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SPECIAL ISSUE: DOGS AND CONSERVATION: CURRENT AND EMERGING CONSIDERATIONS

Every dog has its day: indigenous Tswana dogs are more practical livestock guardians in an arid African savanna compared with their expatriate cousins

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Abstract. Livestock guarding dogs (LGDs) have been used for centuries to reduce depredation on livestock and, more recently, to facilitate the conservation of threatened carnivores. Conservation organisations in southern Africa promote the use of Anatolian shepherds as LGDs. However, livestock farmers in Botswana use a variety of breeds for this purpose, including local landrace "Tswana" dogs. Our study sought to test the overall effectiveness of these local breeds as LGDs. Irrespective of breed, all LGDs reduced livestock losses, with 47.9% of farmers experiencing no losses after obtaining a guarding dog. Owners with more LGDs, and LGDs of a single sex, had greater reductions in livestock losses. Anatolian shepherds displayed more behavioural problems than other breeds in our study. The health of LGDs was reliant on them receiving a balanced diet, and owners with fewer dogs reported fewer health issues. Moreover, Tswana guarding dogs were cheaper to purchase and feed than their purebred counterparts. Our results show that local landrace dogs can be considered a cheaper and more practical alternative to purebred LGDs for reducing livestock losses and for mitigating human-wildlife conflict in Botswana.

Key words: livestock guarding dogs, human-wildlife conflict, carnivore conservation, landrace, Botswana, Canis Africanis

Introduction

In areas where large carnivores and humans overlap, farmer-carnivore conflict is widespread. The resulting threats, both real and perceived, drive persecution of carnivores which threatens the survival of many species (Dickman 2010, Treves & Santiago-Ávila 2020). These threats are particularly acute for species that occur primarily outside of protected areas, and those that are also highly threatened with extinction, such as cheetahs (*Acinonyx jubatus*) and African wild dogs (*Lycaon*

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pictus). Repetitive livestock depredation can also cause considerable financial strain for farmers (Butler 2001, Holmern et al. 2007).

Some farmers use lethal-control in a bid to curb livestock losses, reduce carnivore numbers or merely in retaliation for past losses. Such practice can be common, such as in South Africa where 90% of farmers were reported to purposefully kill carnivores (van Niekerk 2010). In Botswana, it is legal for a farmer to defend their life or livelihood (e.g. livestock) using lethal means, so long as it is reported to the Department of Wildlife and National Parks within seven days (Botswana Government 1992). In general, lethal control is damaging to the environment (Graham et al. 2005, McManus et al. 2015) and has been found to have negligible effects on future livestock losses (Marker et al. 2003a, Fox & Papouchis 2005, McManus et al. 2015), especially through the "sinkhole effect" phenomenon (Stahl et al. 2001, Woodroffe & Frank 2005, Baker et al. 2008). These negative effects can be particularly profound when indiscriminate lethal control is used (McManus et al. 2015). In some areas, the extirpation of entire species has been witnessed, creating trophic cascades in the ecosystem with unexpected and sometimes severe ramifications (Berger 2006).

Ideally, measures taken to mitigate farmer-carnivore conflict should consider the widespread implications for both the humans and the wildlife involved – one that has minimal negative impacts on wildlife and one that is beneficial to the farmer. No one mitigation method is a panacea for all farms or all conflicts, as the effectiveness of each method or combination of methods depends on a complex array of factors (Hodkinson et al. 2007). However, it is thought that a combination of two or more mitigation techniques will usually result in a significant reduction in livestock losses (Fox & Papouchis 2005, Gehring et al. 2010). With proper management and effective mitigation methods in place, coexistence between farmers and carnivores is possible even at high human densities (Linnell et al. 2001).

One method that selectively targets the problem-causing carnivore, reduces livestock losses for extended periods, is cost effective, easy to source and implement, has minimal negative impacts on the environment and involves minimal harm or stress to the target species, is the use of livestock guarding dogs (Pfeifer & Goos 1982, Marker et al. 2003b, 2005, Macdonald & Baker 2004, Mitchell et al. 2004, Shivik 2004, 2006, Nyhus et al. 2005, Woodroffe & Frank 2005, Woodroffe et al. 2005, Gehring et al. 2010, Rigg et al. 2011, Thorn et al. 2012, van Bommel & Johnson 2012, Potgieter et al. 2013, Rust et al. 2013, Leijenaar et al. 2015, Treves et al. 2016, Allen et al. 2019, Kinka & Young 2019). LGDs can be characterised as dogs, regardless of their breed, that live full time with livestock and perform the function of actively deterring carnivores (Young et al. 2019). LGDs achieve this by interrupting the carnivores' hunting sequences, chasing carnivores away, alerting the herd to danger and by acting as a biocontrol measure (Linnell et al. 1996, Gehring et al. 2010, Allen et al. 2019, Drouilly et al. 2020).

Although the history of the use of LGDs worldwide has been well documented (Landry 1999, Rigg 2001, Gehring et al. 2010), few studies describe the modern use of LGDs outside formal placement programmes. The use of LGDs has been encouraged by carnivore conservation organisations since the 1970s as a tool to help protect carnivores from persecution and there are several organisations within Africa that conduct formal placement programmes (Landry 1999, Marker et al. 2005, Gehring et al. 2010, Potgieter et al. 2013, 2016). Monitoring the performance of these dogs, however, is somewhat biased due to the intensive training offered by these organisations. The expert training provided, and the fact that LGDs which do not perform well are swiftly removed from these programmes (Marker et al. 2005, Cheetah Outreach 2013, Whitehouse-Tedd et al. 2020) may bias these samples towards well-behaved LGDs. Considering that most farmers do not have access to these formal placement programmes, nor the finances to purchase or maintain the kinds of purebred dogs that they recommend, it is important to assess how LGDs are used outside of these programmes. Such an assessment would provide a greater understanding of the real-world applications of LGDs, and a chance to consider the use of LGDs as an ongoing, sustainable tool to mitigate farmer-carnivore conflict.

Historically, the use of LGDs in Botswana developed organically via a small number of farmers, rather than through the involvement of an outside organisation. These farmers selected dogs and implemented training and placement strategies based on their own experiences and knowledge. The first reference of LGDs in Botswana appear in

Horgan (2015) and Hovorka & Van Patte (2017). However, a small number of farmers were using LGDs in Botswana when Cheetah Conservation Botswana (CCB) began investigating the technique as a conflict mitigation tool in 2004 (R. Klein, pers. comm.). Consequently, the type of dog most often used for LGDs in Botswana are local, small-medium-sized, landrace dogs, referred locally as "Tswana" dogs (also referred to as "street dogs" or "Canis Africanis", Lord et al. 2014). In some cases, landrace dogs have been found to be effective LGDs if trained properly and fed well (Black & Green 1985, Coppinger et al. 1985, Ribeiro 2004, Gonzalez et al. 2012), but their effectiveness has never been quantified in Africa.

Smaller dogs, like Tswana dogs, are generally better suited for hot, arid conditions compared to larger LGD breeds, such as Anatolian shepherds, great Pyrenees or maremmas, which were originally bred to endure colder climates in Europe (Gehring et al. 2010, Hovorka & Van Patte 2017, Losey et al. 2020). Having small-sized LGDs may also minimise damage to livestock and wildlife, as small LGDs would be more likely to be submissive to livestock and could cause less damage to wildlife species if they develop hunting behaviours (Black 1981, Potgieter 2011). On the other hand, smaller LGDs may be more susceptible to attacks by carnivores and may not be suitable to guard against large or aggressive carnivores (Bangs et al. 2005, Urbigkit & Urbigkit 2010, Losey et al. 2020).

