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Human dimensions of human–lion conflict: a pre- and post-assessment of a lion conservation programme in the Okavango Delta, Botswana

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Summary

Humans are contributing to large carnivore declines around the globe, and conservation interventions should focus on increasing local stakeholder tolerance of carnivores and be informed by both biological and social considerations. In the Okavango Delta (Botswana), we tested new conservation strategies alongside a pre-existing government compensation programme. The new strategies included the construction of predator-proof livestock enclosures, the establishment of an early warning system linked to GPS satellite lion collars, depredation event investigations and educational programmes. We conducted pre- and post-assessments of villagers' livestock management practices, attitudes towards carnivores and conservation, perceptions of human–carnivore coexistence and attitudes towards established conservation programmes. Livestock management levels were low and 50% of farmers lost livestock to carnivores, while 5–10% of owned stock was lost. Respondents had strong negative attitudes towards lions, which kill most depredated livestock. Following new management interventions, tolerance of carnivores significantly increased, although tolerance of lions near villages did not. The number of respondents who believed that coexistence with carnivores was possible significantly increased. Respondents had negative attitudes towards the government-run compensation programme, citing low and late payments, but were supportive of the new management interventions. These efforts show that targeted, intensive management can increase stakeholder tolerance of carnivores.

Introduction

Around the globe, large-carnivore conservation is typically in conflict with human activities, and the way these conflicts are framed can impact human–wildlife coexistence (Treves & Karanth 2003, Woodroffe et al. 2005a, Peterson et al. 2010, Redpath et al. 2013). Most studies of human–wildlife conflict focus on the impacts of wildlife on human livelihoods (e.g., livestock depredations, crop losses or property damage); however, some argue that discussions around these conflicts should be reframed (Peterson et al. 2010). Definitions of 'conflict' centre around human disagreements about incompatible goals and interference in achieving them (Peterson et al. 2010); this precludes wildlife from consideration as party to a conflict, and depicting wildlife as 'conscious human antagonists' can be detrimental (Peterson et al. 2010, Redpath et al. 2015). Young et al. (2010) suggest human–wildlife conflicts be split into two categories: human–wildlife impacts (HWIs), which focus on the impacts of wildlife on humans and their activities (or vice versa); and human–human conflicts about wildlife. This shift has not gained much traction; most published literature has not changed the way these issues are framed (Redpath et al. 2015).

HWIs between large carnivores and humans are well documented; carnivores can kill livestock and people, while people use lethal control methods to minimize carnivores' impacts on their livelihoods (Woodroffe 2001). Humans are responsible for substantial carnivore population declines and range contractions (Woodroffe 2001, Ripple et al. 2014). Those with livelihoods linked to livestock (e.g., food, clothing, income) are least likely to tolerate carnivores (Mishra 1997, Patterson et al. 2004, Frank et al. 2005). Fear, threat of livestock loss and actual losses can all lead to lethal carnivore control (Naughton-Treves & Treves 2005), thus social factors significantly impact carnivore conservation (Treves & Karanth 2003). Generally, these factors include: people's attitudes and behaviours towards carnivores; costs to people coexisting with carnivores; and benefits that act as incentives for people to coexist with carnivores (Winterbach et al. 2013). Incorporating these factors when developing carnivore management plans is vital, as negative attitudes towards these species can hinder conservation initiatives

