Perceived Efficacy of Livestock Guarding Dogs in South Africa: Implications for Cheetah Conservation

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Abstract:	<p>Large wild carnivore predation on domestic livestock and the associated financial losses may increase persecution of carnivore populations. Livestock guarding dogs (LGDs) could provide effective mitigation by protecting stock from depredation. Although this information is available in North America, the cost-effectiveness of LGDs has not been studied in other areas experiencing large carnivore depredation such as South Africa, where the socio-economic context is very different to that of North America. We assessed the costs and benefits of 97 LGDs working on 94 farms in South Africa between 2005 and 2011 by reviewing data collected from questionnaires on perceived depredation losses prior to and during LGD placement, rates of LGD behavioral problems, removals, and pre-senile mortality. Perceived livestock depredation ceased entirely in 91% of LGD placements, with gross mean annual financial savings recuperated by the farmers of U.S. \$3,189 per farm. Annual costs of running the LGD program were \$2,780 per dog. Farmer tolerance towards cheetahs and cheetah population numbers appeared to increase during participation in the LGD program. However, 28% of LGDs had reported behavioral problems, with inattentiveness cited as the most common problem. Seventeen percent of LGDs were removed from the program because of behavioral problems. Premature death was observed in 22% of LGDs, most often due to snake bites. If further corrective behavioural and snake aversion training were implemented, LGDs may offer a cost-effective method of non-lethal predator control and could potentially contribute to the long term mitigation of human-carnivore conflict in South Africa.</p>

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**Perceived Efficacy of Livestock Guarding Dogs in South Africa: Implications for
Cheetah Conservation**

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KEY WORDS *Acinonyx jubatus*, cheetah, depredation, human-wildlife conflict, large
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ABSTRACT Large wild carnivore predation on domestic livestock and the associated
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34
35 One quarter of the world's mammal species are threatened with extinction (Baillie et al.
36 2004), with mega-faunal, slow-reproducing species being particularly susceptible (Mckinney
37 1997). Large carnivores, killed due to both real and perceived threats to game, livestock, and
38 human health and safety, are especially vulnerable (Gittleman et al. 2001). The conservation
39 of large carnivores is particularly problematic as it often places those who wish to restore
40 carnivore populations at odds with livestock producers who may experience economic losses
41 because of large carnivore depredations.

42 Humans have tried to limit livestock loss to carnivores using lethal and non-lethal
43 methods (see Linnell et al. 1996). Although lethal techniques may provide effective short-
44 term solutions for controlling predators (Treves and Naughton-Treves 2005), their widespread
45 application is not conducive to sustainable management of threatened carnivore species
46 (Breitenmoser 1998). Thus there is a need to identify and evaluate cost-effective and practical
47 non-lethal alternatives (Sillero-Zubiri and Laurenson 2001).

48 A common method used to resolve human-wildlife conflict has been to offer
49 compensation to farmers that suffered livestock depredation to offset the costs of carnivore

damage (Wagner et al. 1997). Such schemes have, however, rarely reduced human-wildlife conflict; farmers do not become more tolerant of carnivores, lethal control is still practised, schemes are not cost-effective and carnivore populations rarely increase as a result of the scheme (Nyhus et al. 2005, MacLennan et al. 2009).

Guarding dogs (LGDs) have been used for nearly six millennia to protect livestock (Olsen 1985). However, because of the widespread extermination of some carnivore species during the previous two centuries, many farmers no longer need to use dogs to protect their stock (Linnell et al. 1996). Given the recovery and reintroduction of a number of carnivore populations, some livestock producers have expressed renewed interest for using LGDs. A resurgent interest in LGDs started in Turkey in the 1970s (J. W. De Grazio, Denver Wildlife Research Center, unpublished report) and subsequently spread to North America (Linhart et al. 1979) and, more recently, Australia (Rigg, 2001) and Africa (Marker et al. 2005a).

In South Africa, predators were often, and still are, killed to limit livestock depredation, leading to the extirpation of many large carnivores from extensive portions of unprotected areas (Stuart et al. 1985). This has led to a mesopredator release, where caracal (*Caracal caracal*) and black-backed jackal (*Canis melanogaster*) numbers increased, which caused new depredation problems for small stock farming operations (Lloyd 2007). Reduced intraguild competition due to a decline in lion (*Panthera leo*) and spotted hyena (*Crocuta crocuta*) populations have allowed cheetahs (*Acinonyx jubatus*) to exist on farmland to the north of the country (Marnewick et al. 2007). However, the perceived and real costs that threatened cheetah populations placed upon livestock farms resulted in increased efforts to lethally control this predator. Being that there is a relatively small population of cheetah in South Africa (Marnewick et al. 2007), it is important that conservation efforts include effective mitigation of this human-wildlife conflict.