Anecdotal evidence from CCB indicated that these small, Tswana LGDs were outperforming their large, purebred counterparts as livestock guardians. Therefore, we aimed to identify the key components that make LGDs successful in Botswana by measuring the health and behaviour of the LGDs, determining the costs and benefits involved in owning LGD, investigating whether LGDs reduced livestock losses and whether they improved relationships between their owners and carnivores on their farms.

Material and Methods

Study area

Botswana is a semi-arid to arid country that is characterized by high temperatures and low, inconsistent rainfall with an annual mean of 425 mm (Statistics Botswana 2013a). The country has two distinct seasons, with higher temperatures and most of the rainfall falling in the summer months (November-February), and cooler temperatures and almost no rainfall during the rest of the year (Statistics Botswana 2013a). The majority of Botswana consists of the flat sandveld of the Kalahari Desert, which hosts a variety of savanna habitat that is dominated by thorn bush species such as black thorn *Senegalia mellifera*, camel thorn *Vachellia erioloba*, trumpet thorn *Catophractes alexandri*, buffalo thorn *Ziziphus mucronata* and devil thorn *Tribulus terrestris*. There are two distinct types of farming ventures in Botswana, commercial farms are generally large, fenced ranches, with large paddock sizes ranging from 10-2,000 hectares (Statistics Botswana 2013b). Traditional farming dominates the remaining agricultural landscape and is carried out on communal, unfenced land and is generally farmed in a subsistence manner (Fraser-Celin et al. 2017, Statistics Botswana 2019). Livestock on both commercial and communal farmlands are usually managed with very little human involvement (Muir 2010, Fraser-Celin et al. 2017). The majority of Botswana's farmers have small herds of cattle (< 50), goats and sheep and farm them in a subsistence manner on communal farms (Statistics Botswana 2019).

Questionnaire design and implementation

Questionnaires were designed to cover a range of aspects related to LGD breed, care, health, training and behaviour, farm management and livestock information, carnivore issues and attitudes related to conservation (a copy of the questionnaire is available in Appendix S1). An initial pilot study was conducted via a postal survey (n = 33) and interviews (n = 1) to increase readability, to improve the validity of the responses gained from the survey and to identify problems with the format (Frohlich 2001). Questionnaires were administered between May 2010 and May 2013. Due to the large region of study, a range of methods were used to increase maximum sample size. Postal surveys were chosen as the primary method of data collection, as research has suggested that postal surveys are ideal for investigating sensitive topics such as lethal predator control (Siemiatycki 1979). Postal surveys do, however, bias against people who are illiterate (McCluskey & Topping 2011). Therefore, in-person interviews and telephone interviews were also included. The questionnaire was constructed using mostly closed-ended questions to obtain quantitative data, and pre-formatted scales to increase readability (Frohlich 2001). Four-point Likert scales were used to avoid neutral answers, however "unknown" options were available for most questions to decrease the levels of non-response bias in individual questions (White et al. 2005). Translations were made from English into the two major written languages in the area (Setswana and Afrikaans) and the questionnaires were distributed in all three languages. All respondents had the right to decline to participate, had the details of the research explained to them a priori, and were anonymised in the analyses.

A total of 228 questionnaires were received from farmers across Botswana. However, we removed all pilot questionnaires (n = 34), repeat questionnaires (n = 23), those that answered only a small subset of the questions (n = 59), and those that clearly related to a pet dog and not LGD (e.g. respondent did not have any livestock, n = 6). A total of 106 questionnaires were used for analysis, representing 183 LGDs.

Data analysis

To determine a health care score for each LGD, farmers were asked to report on the number of health problems their LGD had, such as parasites and diseases. For each report a score of one was recorded, where no health problems were listed these were given a score of zero (range zero to three). Similarly, we created a discipline score based on the number of negative behaviours reported by the farmer with respect to chasing or injuring livestock, chasing or injuring game or not staying with the livestock herd (range zero to six).

Linear models (LM) using maximum likelihood were used to assess several predictor variables (breed, sex, diet, age group, number of LGDs owned by the farmer, parentage of the LGD (i.e. if parent dogs were LGDs or not) and the presence of herders during training) that were considered to influence either LGD health or behaviour. In the questionnaire farmers reported breed and also whether their dogs were crossed or not, and these were categorised into four groups: Anatolian shepherds including crosses (nine LGDs from four farmers), purebred dogs (greyhounds, pitbulls and one referred to as a "Staiker") including crosses (31 from 20 farmers), Tswana (124 from 75 farmers), and Tswana-cross (Tswana dogs crossed with any purebred, 20 from 11 farmers). For diet, the variety of foods listed by farmers in the diet of the LGDs was simplified to two categories: pap (maize meal) only, or a variety of food. For the age of LGDs, farmers were asked to report the age in one of five categories (< 18 months, 1.5-3 y, 3-6 y, 6-10 y, > 10 y) as recording an exact age proved difficult for farmers during the pilot study. If farmers had more than one dog, we included the number of dogs owned, but recorded data separately according to breed. In cases where multiple dogs were owned, sex was recorded as male, female or mixed (i.e. both males and females). Herder presence during training of the LGD was recorded (yes or no) and also whether the LGD's parents were LGDs or not (both parents' LGDs, LGD mother, LGD father or both pets). For our linear models we used breed, diet, age, the number of dogs and sex as potential predictors of health and breed, diet, age, the number of dogs, herder presence and parentage as potential predictors of behaviour (disciplinary problems). As the same farmer was used where multiple breeds were owned (n = 3), we initially included Farmer's ID as a random effect in our linear-mixed models, but the inclusion of this variable did not improve model fit and so was removed.

Farmers were asked to report on the average number of livestock lost annually before and after utilising LGD. We calculated a change in livestock loss by subtracting the loss after receiving an LGD from losses prior to obtaining an LGD. We considered whether breed, sex, the number of dogs, farm type (commercial or communal farms) and herd size (range 8-141) influenced the change in loss using a general linear model. Farmers were also asked whether they were more tolerant of carnivores since using LGD and whether they were less likely to use lethal control since using a LGD. We scored all yes answers as one and no answers as zero. A generalised linear model (GLM) with a binomial error distribution and logit link function was used to determine whether farm, breed and length of time using LGDs (range 2-28 years) and change in livestock loss, affected the probability of having an improved level of tolerance toward carnivores or a willingness to forego lethal control.

As there were missing data across the range of predictor and response variables in the questionnaires, we chose to use multiple imputation using the Amelia package (Honaker et al. 2011) to increase efficiency, and reduce the bias that can result from using case wise deletion. We ran five imputations for our dataset and used the Zelig Package in R (Choirat et al. 2017) to run our models. We used Akaike Information Criteria corrected for small sample size (AICc) for model selection using the first imputation for each model, but used all imputations for the final results of the top performing model. All models were checked to ensure that the assumptions were met and assessed for model fit by plotting residuals. All analyses were run in the R programming language (version 4.0.2, R Development Core Team 2017) and significance was set at $P < 0.05$.

We calculated the costs associated with owning an LGD which included purchase price, food, medical and other reported expenses. Whereby total food costs were stated by farmers who owned more than one LGD, the total costs were divided by the number of dogs owned. All monetary values are represented in US Dollars and were converted from Botswana Pula at a rate of BWP1 = USD0.11.