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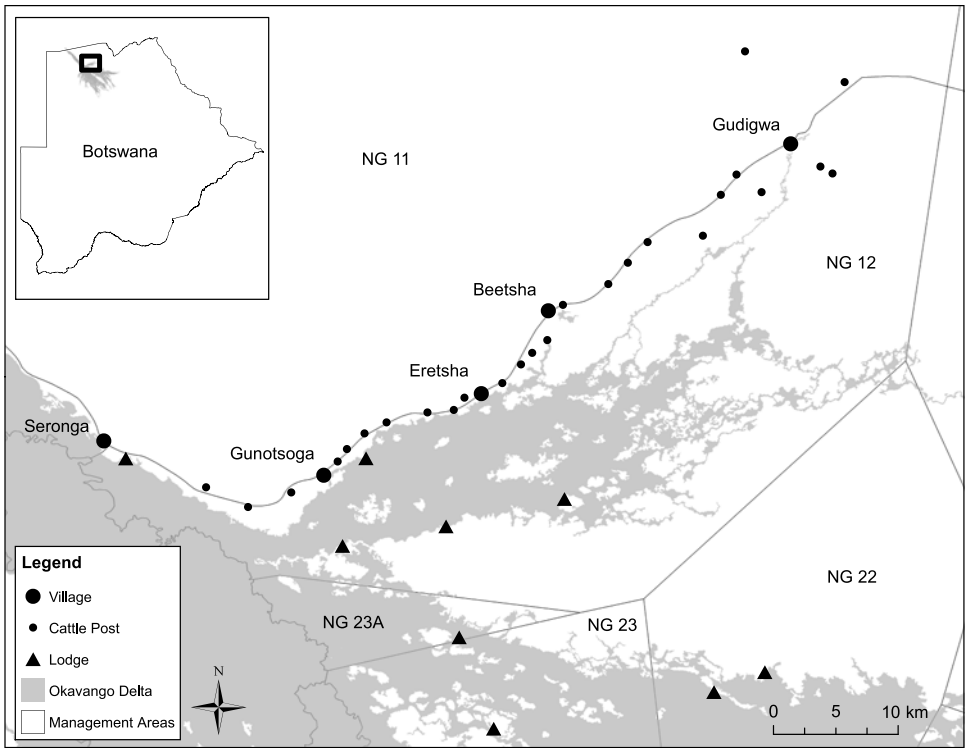

Fig. 1. Study area map showing villages, cattle posts, safari lodges and government-defined management area boundaries. NG = Ngamiland.

(Mishra et al. 2003, Naughton-Treves et al. 2003). Solutions that minimize negative HWIs, increase local stakeholder tolerance of carnivores and cultivate coexistence between people and wildlife are needed (Treves & Karanth 2003, Treves & Bruskotter 2014, Redpath et al. 2015, van Eeden et al. 2018).

Views towards wildlife are often determined by the species' value as a resource (Lamarque et al. 2009). If a species has no monetary value to local stakeholders, it may garner negative attitudes (Mbaiwa et al. 2008, Lamarque et al. 2009). While local opinions of problem carnivore species vary (Li et al. 2015), positive attitudes are associated with lower monetary losses from predation (Dickman 2005), benefits received from ecotourism (Lindsey et al. 2005, Hemson et al. 2009) and increased levels of education and wealth (Naughton-Treves et al. 2003, Zimmermann et al. 2005). Communication of benefits associated with a species, and ways to avoid risk, can lead to increased tolerance and positive perceptions of carnivores (Bruskotter & Wilson 2014). Generally, local community members have low carnivore tolerance levels (Kansky et al. 2014, Inskip et al. 2016). This low tolerance, fuelled by actual and perceived impacts, is regularly exhibited through lethal control practices and contributes to carnivore population declines (Naughton-Treves & Treves 2005, Woodroffe et al. 2005b).

In Botswana, the government established a compensation programme to encourage coexistence with carnivores (Department of Wildlife and National Parks 1998, 2013); it reimburses farmers for losses to carnivores of conservation concern. In the eastern Panhandle of the Okavango Delta, high levels of livestock depredation by wild carnivores in 2013, especially lions (*Panthera leo*), caused villagers to kill *c.* 30–50% of the local lion population (LeFlore et al. 2019, LeFlore 2020). These killings, via retaliatory shooting and poisoning events, served to both eliminate problem individuals and prevent future attacks. In 2014, we developed a multipronged management programme aimed at both lion conservation and minimizing negative HWIs on local stakeholders. This programme established technical solutions and interventions with the goal of bridging the gap between the needs of wildlife and the needs of humans. The management programme independently investigated livestock losses, established a predator-proof livestock enclosure building programme, designed a novel early warning system linked to lion satellite GPS collars, monitored the local lion population and shared information about lions with villagers at schools and village meetings where lions were given local names (see Weise et al. 2018, 2019, LeFlore et al. 2019, LeFlore 2020). We conducted in-person interviews before and after these management interventions were established. Interviews investigated local farmers' livestock management practices, attitudes towards carnivores and conservation, perceptions of HWIs and attitudes towards the established conservation programmes. Given high levels of predation, we hypothesized that respondents had negative attitudes towards carnivores, livestock received little supervision and respondents disapproved of the government's compensation programme (Gusset et al. 2009, Hemson et al. 2009, LeFlore et al. 2019). We expected respondents to support the new management programme but that their tolerance for carnivores would only marginally increase, as factors that affect tolerance and attitudes are complex (Dickman & Hazzah 2016).

