
		No change	1.015	0.277	0	−0.17	0.4	0.67	0.003	0.003	0.267
		Increased	−0.888	0.428	0.038	0.205	0.572	0.72	0.005	0.003	0.117
	African wild dog	Decreased	−1.841	1.073	0.086	0.46	1.22	0.706	−0.008	0.008	0.3
		No change	1.173	0.433	0.007	−0.811	0.514	0.115	0.001	0.002	0.612
		Increased	1.893	0.407	0	−1.854	0.505	0	0.001	0.002	0.76
Mesopredator	African wild cat	Decreased	−8.322	0.271	0.000	6.671	0.003	0.000	−0.001	0.271	0.847
		No change	1.199	0.426	0.000	−0.412	0.002	0.334	−0.005	0.334	0.029
		Increased	0.897	0.49	0.009	−1.604	0.002	0.001	−0.001	0.345	0.697
	Caracal	Decreased	−12.408	0.267	0.000	11.014	0.267	0.000	0.002	0.004	0.528
		No change	1.491	0.392	0.000	−695	0.481	0.148	0.003	0.003	0.292
		Increased	1.31	0.399	0.001	−2.166	0.558	0.000	0.003	0.003	0.347
	Jackal	Decreased	−4.771	5.344	0.372	2.283	5.441	0.675	0.034	0.018	0.064
		No change	0.609	0.686	0.374	−1.237	0.875	0.158	0.036	0.017	0.034
		Increased	2.815	0.598	0.000	−1.189	0.748	0.112	0.033	0.017	0.052
	Serval	Decreased	–	–	–	–	–	–	–	–	–
		No change	−2.047	0.357	0.000	0.434	0.454	0.339	0.003	0.002	0.099
		Increased	−2.703	0.468	0.000	−1.245	0.793	0.116	0.007	0.003	0.013

Table 6. Predicted number of livestock losses before and after attending a farmer training workshop in the four conservancies in the Greater Waterberg Landscape.

Model	Estimated effects					Predicted livestock losses		
	Previous workshop attendance		Estimate β	SE	p-value	exp(β)	Average losses	
Overall (1)	No	β_0	3.301	0.109	0	27.140	β_0	27.14
	Yes	β_1	−0.568	0.156	0	0.567	$\beta_0+\beta_1$	15.38
Predators (2)	No	β_0	2.462	0.114	0	11.728	β_0	11.73
	Yes	β_1	−0.708	0.169	0	0.493	$\beta_0+\beta_1$	5.78
Drought (3)	No	β_0	2.067	0.22	0	7.901	β_0	7.90
	Yes	β_1	−0.851	0.341	0.013	0.427	$\beta_0+\beta_1$	3.37
Poisonous plants (4)	No	β_0	1.38	0.207	0	3.975	β_0	3.97
	Yes	β_1	−1.309	0.371	0.001	0.270	$\beta_0+\beta_1$	1.07
Diseases (5)	No	β_0	0.853	0.238	0	2.347	β_0	2.35
	Yes	β_1	0.204	0.29	0.483	1.226	$\beta_0+\beta_1$	2.88
Theft (6)	No	β_0	−0.681	0.492	0.168	0.506	β_0	0.51
	Yes	β_1	0.868	0.55	0.116	2.382	$\beta_0+\beta_1$	1.21
Birthing problems (7)	No	β_0	−0.633	0.349	0.071	0.531	β_0	0.53
	Yes	β_1	0.491	0.408	0.23	1.634	$\beta_0+\beta_1$	0.87
Snakebite (8)	No	β_0	−1.91	0.485	0	0.148	β_0	0.15
	Yes	β_1	0.329	0.58	0.571	1.390	$\beta_0+\beta_1$	0.21

Smaller settlements may promote biodiversity when compared to larger settlements, due to lower human footprint in the former. If smaller settlements attract a diverse or abundant community of small rodents, this may in turn attract snakes (Schneider 2001, Kerley et al. 2017). In our study, more livestock losses were due to snake bites in smaller settlements. A recent study on snake bite incidents showed 51.5% of the incidents occurred among livestock farmers, indicating high snake activity around kraals and livestock (Mahmood et al. 2018).

Our finding on stock theft in smaller settlements differs from the findings by Sidebottom (2012), who showed that livestock theft was higher with greater availability of livestock, which correlates with larger household and settlement sizes. Livestock theft can impact predators, as farmers often blame predators when livestock go missing, resulting in higher predator persecution and decreased predator tolerance (Rust et al. 2016).