Results

The majority of the 106 farmers completed the questionnaires in Setswana (72.1%), while a smaller proportion were completed in English (23.5%) and Afrikaans (4.4%). Most farmers were from communal grazing areas (73.2%), while 23% were from commercial ranches and a small percentage of farmers (3.8%) did not state their farm type. Most of the questionnaires were completed by interview (48.1%), with the remaining done by post (36.8%) or telephone (15.1%).

A variety of carnivore species were present on the respondents' farms (e.g. cheetahs, lions *Panthera leo*, leopards *Panthera pardus*, African wild dogs) and black-backed jackals (*Canis mesomelas*) were ranked as the biggest problem-causing carnivore (77.6% of respondents reported them to be "causing problems" which could include anything from chasing, injuring or killing livestock or other domestic animals to damaging farm infrastructure). Apart from LGDs, several management methods that were believed to help minimise livestock losses were being utilised by the respondents, the most common being corralling (kraaling) livestock at night (50% of respondents), using herders (35.8%) and utilising lambing/kidding seasons (where lambs or kids are born only at a certain time each year rather than all year round (16%)).

Less than half of the 183 LGDs were reported to suffer from various health ailments (n = 79, 43.1%). The main health issues were parasites (23%) and physical injuries (13.5%) and several unclear causes (7%). Most of the physical injuries resulted from interactions with wildlife, primarily snakebites, porcupines (*Hystrix africaeaustralis*), hyaenas (*Parahyaena brunnea* and *Crocuta crocuta*) and monitor lizards (*Varanus niloticus*). There were significant effects of the quality of the diet and the number of LGDs owned by a farmer on the health score of LGDs (Table 1). Farmers who fed their LGDs a variety of food reported fewer health problems. Similarly, farmers with fewer LGDs reported fewer health problems (Fig. 1).

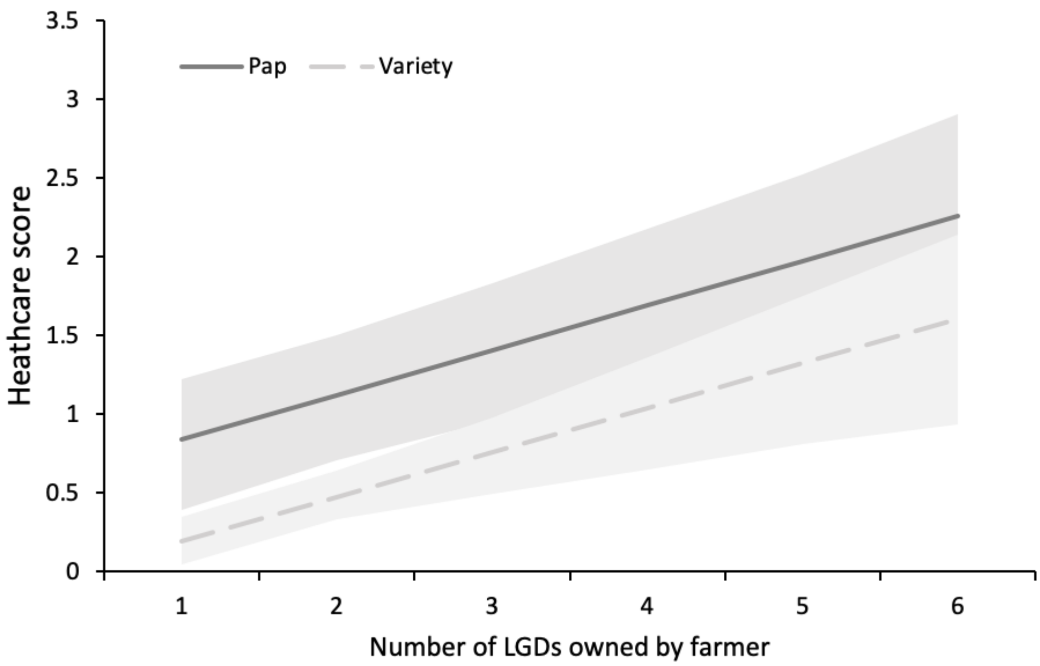

Fig. 1. The relationship between the number of LGDs owned by a farmer and LGD diet on the healthcare score (increasing health problems) reported by farmers. 95% confidence intervals are shown by shading.

Table 1. Results of the top performing Linear Model for determining key factors affecting the health score and discipline score of LGDs in Botswana.

Response	Predictors	Estimate	SE	z	*P*
Healthcare score	Intercept	0.50	0.23	2.20	0.03
	Diet – variety	–0.50	0.23	–2.21	0.03
	Number of dogs	0.21	0.09	2.40	0.02
Discipline score	Intercept	3.13	0.71	4.43	0.00
	Breed – pure	–2.19	0.77	–2.83	0.00
	Breed – Tswana	–2.26	0.71	–3.18	0.00
	Breed – Tswana cross	–1.92	0.82	–2.34	0.02
	Parent – LGD father	0.52	0.56	0.92	0.36
	Parent – LGD mother	0.67	0.49	1.36	0.17
	Parent – pet	–0.16	0.35	–0.46	0.64

LGDs showed a strong level of attentiveness, with 82.4% of farmers reporting the LGD stayed with the herd all of the time, 15.9% stayed most of the time and only 1.7% reporting occasionally staying with the herd. Despite LGDs remaining with the herd, 60.3% of the dogs were reported to show disciplinary problems. These behaviours included chasing or injuring livestock (25.7% often, 6.7% rarely) and chasing or injuring wildlife (13.4% often, 6.1% rarely). Our top-ranking model for the discipline scores showed that breed was a significant factor (Table 2). Farmers owning Anatolians reported significantly more behavioural problems than those who owned other purebreds, Tswana or Tswana-crosses (Fig. 2). In terms of the presence of aggressive guarding behaviours, 34.3% of respondents said that their LGDs attacked threatening carnivores. Other behaviours cited included barking (60.8% of LGDs), chasing (23.5%), bluff attacks (4.2%), herding the livestock (2.4%) and ignoring the threat (4.2%).

Farmers were asked to report on the purchase prices of their LGDs and to estimate the annual costs for their dogs (Table 3). The proportion of farmers who purchased their LGDs was low, with only 10.5% of Tswana-cross, 13.9% of Tswana and 50% of non-Tswana dogs (Anatolians or purebreds) being purchased. The vast majority of Tswana LGDs (85.2%) were either bred by the