Study area

This study was conducted in northern Botswana within the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA), an area of critical importance for lion conservation (Funston 2014). The KAZA TFCA is *c.* 440 000 km^2, spans five countries, includes 36 protected areas and is home to one of the largest lion populations in Africa (*c.* 3500 lions; Funston 2014), classifying it as a lion stronghold (Riggio et al. 2013). We focused on the eastern panhandle of the Okavango Delta (Fig. 1), a seasonally flooded wetland (McCarthy et al. 2000, Kgathi et al. 2006) that connects the Delta to the rest of the KAZA TFCA and supports

people, their livestock and plentiful wildlife (Ramberg et al. 2006, Fynn et al. 2015).

Our research encompassed government-defined management areas that were slated for uses ranging from human habitation and natural resource consumption (Ngamiland (NGs) 11 and 12) to wildlife management and community/internationally run ecotourism (NGs 22, 23 and 23A) (Figure 1). Hunting is not allowed as Botswana imposed a national hunting ban in 2014 (Mbaiwa 2018). Four ethnic groups inhabit NGs 11 and 12 (Bakgaladadi, Bambukushu, Basarwa and Bayei) and speak four languages (Sekgaladi, Sembukushu, Sesarwa and Seyei). Most people also speak Setswana, one of two national languages in Botswana. English, the second, is not widely spoken.

Villagers are agropastoralists, keeping livestock (cattle, *Bos taurus*/*Bos indicus*; goat, *Capra hircus*; horse, *Equus caballus*; and donkey, *Equus asinus*) and tending crops during the growing season (typically December–April). Livestock are typically protected overnight in traditional thorn branch or wooden post enclosures, referred to locally as '*kraals*' (LeFlore et al. 2019). People live in villages and smaller familial settlements (cattle posts (CPs)). This study included four focal villages (Beetsha, Eretsha, Gudigwa and Gunotsoga) and associated CPs due to high levels of livestock depredation and proximity to critical lion habitat; there were *c.* 700–1600 people/village (total *c.* 4000) (Botswana Population and Housing Census 2011).

Methods

We conducted 409 structured interviews across focal villages in October–December 2014 and October–December 2016 (initial n = 201, follow-up n = 208). Respondents were organized by where they lived, either village centre (VC) or CP. Adult (ages ≥18 years) male and female respondents were opportunistically selected. We attempted to speak with heads of households, capturing the most influential opinions. Interviews were conducted in English and translated into a local language by native speakers MT and TCD, depending on respondent preference. We resampled the 2014 respondents during follow-up surveys in 2016 (resample rate = 65%). When circumstances made this impossible (e.g., death, remote employment, refusal), we selected additional respondents, maintaining similar sample sizes. New and repeat respondent data were pooled as management treatments were applied across all villages. In addition, no significant differences were found between key demographic characteristics or attitude metrics when compared via two-tailed Pearson's χ^2 tests and t-tests (Supplementary Table S1, available online).

Interviews comprised open- and close-ended questions with opportunities for additional explanation. Questions focused on the following: demographics; livestock husbandry techniques; livestock losses; attitudes towards carnivores; perceptions of wildlife, conservation and HWIs; attitudes towards the government compensation programme; and attitudes towards new management interventions (Table S2). Respondents were informed that responses were confidential, participation was voluntary and answering all questions was not mandatory. Initial interviews lasted 47 minutes on average (range 20–156 minutes, median 45 minutes) and follow-up interviews lasted 27 minutes (range 11–74 minutes, median 28 minutes). Results were analysed using tolerance scores, descriptive statistics, χ^2 and t-tests through R statistical software (R version 3.5.1; R Core Team 2018). Tolerance scores were calculated based on responses to questions regarding respondents' attitudes towards carnivores and the government-run compensation programme using a five-point Likert scale. Responses ranged from 'strongly dislike/approve' to 'strongly like/disapprove', and mean tolerance/approval scores were obtained by assigning values ranging from −2 to +2 to these responses.