Impacts of workshop attendance

Our results show that workshop participation had significant impact on farmers' perceptions of certain predator species' population abundance. After workshop attendance, more participants had correct perceptions about the predator abundances. For example, before attending a workshop more participants considered brown hyenas and African wild dog populations to be increasing, whereas brown hyena

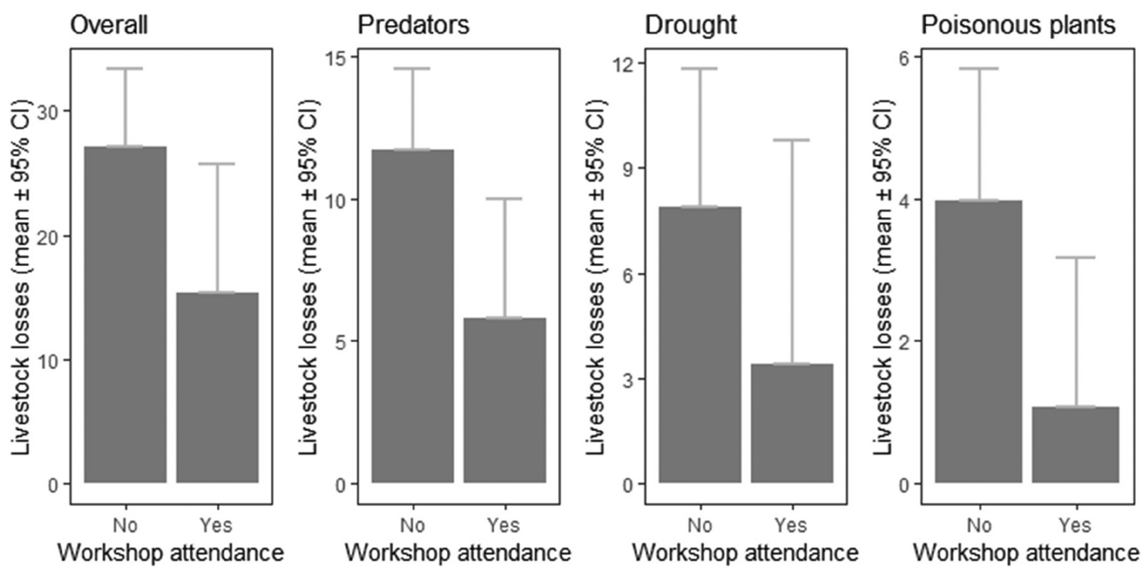

Figure 2. Comparison of the number of livestock loss per participant for overall factors and the three main factors which cause livestock loss before (no) and after (yes) attending a farmer training workshop.

population is likely stable (MEFT et al. 2022), and African wild dog declining in Namibia.

The amount of livestock losses experienced also had a positive and significant relationship with perceiving that there were constant abundances or increases in of brown hyena, jackal and serval. This suggests that brown hyena and jackal may be the most locally abundant and possibly most common species causing livestock losses, which can inflate the sighting frequencies of these species. We are interpreting the output for serval with caution due to potential issues in reliability of serval identification by community members (Verschueren et al. 2020) and because serval are not known to depredate on livestock. Other studies have also shown that farmers perceived certain predator species to be abundant due to high sighting frequencies (Marker et al. 2003, Dickman 2008, Gusset et al. 2009).

The ranging behavior of carnivores typically covers vast areas (Creel and Creel 2002, Marker and Dickman 2005, Skinner et al. 2005, Pomilia et al. 2015, Welch et al. 2016), which could cause local people to perceive higher population abundances for these species. This could lead to higher levels of persecution towards carnivores by farmers. In the farmer training workshops, predator ecology and threats faced by these species were emphasized, resulting in improved carnivore knowledge and the significant reversal in the perceptions of predator populations. By providing farmers with knowledge of predator ecology (e.g. prey preference and when predators typically hunt), farmers can manage their livestock to reduce the incidence of predators taking their livestock.