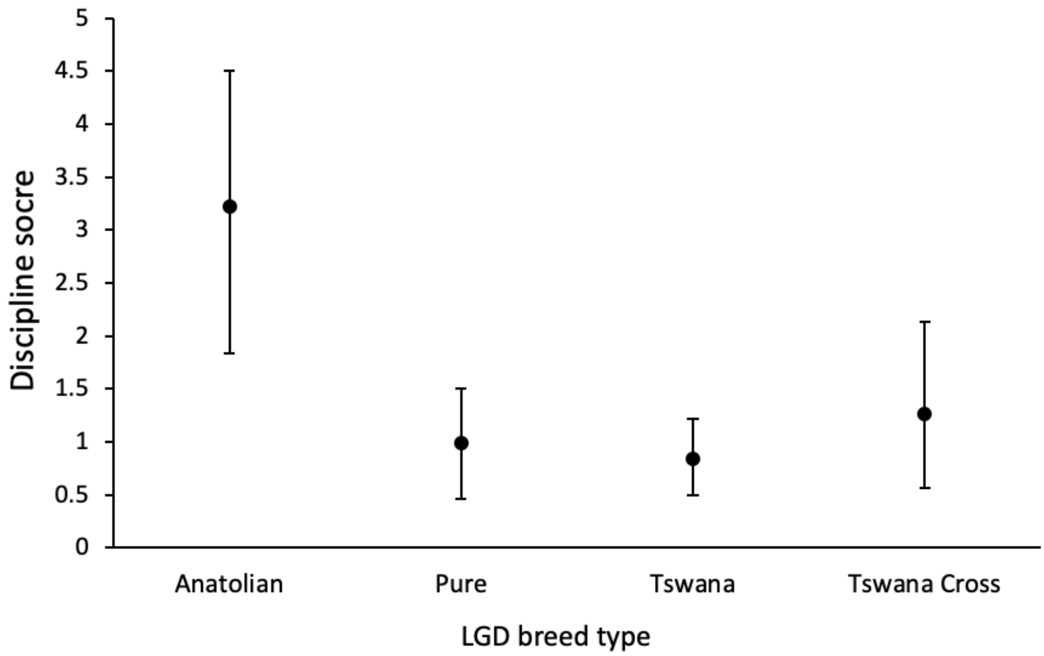

Fig. 2. Model expected relationship of LGD breed types with discipline score (95% confidence intervals) reported by the farmer.

Table 2. Results of the model selection analysis for Healthcare and Discipline models using Akaike Information Criteria (AIC).

Model	Model parameters	K	AICc	Delta AICc	Weight	LogLik
Healthcare score	Diet + number dogs	4	215.84	0	0.69	–103.73
	Diet + number dogs + breed	7	218.18	2.33	0.21	–101.55
	Diet + number dogs + age	8	221.31	5.46	0.04	–101.95
	Diet + number of dogs + sex	9	222.36	6.52	0.03	–101.29
	Diet + number dogs + breed + age	11	222.94	7.10	0.02	–99.14
	Number dogs	3	225.87	10.03	0	–109.83
	Diet + number dogs + age + sex	10	226.09	10.25	0	–101.94
	Diet + number dogs + breed + age + sex	13	227.68	11.84	0	–98.97
	Diet	3	229.67	13.82	0	–111.72
Discipline score	Breed + parent	8	388.32	0	0.28	–185.46
	Breed	5	388.44	0.12	0.26	–188.94
	Breed + sex	7	388.55	0.23	0.25	–186.73
	Breed + sex + parent	10	390.25	1.92	0.11	–184.02
	Breed + sex + parent + herder	11	392.02	3.70	0.04	–183.68
	Breed + sex + parent + number dogs	11	392.11	3.79	0.04	–183.72
	Breed + sex + parent + number dogs + herder	12	393.77	5.44	0.02	–183.29
	Breed + sex + parent + number dogs + herder + age	16	403.09	14.77	0	–182.65

owner themselves, given to the farmer or found by the famer and therefore purchase price was nil in these cases. Of those dogs that were purchased, Anatolians and purebred dogs were the most expensive dogs to purchase. Purebred and Tswana cross dogs were the most expensive LGDs to feed.

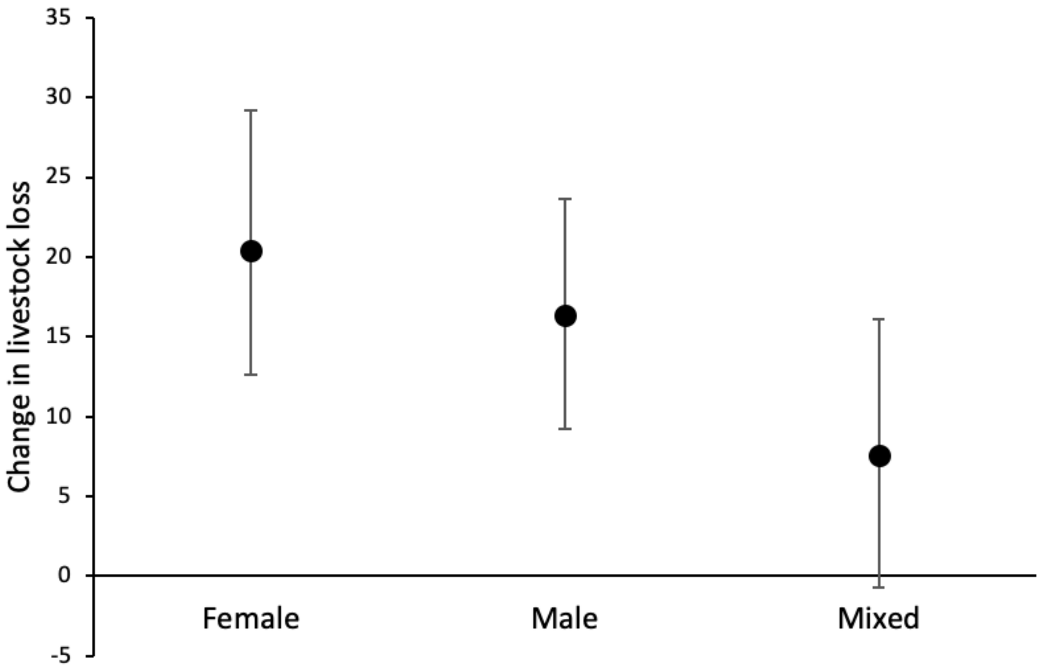

Fig. 3. Model expected change in livestock loss relative (95% confidence intervals) relative to the composition of sex of LGDs of farmers. Values set for other variables include average herd size, average number of dogs owned and for commercial farmers.

Table 3. Mean estimated costs in USD for purchasing and maintaining four categories of livestock guarding dogs in Botswana.

	Anatolian			Purebreds			Tswana cross			Tswana		
Tangible costs	mean (SD)	range	n	mean (SD)	range	n	mean (SD)	range	n	mean (SD)	range	n
Purchase price	85.56 (103.3)	0-220	9	51.61 (65.5)	0-187	26	1.45 (6.3)	0-28	19	9.23 (30.6)	0-165	115
Food (annual)	107.25 (66.7)	49-165	4	268.4 (388.0)	5-1100	25	142.67 (196.3)	5-495	20	89.72 (103.1)	0-550	105
Medical (annual)	27.5 (31.8)	0-55	4	32.21 (43.4)	0-193	25	5.99 (9.6)	0-22	20	35.75 (98.5)	0-660	104
Other (annual)	0.00 (0)	0	4	35.5 (64.0)	0-165	22	0.00 (0)	0	20	17.27 (118.0)	0-1128	96
Total maintenance costs	134.75 (98.4)	49.5-220	4	331.84 (458.9)	5.5-1320	25	148.67 (203.9)	5.5-517	20	138.28 (191.5)	0-1293	107

Tswana dogs had, on average, higher medical costs than other breeds.