Results

Respondent demographics

There were 201 initial (100 VC, 101 CP) and 208 follow-up (111 VC, 97 CP) interviews conducted across the four villages, with totals per village (VC and CP) ranging from 47 to 56 (Tables S3 & S4). More men than women were interviewed in both rounds (initial 69%, n = 139; follow-up 71%, n = 148), with most respondents being heads of their household (65%, n = 131; 63%, n = 131), which included seven people/household on average. Based on the Botswana Population and Housing Census (2011), projected national population growth rates (World Bank 2016) and respondents speaking for approximately seven people, we estimate our samples represented *c.* 30% of the total population in the area. Most respondents from the two rounds had either received no education (43%, n = 87 and 37%, n = 76, respectively) or attended secondary school (37%, n = 74 and 36%, n = 75, respectively). Most respondents owned livestock (71%, n = 143 and 82%, n = 171, respectively).

Perceptions of wildlife and conservation

Most initial respondents (75%, n = 151) believed there was more wildlife than 10 years before and that livestock predation levels were increasing (79%, n = 159). Only 18% (n = 36) of respondents thought coexistence with carnivores was possible, and 87% (n = 174) believed livestock were lions' most favoured prey. More CP respondents believed livestock were a lion's top prey choice than VC respondents (n = 93 versus 81, $\chi^2 = 4.39$, p = 0.036). When asked about ways to improve coexistence, respondents suggested minimizing interactions by keeping carnivores separate from people/livestock (25%, n = 50), keeping carnivores in national parks (13%, n = 27), keeping carnivores within fences (10%, n = 21), removing carnivores altogether (8%, n = 15) or that improvement was impossible (8%, n = 16).

Most initial respondents (83%, n = 167) claimed not to use lethal control to manage HWIs, although 47% of farmers (n = 67) stated they had zero tolerance of livestock depredations (i.e., after one event they would retaliate, killing offenders). Only two individuals (1%) cited killing predators to control HWIs. When asked about their knowledge of other villagers' use of lethal control within the last year, four individuals (2%) reported a total of four separate instances of individual lion killings. In the follow-up surveys, 6% (n = 12) of respondents reported using lethal control methods to manage HWIs; 3% (n = 7) reported they knew of a total of seven lions, four spotted hyenas and eight African wild dogs killed by villagers in the previous year.

Most initial respondents (87%, n = 174) believed national parks are good, citing income for the government (95%, n = 191), protecting wildlife for future generations (94%, n = 189), keeping wildlife from livestock (87%, n = 175) and reducing HWIs (81%, n = 163) (Table 1). A third believed national parks take land from people (37%, n = 74) or livestock (35%, n = 70), and half thought they take land from hunting (49%, n = 99).

While more initial respondents believed wildlife benefitted them (56%, n = 112, $\chi^2 = 4.00$, p = 0.046) and supported the national hunting ban (66%, n = 132, $\chi^2 = 23.59$, $p < 0.001$), VC and CP respondents' views were dissimilar. More VC respondents believed wildlife benefitted them (72%, n = 72 versus 40%, n = 40,

Table 1. Percentages of 'yes' responses (numbers of respondents in parentheses) to questions of conservation importance from initial surveys in 2014 (VC n = 100, CP n = 101, total n = 201) and follow-up surveys in 2016 (VC n = 111, CP n = 97, total n = 208) by location with associated χ^2 tests for homogeneity.