Overall, we documented a reduction in livestock losses by 56.7% after participants had attended a workshop. In particular, livestock losses caused by the main factors (predators and drought) were significantly reduced after attending a workshop, highlighting the importance of education in improving human–predator coexistence. A possible explanation for the high livestock losses recorded among participants before attending a workshop is inadequate ability to apply field-based mitigation measures (e.g. livestock guarding dogs and herders) to prevent predator related livestock losses; and absence of livestock management practices compatible with predator coexistence (e.g. calving seasons, calving kraals, rotational grazing and improved livestock health) (Marker et al. 2005, Potgieter et al. 2013, Dickman et al. 2018b). Workshop modules were designed to cover practical and theoretical aspects related to cause-specific predator kill identification, predator identification and ecology, livestock husbandry techniques (e.g., treatment, dehorning, nutrition), and herd management (livestock guarding dogs, herders, kraaling). These topics presented in the training programs appeared to be effective at reducing livestock losses in our study area, as participants showed better knowledge in livestock management and predator identification and ecology after attending a workshop.

This study has shown how lack of adequate knowledge about predators may escalate livestock losses and persecution of predator populations, leading to increased HWC. Therefore, better knowledge of wildlife coexistence strategies can lead to higher tolerance of livestock losses and reduction of HWC (Romanach et al. 2007). Without workshop exposure, there may be more livestock losses and incorrect perceptions regarding predator abundances, which could result in perpetual HWC and ultimately extirpation of some predator populations. Megaze et al. (2017) provide another example on the importance of education in conservation, as people with better education have more favorable attitudes towards wildlife and conservation.

Limitations and areas for future development

Although the farmer training workshops were open to any participants, more male than female community members attended. This could be due to cultural norms in some societies where it is the man's responsibility to care for the livestock, while women tend to household responsibilities (Aditya 2016). Other studies (Dickman 2008, Rust and Marker 2014) have shown that risk perceptions related to human–wildlife conflict are influence by gender, for example men who encounter wildlife more frequently due to their responsibilities of herding livestock perceive wildlife abundance and human–predator conflict differently to women. Women should be encouraged to engage in farmer training workshops because they are known to interact differently with the environment, are important contributors to conservation, and they pass on their knowledge through cultural and daily activities (Goldman et al. 2021, Marker et al. 2022). Therefore, without balanced gender representation, misperceptions about wildlife could perpetuate.

Conclusions and management recommendations

Our results indicate that workshop exposure was beneficial in addressing HWC within Eastern Communal Conservancies of Namibia. We found that livestock losses were experienced by most participants and were largely caused by predators and drought. However, after the attendance to a workshop, participants reported fewer livestock losses, and the amount of livestock loss from predators and droughts was reduced. Settlement characteristics were responsible for some of the variation in the livestock losses experienced partly due to human density, abundance of wildlife in the area, and economic factors. Livestock losses were significantly higher among participants before attending a workshop, suggesting that their management techniques used to control livestock losses were not effective. Additionally, with no workshop exposure, there were incorrect perceptions regarding the abundance of predators in the area, which may lead to negative attitudes regarding these species or ineffective livestock and predator management practices. With workshop exposure, these patterns were reversed, suggesting that HWC could be substantially improved by implementing tailored educational programs with rural communities.

Our study provides baseline information for incorporation into future workshop planning. We recommend: 1) long-term monitoring of workshop participants and of the impacts the workshops have on their attitudes and perceptions regarding predators; 2) monitoring of livestock losses and challenges faced in implementing HWC mitigation measures; and 3) encouragement of more woman participation in workshops as disproportionately fewer women participated in this study and issues relating to HWC may be influenced by gender.

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Permits – Prior and inform consent was used when collecting data from study participants. The participants contributed information to the study of their own will and were informed that by completing and returning the questionnaire survey, they agreed to participate in this study and that any personal information would remain confidential.

Author contributions

Laurie L. Marker: Conceptualization (lead); Funding acquisition (lead); Investigation (lead); Resources (lead); Writing – review and editing (equal). **David Shipingana:** Data curation (equal); Formal analysis (equal); Methodology (equal). **Gabriela Fleury:** Data curation (supporting); Formal analysis (supporting); Methodology (supporting); Writing – original draft (equal). **Lauren Pfeiffer:** Writing – review and editing (equal); Validation (supporting). **Annetjie Pöntinen:** Methodology (supporting); Writing – original draft (equal). **Bogdan Cristescu:** Writing – review and editing (equal); Validation (supporting). **Matti T. Nghikembua:** Data curation (equal); Formal analysis (equal); Methodology (equal); Writing – original draft (equal); Writing – review and editing (equal); Validation (lead).

Transparent peer review

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Data availability statement

The data supporting this study are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.dr7sqvb7z (Marker et al. 2024). Supporting educational material for farmer training workshops can be made available upon reasonable request from the corresponding author.

Supporting information

The Supporting information associated with this article is available with the online version.

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