The majority of famers reported that their LGDs successfully protected their livestock (93.4%). Only a few disagreed (2.8%) or did not respond (3.8%). Similarly, almost all farmers would recommend the use of LGDs (97.2%). Only one percent would not (1.8% did not respond). For farmers who had originally experienced some level of livestock loss and reported both before and after losses (n = 73), 47.9% reported that they had their losses reduced to zero after using LGD. Most of these respondents (60%) had lost large numbers of livestock (10+ animals annually) prior to getting LGD. There were no reports by any farmer that showed an increase in loss levels after receiving LGD. However, a small number of farmers (n = 10) reported continually high levels of loss both before and after using LGDs. Our top performing model for assessing changes in livestock loss found that LGD sex, farm type and the number of LGDs owned by farmers were important in influencing loss (Table 4). Farmers who had both male and female LGDs had lower reductions in their livestock losses compared to farmers who had LGDs of the same sex (Fig. 3). Farmers who had more dogs had lower livestock losses and this was also seen for farmers on commercial farms.

The majority of farmers (57.5%) stated they were "more tolerant of carnivores since using LGD" compared to 27.4% who disagreed, whereas 15% did not answer. Of those that responded to questions regarding lethal control (n = 92), 25% of farmers stated that they "have never used lethal control", 45.7% of farmers agreed that they would "not use lethal control now I have a LGD", 8.7% would use lethal control legally and only if they "have livestock losses and can confirm the problem animal whilst abiding by Department of Wildlife regulations", 1.1% would "assess when it happens" and 19.5% of farmers would "continue to use lethal control on predators", whether they experienced livestock losses or not. The level of tolerance and the likelihood of using lethal control since using a LGD were not significantly affected by any of our predictor variables (Table 4). Despite the top performing model for tolerance of carnivores including the length of time a farmer had utilised a LGD, this was not significant. Top performing models ranked using AICc are shown in Table 5.

Table 4. Results of the top performing Linear Model for determining key factors affecting change in livestock loss and farmer attitudes toward carnivore tolerance and lethal control.

Response	Predictors	Estimate	SE	z	*P*
Livestock change	Intercept	–6.56	6.70	–0.98	0.33
	Sex – female	13.61	4.92	2.76	0.01
	Sex – male	10.66	4.61	2.31	0.02
	Herdsize	0.09	0.05	1.86	0.06
	Farmtype – communal	–7.85	3.32	–2.37	0.02
	Number of dogs	5.36	1.91	2.81	0.00
Tolerance	(Intercept)	0.09	0.40	0.23	0.82
	Length own LGD	0.06	0.04	1.35	0.18
Lethal control	Intercept	–0.07	0.19	–0.38	0.71

Discussion

For a type of dog that is only recently being recognised as LGD, the Tswana landrace dogs showed comparative effectiveness, preferable behaviour and greater cost-efficiency than their European counterparts when used in Botswana.

The ability of LGDs in our study to reduce livestock losses to carnivores was comparable with other countries (Marker et al. 2005, Rust et al. 2013), which is especially impressive when it is considered that the LGDs in our study did not benefit from assistance or outside training in any way. Although modelling of these data indicates that livestock reductions were not influenced by breed, the number of LGDs being used by any one farmer and the sex of the LGDs did influence performance. It was interesting that the farmers who had both male and female LGDs reported significantly lower reductions in livestock losses. It is not clear why mixed pairs would be less effective in reducing livestock loss, this may be due to behavioural dominance between sexes or distractions caused by mating behaviours (Rigg 2005) and further investigations with larger sample sizes would be beneficial. What is clear is that LGDs have the ability to significantly reduce levels of depredation on a farmers' small stock (goats and sheep) and should be considered as a tool to preferably be combined with other mitigation measures such as corralling livestock, herders, adaptive management and even deterrents (Bruns et al. 2020).

Although disciplinary problems were common in our study, it was notable that the instances of behavioural problems within the entire sample were within the ranges of other LGD studies (Green et al. 1984, Coppinger et al. 1988, Hansen & Smith 1999, Potgieter et al. 2013, Zingaro et al. 2017, Young et al. 2019, Whitehouse-Tedd et al. 2020). What was interesting was that our results showed that Anatolian shepherds displayed significantly more behavioural problems than other breeds. This finding matches previous studies that have shown that Anatolians often display overly aggressive behaviours (Coppinger et al. 1988, Green & Woodruff 1988, 1990) and can cause considerable damage to both target and non-target wildlife species (Potgieter et al. 2013, 2016). Numerous studies have reported on the extent to which LGDs may cause damage to threatening and non-threatening wildlife (Potgieter et al. 2013, 2016, Kelly 2018, Drouilly et al. 2020) and although our study looked at the rates of chasing and injuring wildlife and livestock, the numbers of wildlife and livestock killed by the LGDs themselves were not validated. It has been suggested that smaller and more timid LGDs may have less negative impact on wildlife (Black 1981, Potgieter 2011), and further investigations into exactly how many target and non-target species are killed or injured by LGDs in Botswana would be highly beneficial.

The comparison between the disciplinary problems observed in the LGDs in our study and those in other studies is important considering that ours consisted entirely of LGDs that were placed and trained by the owners themselves. This "in house" placement means that the farmers did not receive any institutional assistance compared to LGD placement programmes run by Non-Government Organisations (NGOs) who provide LGDs with continuous, repetitive monitoring, and corrective training where necessary (Marker et al. 2005,

Table 5. Results of the model selection analysis for change in livestock loss, tolerance and lethal control models using Akaike Information Criteria (AIC).

Response	Model parameters	K	AICc	Delta AICc	Weight	LogLik
Change in livestock loss	Sex + farmtype + herdsize + number of dogs	7	916.88	0	0.37	–450.89
	Sex + farmtype + number of dogs	6	917.39	0.51	0.29	–452.29
	Sex + herdsize + number of dogs	6	919.84	2.96	0.08	–453.51
	Farmtype + number of dogs	4	919.87	2.99	0.08	–455.75
	Sex + number of dogs	5	920.51	3.63	0.06	–454.97
	Herdsize + number of dogs	4	920.75	3.87	0.05	–456.18
	Number of dogs	3	921.75	4.87	0.03	–457.76
	Farmtype + herdsize + number of dogs + breed	8	923.33	6.45	0.01	–452.95
Tolerance	Length LGD	2	145.60	0.00	0.28	–70.75
	Intercept	1	146.24	0.64	0.20	–72.10
	Length LGD + farmtype	3	146.29	0.69	0.20	–70.03
	Length LGD + change LL	3	147.35	1.75	0.12	–70.56
	Length LGD + farmtype + change LL	4	147.83	2.23	0.09	–69.73
	Length LGD + breed	5	147.95	2.35	0.09	–68.69
	Length LGD + farmtype + change LL + breed	7	150.53	4.93	0.02	–67.72
Lethal control	Intercept	1	154.38	0.00	0.28	–76.17
	Length LGD	2	154.56	0.18	0.26	–75.23
	Farmtype	2	156.42	2.03	0.10	–76.15
	Change LL	2	156.42	2.04	0.10	–76.15
	Length LGD + change LL	3	156.56	2.17	0.10	–75.17
	Length LGD + farmtype	3	156.66	2.28	0.09	–75.22
	Farmtype + change LL	3	158.48	4.10	0.04	–76.13
	Length + farmtype + change LL	4	158.68	4.29	0.03	–75.15

Potgieter et al. 2013). Corrective training is arguably the most important part of interventions provided by external organisations (Green et al. 1984, Hansen et al. 2002, Marker et al. 2005, Whitehouse-Tedd et al. 2020). For example, a large portion (44%) of LGDs in South Africa ceased misbehaving when corrective training was administered (Whitehouse-Tedd et al. 2020) and it can be assumed that the LGDs in our study that had "rare" disciplinary problems also responded to the corrective training carried out by their owners.