Question	VC	CP	χ^2	P-value	Total	χ^2	P-value
2014							
Is there more wildlife now than 10 years ago?	77 (77)	73 (74)	0.20	0.654	75 (151)	66.02	<0.001*
Do you have a family member who has a job associated with wildlife?	35 (35)	27 (27)	1.25	0.262	31 (62)	28.26	<0.001*
Believe level of human–carnivore impact is increasing	70 (70)	88 (89)	8.91	0.003*	79 (159)	203.94	<0.001*
Believe coexistence with carnivores is possible	26 (26)	10 (10)	7.80	0.005*	18 (36)	81.92	<0.001*
Believe domestic prey are a lion's top food choice	81 (81)	93 (92)	4.39	0.036*	87 (174)	117.88	<0.001*
Do you believe that national parks are good?	87 (87)	86 (87)	<0.001	1.000	87 (174)	124.48	<0.001*
Do you think national parks generate money for the government?	95 (95)	95 (96)	<0.001	1.000	95 (191)	182.19	<0.001*
Do national parks protect wildlife for future generations?	95 (95)	93 (94)	0.08	0.780	94 (189)	171.74	<0.001*
Do national parks keep wildlife away from livestock?	84 (84)	90 (91)	1.16	0.281	87 (175)	123.21	<0.001*
Do national parks decrease interactions between livestock and wildlife?	82 (82)	80 (81)	0.02	0.884	81 (163)	91.65	<0.001*
Do national parks take land away from people?	27 (27)	47 (47)	7.42	0.006*	37 (74)	10.91	<0.001*
Do national parks take land away from livestock?	29 (29)	41 (41)	2.49	0.115	35 (70)	14.55	<0.001*
Do national parks take land away from hunting?	44 (44)	54 (55)	1.80	0.180	49 (99)	0.13	0.719
Does wildlife benefit you?	72 (72)	40 (40)	20.08	<0.001*	56 (112)	4.00	0.046*
Do you support the national hunting ban?	75 (75)	56 (57)	6.88	0.008*	66 (132)	23.59	<0.001*
It is illegal to collect firewood in national parks?	76 (76)	88 (89)	4.23	0.040*	82 (165)	95.34	<0.001*
2016							
Believe level of human–carnivore impact is increasing	70 (78)	78 (76)	1.36	0.243	74 (154)	155.81	<0.001*
Believe coexistence with carnivores is possible	31 (34)	26 (25)	0.39	0.535	28 (59)	36.92	<0.001*
Do you have a family member who has a job associated with wildlife?	51 (56)	39 (38)	2.22	0.136	45 (94)	1.92	0.166
Does wildlife benefit you?	88 (98)	74 (72)	5.95	0.015*	82 (170)	85.45	<0.001*
Do you support the national hunting ban?	67 (74)	62 (60)	0.33	0.563	64 (134)	17.31	<0.001*
Seen predator-proof *kraals*	99 (89)	90 (87)	2.90	0.088	89 (186)	129.31	<0.001*
Believe predator-proof *kraals* are more secure than traditional *kraals*	81 (90)	84 (81)	0.08	0.784	82 (171)	126.15	<0.001*
Farmers who want a predator-proof *kraal*	90 (73)	88 (79)	0.06	0.808	89 (152)	127.01	<0.001*
Farmers interested in building a predator-proof *kraal* for themselves	62 (50)	63 (57)	<0.01	0.954	63 (107)	16.69	<0.001*
Farmers who received a lion alert	32 (26)	40 (36)	0.84	0.361	36 (62)	12.92	<0.001*
Believe lion alerts are beneficial	79 (88)	82 (80)	0.17	0.684	81 (168)	145.45	<0.001*
Know at least one lion's given local name	44 (49)	39 (38)	0.34	0.559	42 (87)	5.26	0.022*
Claim project efforts have increased their tolerance of lions	38 (42)	62 (60)	11.01	<0.001*	49 (102)	0.89	0.347
Farmers who have changed their husbandry practices	68 (55)	71 (64)	0.08	0.773	70 (119)	34.51	<0.001*
Perceive lions as a problem	80 (74)	88 (85)	10.20	0.001*	80 (167)	77.92	<0.001*

Follow-up surveys also included questions regarding the established management interventions. Total percentage 'yes' responses (number of respondents in parentheses) and associated χ^2 goodness of fit tests also shown.
*Significant p-values.
CP = cattle post; VC = village centre.

$\chi^2 = 20.08$, $p < 0.001$) and supported the hunting ban (75%, n = 75 versus 56%, n = 57, $\chi^2 = 6.88$, $p = 0.008$) (Table 1). Conversely, more CP respondents (47%, n = 47; VC 27%, $\chi^2 = 7.42$, $p = 0.006$) believed national parks take land from people and held more negative views towards carnivores. More CP respondents believed livestock predation was increasing (88%, n = 89 versus 70%, n = 70, $\chi^2 = 8.91$, $p = 0.003$), and fewer believed coexistence was possible (10%, n = 10 versus 26%, n = 26, $\chi^2 = 7.80$, $p = 0.005$).

As with initial surveys, more VC follow-up respondents believed wildlife benefitted them compared to CP respondents (88%, n = 98 versus 74%, n = 72, $\chi^2 = 5.95$, $p = 0.015$) (Table 1). In general, more follow-up respondents believed wildlife benefitted them (82%, n = 170, $\chi^2 = 85.45$, $p < 0.001$) (Table 1), a significant increase from initial surveys ($\chi^2 = 31.1$, $p < 0.001$) (Table 2). Respondents who supported the hunting ban remained constant between initial and follow-up surveys (66%, n = 132 versus 64%, n = 134, $\chi^2 = 0.03$, $p = 0.872$), as did those who believed that livestock depredations were increasing (79%, n = 159 versus 74%, n = 154, $\chi^2 = 1.19$, $p = 0.275$ (Table 2).

Livestock husbandry

In initial surveys, only 6% (n = 8) of livestock owners paid a herder to guard livestock, 7% (n = 10) had children herd livestock and 1%

Table 2. Comparison by χ^2 tests for homogeneity for key questions involving wildlife, conservation and livestock management from initial surveys in 2014 and follow-up surveys in 2016.

Question	2014	2016	χ^2	P-value
All respondents				
Believe wildlife benefits them	56 (112)	82 (170)	31.10	<0.001*
Have family member who has a job associated with wildlife	31 (62)	45 (94)	8.32	0.004*
Support the hunting ban	66 (132)	64 (134)	0.03	0.872
Believe number of livestock predation events is increasing	79 (159)	74 (154)	1.19	0.275
Believe coexistence with carnivores is possible	18 (36)	28 (59)	5.69	0.017*
Livestock owners				
Kraal livestock at night	96 (137)	88 (150)	5.49	0.020*
Kraal livestock every night	60 (85)	69 (116)	2.03	0.154
Pay a livestock herder	6 (8)	6 (10)	<0.01	1.000
Have a child herd livestock	7 (10)	14 (24)	3.30	0.069
Always have herder with livestock	1 (2)	8 (13)	5.30	0.021*
Lost livestock to carnivores	50 (72)	46 (79)	0.38	0.535

Percentages of respondents who answered 'yes' shown (numbers of respondents in parentheses). All respondents answered questions about wildlife and conservation (2014 n = 201, 2016 n = 208), while only livestock owners answered questions about livestock management (2014 n = 143, 2016 n = 171).
*Significant p-values.

Table 3. Mean tolerance/approval scores by location for initial surveys in 2014 (VC n = 100, CP n = 101, total n = 201) and follow-up surveys in 2016 (VC n = 111, CP n = 97, total n = 208) with associated t-statistics.

	Initial						Follow-up						Comparison	
Question	VC	CP	t	P-value	Total	σ	VC	CP	t	P-value	Total	σ	t	P-value
Tolerance of lions	−0.60	−0.97	2.57	0.011*	−0.79	1.03	0.10	−0.39	3.10	0.002*	−0.13	1.16	−6.04	<0.001*
Tolerance of lions being close to villages	−1.37	−1.69	3.46	<0.001*	−1.53	0.67	−1.32	−1.59	1.99	0.048*	−1.45	0.98	−0.97	0.333
Tolerance of predators	−0.09	−0.77	4.54	<0.001*	−0.45	1.11	0.07	−0.15	1.45	0.15	−0.03	1.08	−3.70	<0.001*
Approval of compensation programme	−0.01	−0.17	0.82	0.413	−0.09	1.34	NA							

Further comparison by t-statistic of total mean tolerance scores between initial and follow-up surveys also shown.
*Significant p-values.
CP = cattle post; VC = village centre.

(n = 2) always had a herder with livestock (Table 2). Most livestock owners reported *kraaling* livestock at night (96%, n = 137), but only 60% (n = 85) reportedly *kraal* livestock every night. Most (76%, n = 109) livestock owners were willing to modify husbandry practices to minimize depredations. Some 50% (n = 72) of livestock owners lost livestock to carnivores in the year before initial surveys and 46% (n = 79) lost livestock during the study. Initial respondents owned 3611 livestock and follow-up respondents owned 3383 livestock, with cattle being the most prevalent livestock in the area (Table S5). In the year leading up to the initial surveys, respondents reported that 10% (n = 371) of owned livestock were killed by carnivores. This number declined during the study as respondents reported losing 5% (n = 181) of livestock, with lions responsible for 75% of those losses. According to government valuation of livestock by national average market value (Department of Wildlife and National Parks 2013), livestock killed by carnivores in the year before the initial surveys were valued at *c.* US$97,000, and during the study killed livestock were valued at *c.* US$47,000 (Table S6).