Tswana LGDs proved to be a cheaper alternative to Anatolians and other purebred LGDs when it came to the costs to obtain the dogs and their feeding. Considering that 85.2% of Tswana LGDs were sourced for free, and even those that were purchased averaged only $9, which means that financial restrictions should not inhibit farmers from sourcing and training their own landrace LGDs. The significantly lower food costs for Tswana dogs in our study (average of $90/year), is considerably lower than other programmes, such as $268-750 for Anatolian shepherd LGDs from Cheetah Conservation Fund's programme in Namibia (Rust & Marker 2013) or $142 for Patagonian LGDs in Gonzalez et al. (2012) (which are referred to as "mixed-breeds" but from their description are likely to be landrace dogs). This difference could be explained by the low protein requirements of landrace dogs (Hovorka & Van Patte 2017). One distinct benefit of the cheap initial financial outlay of Tswana LGDs is that it does not take a long time before they become profitable. Whereas with more expensive breeds it can take two-three years before a dog saves enough livestock to pay for its purchasing cost (Marker et al. 2005, van Bommel & Johnson 2012). The average yearly cost of the dogs in our study (food, medical and other – $109) are still significantly lower than those stated in other studies (e.g. Gehring et al. 2010 – $1,040 and Ostavel et al. 2009 – €750). It is unclear why Tswana LGDs reported higher medical costs as they had comparable health scores to other breeds, though it is possible that the larger sample size of Tswana dogs simply represented a greater number of dogs needing medical care than the other LGD types. The financial costs of NGO-led LGD placement programmes is significant. For example, Cheetah Outreach Trust spends $2,780 for each Anatolian LGD that is placed (Rust et al. 2013) while CCB's new placement program spends $230 to place each Tswana LGD (CCB, unpublished data). Based on these results, LGD placement programmes might cut costs significantly while maintaining high levels of effectiveness, if they instead utilised landrace dogs.

It is important to note that our study only investigated the direct costs and benefits of LGDs. However, a long list of indirect costs and benefits also play important roles in influencing the attitude of the owner and the conservation impact of the LGD. Time spent training the dog, feeding the dog, and caring for the dog as well as time spent worrying about the dog or monitoring the dog can all be considered indirect costs that were not quantified by our study. Similarly, the direct costs associated with livestock that had been injured or killed by the LGD itself, including medical costs associated with treating injured livestock were entered in the "other costs" section of this questionnaire by some farmers, though it was not investigated thoroughly. Similarly, indirect benefits have been cited as important in reducing human-wildlife conflict (Barua et al. 2013) and in this context could include the peace of mind associated with owning a successful LGD, the time a farmer saves by not having to attend to the livestock themselves, or the time taken to find them in the bush and bring them back to the farm, and the emotional impacts avoided by not losing their animals to carnivores. Further studies looking into the indirect costs and benefits associated with LGDs, especially in regard to how these influence attitudes towards carnivores would be beneficial.

Numerous studies have investigated the effectiveness of LGDs at reducing livestock losses (Marker et al. 2005, van Bommel & Johnson 2012, Potgieter et al. 2013, Rust et al. 2013, Leijenaar et al. 2015). However, the degree to which a LGD's effectiveness influences a farmers' willingness to persecute carnivores is often assumed and not quantified. The finding that 19.5% of farmers in our study stated that they would continue to use lethal control despite having an effective LGD is concerning. Although still less than the 90% of farmers in South Africa that were reported to use lethal means to control carnivores (van Niekerk 2010), this figure implies that farmers in Botswana are willing to indiscriminately kill carnivores rather than targeting them in response to livestock attacks. Lethal control in itself can be damaging to wildlife but also counterproductive for reducing livestock losses (McManus et al. 2015, Thorn et al. 2015, Treves et al. 2016, Nattrass et al. 2019). However, indiscriminate killing of carnivores has been cited as one of the biggest threats to wildlife populations (Thorn et al. 2015). Our findings reinforce the need for future studies to consider the link between livestock depredation and carnivore persecution. In addition, the influence of successful LGDs on a farmers' willingness to kill carnivores should be investigated further. Nevertheless, 45.7% of farmers said they would no longer use lethal control of carnivores now that they have a LGD, which still indicates a positive conservation impact for these LGDs.

Our study relied on farmers' self-reports of annual average livestock losses both before and after they used LGDs (sensu Marker et al. 2005). No validation of these losses was possible due to the large sample size, the magnitude of the study area, and the historical nature of the reports. Although perception plays a huge role in conflict situations and, as such, the perceived losses hold value in assessing a farmers' belief in how effective their LGDs have been, it should be noted that this self-reporting method does not reliably measure actual livestock loss over time, especially in the event of reporting historical data. This method of data collection therefore comes with its own inherent bias (Stone et al. 2009). However, self-reporting or respondent perceptions are often the only way to gather meaningful data on livestock losses.

Although our study is one of the few to demonstrate differences between landrace LGDs and other breeds, it is important to note that the sample sizes were skewed heavily towards Tswana and Tswana-cross dogs and further investigations with more robust sample sizes for purebred dogs would be beneficial.

The comparable performance of Tswana LGDs in reducing livestock losses and maintaining better disciplinary scores than Anatolian shepherds suggests that they should not only be considered as a cheaper alternative but also one that requires less supervision and corrective training than Anatolian shepherd LGDs. Small body size has been associated with lower food demands (Losey et al. 2020), which may explain the Tswana dogs' lower food costs. Placement programmes initiated by NGOs could save considerable expenses if they purchased landrace puppies from their local farmers, if they are available. Furthermore, an approach that promotes the use of landrace dogs as LGDs sourced and trained by farmers themselves but provides support in veterinary care of corrective training where needed (Ribeiro et al. 2017), may be more cost-effective at increasing the use of LGDs at a larger scale (Dickman et al. 2018). Using this approach, CCB has seen an increase in the use of LGDs from 5% in 2005 to 38% in 2019 (Cheetah Conservation Botswana, unpublished data) which is considerably higher than the 4% of farmers using LGDs in South Africa (van Niekerk 2010). In terms of scaling up, such an approach might be the most efficient way to help more farmers reduce livestock losses and for conservation organisations to create more widespread conservation impacts.

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Literature

Allen B.L., Allen L.R., Ballard G. et al. 2019: Animal welfare considerations for using large carnivores and guardian dogs as vertebrate biocontrol tools against other animals. *Biol. Conserv. 232: 258–270.*

Baker P.J., Boitani L., Harris S. et al. 2008: Terrestrial carnivores and human food production: impact and management. *Mammal Rev. 38: 123–166.*

Bangs E., Jimenez M., Niemeyer C. et al. 2005: Livestock guarding dogs and wolves in the Northern Rocky Mountains of the United States. *Carnivore Damage Prevention News 8: 32–39.*

Barua M., Bhagwat S.A. & Sushrut J. 2013: The hidden dimensions of human-wildlife conflict: health impacts, opportunity and transaction costs. *Biol. Conserv. 157: 309–316.*

Berger K.M. 2006: Carnivore-livestock conflicts: effects of subsidized predator control and economic correlates on the sheep industry. *Conserv. Biol. 20: 751–761.*

Black H.L. 1981: Navajo sheep and goat guarding dogs: a new world solution to the coyote problem. *Rangelands 3: 235–237.*

Black H.L. & Green J.S. 1985: Navajo use of mixed-breed dogs for management of predators. *J. Range Manag. 38: 11–15.*

Botswana Government 1992: Wildlife conservation and national parks act: subsidiary legislation – national parks and game reserves regulations. *www.laws.gov.bw*

Bruns A., Waltert M. & Khorozyan I. 2020: The effectiveness of livestock protection measures against wolves (*Canis lupus*) and implications for their co-existence with humans. *Glob. Ecol. Conserv. 21: 1–9.*

Butler J.R.A. 2001: The economic costs of wildlife predation on livestock in Gokwe communal land, Zimbabwe. *Afr. J. Ecol. 38: 23–30.*

Cheetah Outreach 2013: Anatolian shepherd livestock guarding dog project progress report. *Cheetah Outreach, South Africa.*

Choirat C., Honaker J., Imai K. et al. 2017: Zelig: everyone's statistical software, version 5.0-14. *http://zeligproject.org*

Coppinger R., Coppinger L., Laneloh G. et al. 1988: A decade of the use of livestock guarding dogs. *Proceedings of 13th Vertebrate Pest Conference, University of Nebraska, Lincoln.*

Coppinger R.P., Smith C.K. & Miller L. 1985: Observations on why mongrels may make effective livestock protecting dogs. *J. Range Manag. 38: 560–561.*

Dickman A.J. 2010: Complexities of conflict: the importance of considering social factors for effectively resolving human – wildlife conflict. *Anim. Conserv. 13: 458–466.*

Dickman A., Potgieter G., Horgan J. et al. 2018: Use of livestock guarding dogs to reduce human-cheetah conflict. In: Marker L., Boast L.K. & Schmidt-Küntzel A. (eds.), Cheetahs: biology and conservation. *Academic Press, San Diego: 209–221.*

Drouilly M., Kelly C., Cristescu B. et al. 2020: Investigating the hidden costs of livestock guarding dogs: a case study in Namaqualand, South Africa. *J. Vertebr. Biol. 69: 20033. https://doi.org/10.25225/jvb.20033*.

Fox C.H. & Papouchis C.M. 2005: Coyotes in our midst: coexisting with an adaptable and resilient carnivore. *Animal Protection Institute, Sacremento.*

Fraser-Celin V.-L., Hovorka A.J., Hovork M. et al. 2017: Farmer-African wild dog (*Lycaon pictus*) relations in the eastern Kalahari region of Botswana. *Koedoe 59: a1366. doi:http://dx.doi.org/10.4102/koedoe.v59i2.1366.*

Frohlich M.T. 2001: Techniques for improving response rates in OM survey research. *J. Oper. Manag. 20: 53–62.*

Gehring T.M., VerCauteren K.C. & Landry J.-C. 2010: Livestock protection dogs in the 21st Century: is an ancient tool relevant to modern conservation challenges? *BioScience 60: 299–308.*

Gonzalez A., Novaro A., Funes M. et al. 2012: Mixed-breed guarding dogs reduce conflict between goat herders and native carnivores in Patagonia. *Hum.-Wildl. Interact. 6: 327–334.*

Graham K., Beckerman A.P. & Thirgood S. 2005: Human-predator-prey conflicts: ecological correlates, prey losses and patterns of management. *Biol. Conserv. 122: 159–171.*

Green J.S. & Woodruff R.A. 1988: Breed comparisons and characteristics of use of livestock guarding dogs. *J. Range Manag. 41: 249–251.*

Green J.S. & Woodruff R.A. 1990: ADC guarding dog program update: a focus on managing dogs. *Proceedings of 14th Vertebrate Pest Conference, University of Nebraska, Lincoln: 233–236.*

Green J.S., Woodruff R.A. & Tueller T.T. 1984: Livestock guarding dogs for predator control: costs, benefits and practicality. *Wildl. Soc. Bull. 12: 44–50.*

Hansen I. & Smith M.E. 1999: Livestock-guarding dogs in Norway, part II: different working regimes. *J. Range Manag. 52: 312–316.*

Hansen I., Staaland T. & Ringsø A. 2002: Patrolling with livestock guard dogs: a potential method to reduce predation on sheep. *Acta Agric. Scand. A 52: 43–48.*

Hodkinson C., Komen H., Snow T. et al. 2007: Predators and farmers. *Endangered Wildlife Trust, Johannesburg.*

Holmern T., Nyahongo J.W. & Røskaft E. 2007: Livestock loss caused by predators outside the Serengeti National Park, Tanzania. *Biol. Conserv. 135: 534–542.*

Honaker J., King G. & Blackwell M. 2011: Amelia II: a program for missing data. *J. Stat. Softw. 45: 1–47.*

Horgan J. 2015: Testing the effectiveness and cost-efficiency of LGSDs in Botswana. *MSc thesis, Rhodes University, South Africa.*

Hovorka A. & Van Patte L. 2017: The lives of domestic dogs (*Canis Africanis*) in Botswana. *Pula: Botswana Journal of African Studies 31: 53–64.*

Kelly C. 2018: Investigating the hidden costs of livestock guarding dogs and the diet of a sympatric predator in Namaqualand, South Africa. *University of Cape Town, Cape Town.*

Kinka D. & Young J.K. 2019: Evaluating domestic sheep survival with different breeds of livestock guardian dogs. *Rangel. Ecol. Manag. 72: 923–932.*

Landry J.-M. 1999: The use of guard dogs in the Swiss Alps: a first analysis. *KORA, Bericht.*

Leijenaar S., Cilliers D. & Whitehouse-Tedd K. 2015: Reduction in livestock losses following placement of livestock guarding dogs and the impact of herd species and dog sex. *J. Agric. Biodivers. Res. 4: 9–15.*

Linnell J.D.C., Smith M.E., Odden J. et al. 1996: Strategies for the reduction of carnivore-livestock conflicts: a review. *NINA Oppdragsmelding 443: 1–116.*

Linnell J.D.C., Swenson J.E. & Andersen R. 2001: Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Anim. Conserv. 4: 345–349.*

Lord K., Coppinger L. & Coppinger R. 2014: Differences in the behavior of landraces and breeds of dogs. In: Grandin T. & Deesing M.J. (eds.), Genetics and the behavior of domestic animals, 2nd ed. *Academic Press, Cambridge: 195–235.*

Losey R.J., Nomokonova T., Kosintsev P.A. et al. 2020: Dog body size in Siberia and Russian Far East and its implications. *Quat. Sci. Rev. 241: 106430. doi:10.1016/j.quascirev.2020.106430.*

Macdonald D.W. & Baker S.E. 2004: Non-lethal control of fox predation: the potential of generalized aversion. *Anim. Welf. 13: 77–85.*

Marker L., Dickman A.J. & Macdonald D.W. 2005: Perceived effectiveness of livestock-guarding dogs placed on Namibian farms. *Range. Ecol. Manag. 58: 329–336.*

Marker L., Dickman A.J., Mills M.G.L. & Macdonald D.W. 2003a: Aspects of the management of cheetahs, *Acinonyx jubatus* jubatus, trapped on Namibian farmlands. *Biol. Conserv. 114: 401–412.*

Marker L., Mills M.G.L. & Macdonald D.W. 2003b: Factors influencing perceptions of conflict and tolerance toward cheetahs on Namibian farmlands. *Conserv. Biol. 17: 1290–1298.*