While fewer respondents reported *kraaling* their livestock at night during the study (88% (n = 150), down from 96% (n = 137), $\chi^2 = 5.49$, p = 0.02), more *kraaled* their livestock every night (60% (n = 85) to 69% (n = 116), $\chi^2 = 2.03$, p = 0.154). Respondents who paid a herder remained constant (6% (n = 8) to 6% (n = 10)); respondents who had children herd livestock (7% (n = 10) to 14% (n = 24), $\chi^2 = 3.30$, p = 0.069) and always had a herder with livestock (1% (n = 2) to 8% (n = 13), $\chi^2 = 5.3$, p = 0.021) increased.

Tolerance/approval scores

Initial surveys yielded a tolerance score for lions of –0.79 (σ = 1.03) (Table 3), with 61% (n = 123) of respondents having negative attitudes. Initial survey respondents were less tolerant of having lions close to the village (tolerance score = –1.53, σ = 0.67), with 94% (n = 189) of respondents having negative attitudes. Respondents were slightly more tolerant of predators in general, with 48% (n = 96) having negative attitudes (tolerance score = –0.45, σ = 1.11). For these metrics, CP respondents had significantly more negative attitudes than VC respondents.

Overall, 59% (n = 118) of respondents had negative attitudes towards the government-run compensation programme (approval score = –0.09, σ = 1.34) (Table 3), with 84% (n = 99) citing low and slow payments as reasons for dissatisfaction. There was no significant difference in approval scores between VC and CP. Initial survey respondents were asked about their interest in a potential non-government livestock insurance. A total of 90% (n = 129) of livestock owners were interested and 86% (n = 111) were willing to pay to participate; however, they were unwilling to pay enough to sustain the programme, with 69% (n = 76) only willing to pay less than *c.* US$25 annually (BWP250, range US$10–600, mean US$46; US$1 = BWP10, July 2015).

Follow-up respondents were more tolerant of lions and carnivores than initial respondents, with tolerance scores increasing to –0.13 (σ = 1.16, t = –6.04, p < 0.001) and –0.03 (σ = 1.08, t = –3.70, p < 0.001), respectively (Table 3). There was no significant difference in tolerance of lions near villages (tolerance score = –1.45, σ = 0.98, t = –0.97, p = 0.333). CP respondents continued to have stronger negative attitudes towards lions and having lions near villages than VC respondents.

Management programme perceptions

Follow-up respondents had positive views of the established management programme. Most had seen the predator-proof *kraals* (89%, n = 186) and believed they were more secure than traditional *kraals* (82%, n = 171). Most livestock owners (89%, n = 152) wanted their own *kraal*, with 63% (n = 107) interested in building one, citing limited time and resources as impediments. Only 36% of farmers (n = 62) had received a lion alert, but most believed alerts were beneficial (81%, n = 168). A total of 42% of respondents (n = 87) knew the local name of at least one lion. Half (49%, n = 102) believed management interventions increased their lion tolerance, with a more significant increase occurring with CP respondents ($\chi^2 = 11.01$, p < 0.001). Most livestock owners (70%, n = 119) reported changing husbandry practices due to the programme, increasing the frequency of *kraaling*. Despite these positive trends, 80% of respondents (n = 167) still perceived lions to be problematic.

Discussion

Livestock husbandry and losses

Limited livestock supervision, which contributes to predation levels in northern Botswana, likely results from complacency following the establishment of the government compensation programme and a declining herding culture (Breitenmoser et al. 2005, Dickman et al. 2011). Children attend school and are unable to tend livestock, villagers state that herding is looked down upon as a profession and farmers do not have the resources to pay herders. These circumstances, along with growing human and livestock populations, have led to increased livestock depredation (Messmer 2000, Krafte Holland et al. 2018). Improved livestock management methods minimize HWIs and help decrease the number of carnivore killings (Ogada et al. 2003, Treves & Karanth 2003, Woodroffe et al. 2007), and future efforts to prevent predation should focus on improving livestock management and educating farmers about the

benefits of better livestock management (Eklund et al. 2017, Krafte Holland et al. 2018).