McCluskey S. & Topping A.E. 2011: Increasing response rates to lifestyle surveys: a pragmatic evidence review. *Perspect. Public Health 131: 89–93.*

McManus J.S., Dickman A.J., Gaynor D. et al. 2015: Dead or alive? Comparing costs and benefits of lethal and non-lethal human-wildlife conflict mitigation on livestock farms. *Oryx 49: 687–695.*

Mitchell B.R., Jaeger M.M. & Barrett R.H. 2004: Coyote depredation management: current methods and research needs. *Wildl. Soc. Bull. 32: 1209–1218.*

Muir M. 2010: Human-predator conflict and livestock depredations: methodological challenges for wildlife research and policy in Botswana. *J. Int. Wildl. Law Policy 13: 293–310.*

Nattrass N., Conradie B., Stephens J. et al. 2019: Culling recolonizing mesopredators increases livestock losses: evidence from the South African Karoo. *Ambio 49: 1222–1231.*

Nyhus P.J., Osofsky S.A., Ferraro P. et al. 2005: Bearing the costs of human-wildlife conflict: the challenges of compensation schemes. In: Woodroofe R., Thirgood S. & Rabinowitz A. (eds.), People and wildlife: conflict or coexistence? *Cambridge University Press, Cambridge: 107–121.*

Ostavel T., Vuori K.A., Sims D.E. et al. 2009: The first experience of livestock guarding dogs preventing large carnivore damages in Finland. *Estonian J. Ecol. 58: 216–224.*

Pfeifer W.K. & Goos M.W. 1982: Guard dogs and gas exploders as coyote depredation control tools in North Dakota. *Proceedings of 10th Vertebrate Pest Conference, University of Nebraska, Lincoln: 54–61.*

Potgieter G.C. 2011: The effectiveness of livestock guarding dogs for livestock production and conservation in Namibia. *MSc. thesis, Nelson Mandela Metropolitan University, Port Elizabeth.*

Potgieter G.C., Kerley G.I.H. & Marker L.L. 2016: More bark than bite? The role of livestock guarding dogs in predator control on Namibian farmlands. *Oryx 50: 514–522.*

Potgieter G.C., Marker L.L., Avenant N.L. & Kerley G.I.H. 2013: Why Namibian farmers are satisfied with the performance of their livestock guarding dogs. *Hum. Dimens. Wildl. 18: 403–415.*

R Development Core Team 2017: R: a language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria.*

Ribeiro S. 2004: Recovering the use of livestock guarding dogs in Portugal: results of a long-term action. *Carnivore Damage Prevention News 7: 2–5.*

Ribeiro S.J., Dornig A., Guerra J. et al. 2017: Livestock guarding dogs today: possible solutions to perceived limitations. *Carnivore Damage Prevention News 15: 36–53.*

Rigg R. 2001: Livestock guarding dogs: their current use worldwide. *IUCN/SSC Canid Specialist Group Occasional paper. http://www.canids.org/occasionalpapers/*

Rigg R. 2005: Livestock depredation and livestock guarding dogs in Slovakia. *Carnivore Damage Prevention News 8: 17–27.*

Rigg R., Findo S., Wechselberger M. et al. 2011: Mitigating carnivore-livestock conflict in Europe: lessons from Slovakia. *Oryx 45: 272–280.*

Rust N.A. & Marker L.L. 2013: Cost of carnivore coexistence on communal and resettled land in Namibia. *Environ. Conserv. 41: 45–53.*

Rust N.A., Whitehouse-Tedd K.M. & MacMillan D.C. 2013: Perceived efficacy of livestock-guarding dogs in South Africa: implications for cheetah conservation. *Wildl. Soc. Bull. 37: 690–697.*

Shivik J.A. 2004: Non-lethal alternatives for predation management. *Sheep & Goat Research Journal 19: 64–71.*

Shivik J.A. 2006: Tools for the edge: what's new for conserving carnivores. *Bioscience 56: 253–259.*

Siemiatycki J. 1979: A comparison of mail, telephone and home interview strategies for household health surveys. *Am. J. Public Health 69: 238–245.*

Stahl P., Vandel J.M., Herrenschmidt V. et al. 2001: The effect of removing lynx in reducing attacks on sheep in the French Jura Mountains. *Biol. Conserv. 101: 15–22.*

Statistics Botswana 2013a: Annual agricultural survey report 2011. *Republic of Botswana's Central Statistics Office, Gaborone.*

Statistics Botswana 2013b: Botswana environment statistics, 2012. *Republic of Botswana's Central Statistics Office, Gaborone.*

Statistics Botswana 2019: Annual agricultural survey report 2017. *Statistics Botswana, Gaborone.*

Stone A.A., Turkkan J.S., Bachrach C.A. et al. 2009: The science of self report: implications for research and practice. *Lawrence Erlbaum Associates Inc., New Jersey.*

Thorn M., Green M., Dalerum F. et al. 2012: What drives human-carnivore conflict in the North West Province of South Africa? *Biol. Conserv. 150: 23–32.*

Thorn M., Green M., Marnewick K. et al. 2015: Determinants of attitudes to carnivores: implications for mitigating human-carnivore conflict on South African farmland. *Oryx 49: 270–277.*

Treves A., Krofel M. & McManus J. 2016: Predator control should not be a shot in the dark. *Front. Ecol. Environ. 14: 380–388.*

Treves A. & Santiago-Ávila F.J. 2020: Myths and assumptions about human-wildlife conflict and coexistence. *Conserv. Biol. 34: 811–818.*

Urbigkit C. & Urbigkit J. 2010: A review: the use of livestock protection dogs in association with large carnivores in the Rocky Mountains. *Sheep & Goat Research Journal 25: 1–8.*

van Bommel L. & Johnson C.N. 2012: Good dog! Using livestock guardian dogs to protect livestock from predators in Australia's extensive grazing systems. *Wildl. Res. 39: 220–229.*

van Niekerk H.N. 2010: The cost of predation on small livestock in South Africa by medium-sized predators. *MSc. thesis, University of the Free State, Bloemfontein.*

White P.C.L., Jennings N.V., Renwick A.R. et al. 2005: Questionnaires in ecology: a review of past use and recommendations for best practice. *J. Appl. Ecol. 42: 421–430.*

Whitehouse-Tedd K., Wilkes R., Stannard C. et al. 2020: Reported livestock guarding dog-wildlife interactions: implications for conservation

and animal welfare. *Biol. Conserv. 241: 108249. https://doi.org/10.1016/j.biocon.2019.108249.*
Woodroffe R. & Frank L.G. 2005: Lethal control of African lions (*Panthera leo*): local and regional population impacts. *Anim. Conserv. 8: 91–98.*
Woodroffe R., Thirgood S. & Rabinowitz A. 2005: People and wildlife: conflict or coexistence? *Cambridge University Press, Cambridge.*
Young J.K., Draper J.P. & Kinka D. 2019: Spatial associations of livestock guarding dogs and domestic sheep. *Hum.-Wildl. Interact. 13: 7–15.*
Zingaro M., Salvatori V., Vielmi L. et al. 2017: Are the livestock guarding dogs where they are supposed to be? *Appl. Anim. Behav. Sci. 198: 89–94.*

Supplementary online material

Appendix S1. Livestock guarding dog questionnaire (https://www.ivb.cz/wp-content/uploads/JVB-vol.-69-3-2020-Horgan-et-al.-Appendix-S1.pdf).