Initial reports that 10% of livestock were lost to carnivores in 1 year were above levels elsewhere (0.02–5.50%; Kruuk 1980, Karani 1994, Frank 1998, Patterson et al. 2004, Graham et al. 2005, Kolowski & Holekamp 2006, Hemson et al. 2009). This is likely due to unusually high levels of predation prior to the study (LeFlore et al. 2019), overstatement of actual losses (purposefully or due to recall bias) (Tarrant et al. 1993) and/or negative attitudes/perceptions of carnivores (Dickman 2010, Dickman et al. 2014). Depredation levels over the 2-year span between surveys (5%) were in line with the trends noted above. This reduction could be caused by stronger management practices resulting from the established programme, a decline in the local lion population as a result of retaliatory killings in 2013 and/or more awareness of the issues during the study. Losses claimed here were reported through an interview process and potentially influenced by response or recall bias. However, both perceived costs and actual losses impact attitudes and perceptions of local stakeholders, all directly affecting conservation (Dickman & Hazzah 2016). Although overall levels of loss may have been overestimated, our independent investigations confirmed what villagers reported here – lions were responsible for 75% of livestock losses (LeFlore et al. 2019).

Attitudes towards carnivores

CP respondents had more negative perceptions of wildlife, conservation and HWIs than VC respondents. CP residents typically have fewer resources, less access to education (Lagendijk & Gusset 2008, Gebresenbet et al. 2018), live more remotely, own more livestock and are more likely to have negative interactions with carnivores, contributing to negative attitudes (Zimmerman et al. 2005). Even though respondents generally had low tolerance of carnivores, only 6% or less reported using lethal control to manage HWIs, which is lower than another study in Botswana, where *c*. 12% had attempted to kill a lion (Hemson et al. 2009). Given previous retaliatory killings and poisoning events in 2013 (LeFlore et al. 2019), this low level is unlikely; respondents may have been reluctant to share information because carnivore killing is illegal (Cross et al. 2013). We therefore utilized projective questioning to ask people about others' behaviour, in addition to their own (Cross et al. 2013). While the effects and frequency of carnivore killings in northern Botswana are still largely unknown (Gusset et al. 2009), they were significant in East Africa (Woodroffe & Frank 2005), where 19 out of 20 collared lions were lost in retaliatory killings. Investigation into lethal control of lions and other carnivores in the Delta is required.

Half of all farmers had lost livestock to carnivores and *c*. 90% of respondents believed a lion's top prey choice was livestock. Actual losses to and perceived costs of carnivores contribute to local stakeholders' negative attitudes (Naughton-Treves 1997, Naughton-Treves et al. 2003). These real and perceived costs likely contribute to the belief that coexistence with lions is impossible. We suggest that the government-run compensation programme alone has not effectively changed villagers' willingness to coexist with carnivores and requires modification (Gusset et al. 2009).

Management programme efficacy

While farmers were willing to participate, a non-governmental insurance programme proved infeasible. Farmers were only willing to pay a minimal premium, so a continued significant external investment would be required (Nyhus et al. 2003, 2005, Dickman et al. 2011). Management strategies are likely only popular and effective if community costs are kept to a minimum. Our results suggest that intensive management programmes, established here alongside government compensation, can positively impact tolerance of carnivores. We posit that an expansion and streamlining of the lion alert programme, along with increased levels of herding, could greatly reduce livestock losses in the area and help increase tolerance further. Tolerance scores significantly increased, although respondents continued to have negative attitudes towards carnivores, albeit response bias may have influenced these reported attitudes. However, this was unlikely, as respondents maintained strong negative attitudes towards lions near their village, while general attitudes towards lions significantly increased. Conservation efforts encouraging human–carnivore coexistence typically target reducing livestock depredation, providing economic incentives for coexistence and/or improving tolerance through education (Western et al. 2019). The management efforts discussed here, alongside government compensation, address the targets mentioned above while supporting the effectiveness of a multipronged approach to promoting coexistence with carnivores (Western et al. 2019). Increased local stakeholder tolerance of and coexistence with carnivores can be achieved through intensive, interdisciplinary and locally tailored management actions (Dickman 2010, Dickman et al. 2011, Treves & Bruskotter 2014).

Conclusion

While tolerance levels increased over the course of our study, negative attitudes persisted and likely impede coexistence with carnivores in the Okavango Delta and KAZA TFCA (Mishra et al. 2003, Naughton-Treves & Treves 2005, Funston 2014). Both real and perceived costs contribute to negative attitudes. Addressing these attitudes should be central to future conservation efforts, and understanding site-specific HWIs is necessary before implementing mitigation strategies (Woodroffe et al. 2007, Dickman et al. 2011). The governmental compensation programme alone does not fully address HWIs or negative attitudes towards carnivores (Dickman et al. 2011) and requires revision. Understanding the viewpoints of people affected by HWIs is integral to the development and assessment of conservation management strategies.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S0376892920000120.

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