74 Livestock guarding dogs could provide an alternative solution to resolve some of the
75 issues faced by compensation schemes by offering a non-lethal method to limit depredation,
76 thereby potentially increasing tolerance of farmers towards carnivores (Green et al. 1984),
77 reducing the need for lethal persecution and allowing predators to roam freely on livestock
78 farms, which could increase potential habitat. Farmers perceived LGDs as being very
79 successful for limiting livestock depredation due to cheetahs in Namibia (Marker et al.
80 2005a), which inspired the initiation of a similar project in South Africa in 2005 by a non-
81 governmental organization (NGO), Cheetah Outreach. This organization provided LGDs, in
82 partnership with the Endangered Wildlife Trust, to farmers who reported livestock losses to
83 predators in an effort to ameliorate livestock-carnivore conflicts (C. Stannard and L. Smith,
84 Cheetah Outreach, unpublished report). Although early results of these trials are promising,
85 there have previously been problems reported in studies of LGDs, which may limit their
86 efficacy and subsequent adoption by others (Coppinger et al. 1983, Rigg 2005).

87 The objective of our research was to identify factors that may limit LGD efficacy and
88 cost effectiveness. This research expanded upon previous work with LGDs in southern Africa
89 (Marker et al. 2005a,b) by calculating the perceived efficacy of LGDs' ability to limit
90 depredation through measuring reported changes in depredation values prior to and upon
91 placement of LGDs and by calculating the financial costs and benefits of LGDs for limiting
92 perceived depredation. We also aimed to understand whether LGD ownership increased
93 tolerance towards cheetahs or increased cheetah populations (seen as a surrogate for reduced
94 lethal control of this species). Using previously collected data from questionnaires conducted
95 by Cheetah Outreach's Anatolian Project Coordinator (hereafter denoted as 'Dog Officer'),
96 the following factors related to the efficacy of LGDs were evaluated: 1) ability to reduce
97 reported depredation, including analysis into whether LGDs were more effective at guarding
98 certain species of stock; 2) financial costs and savings for limiting depredation; 3) attitudes

towards cheetahs; 4) frequency of behavioral problems; 5) incidence of pre-senile mortality (death before 10 years of age); and 6) frequency and cause of dog removal. Although we determined perceived rather than real depredation, it is the perceived loss that affect farmers' attitudes and behavior towards predators (Marker et al. 2003).

STUDY AREA

Placement of LGDs occurred almost exclusively in the South African cheetah home range in the northern regions of the country (Fig. 1). The study area is characterized by a semiarid savannah agricultural habitat (Buk and Marnewick 2010). Producers incorporate sheep, goats, cattle, or mixed livestock species in grazing operations ranging from 400 to 10,400 ha ($x = 3,966$ ha). Land uses include livestock producers, game ranches and nature reserves (C. Stannard and L. Smith, Cheetah Outreach, unpublished report).

An Anatolian shepherd (*Canis lupus familiaris*) LGD was provided by the NGO free of charge to a farmer who was experiencing cheetah depredation. The NGO also provided the first year's supply of dog food and veterinary coverage and full reimbursement for neutering the puppy. This was to offset the prohibitively high initial costs of obtaining a LGD that farmers would otherwise have incurred (Green et al. 1984). Puppies were raised by their mothers with sheep present for at least the first 6-8 weeks of life with minimal human contact before being transferred to the selected farm that has experienced depredation. The dog was then kept on the farm with a small flock of their intended stock species for the next few months for imprinting to occur before being released out with the rest of the herd as per instructions from J. R. Lorenz (unpublished report, 1989). The dogs were neutered at 8-months of age. Between May 2005 and July 2011, 97 dogs were provided to farmers.

Upon dog placement, farmers were offered comprehensive information on effective LGD care and training methods, including advice for dealing with potential behavioral or health problems they may encounter with the dog. The Dog Officer maintained regular

contact with the farmer, visiting the property once a month in the first year of dog placement, quarterly for the second year and annually thereafter to assess on-going livestock depredation, dog health and behavioral problems. A behavioral problem was defined when either the owner reported undesirable behavioral traits to the Dog Officer, or when the Dog Officer noticed such behavior on his visits, which were based upon those laid out by Coppinger and Coppinger (1980), i.e. lack of attentiveness, trustworthiness or protectiveness. The farmer was advised to contact Cheetah Outreach immediately if any behavioral problems were observed in their LGDs, ensuring that these were dealt with in the most efficient manner. Behavioral problems were noted in Cheetah Outreach's biannual LGD progress report, which also includes any follow-up corrective training undertaken, reasons for removal or death of a LGD, and frequency of depredations (C. Stannard and L. Smith, unpublished report).

METHODS

Face-to-face structured questionnaires were conducted by the Dog Officer with all farmers who had contacted Cheetah Outreach requesting a LGD. This was to determine whether the farm was suitable for a LGD. Suitable farms were declared those that were located in an area with cheetahs and where the farm had suffered livestock depredation in the last year. Questions in this initial questionnaire included the farmer's perceived annual livestock depredation rate, which predators were perceived as responsible, the type of stock on the farm, the size of the farm and the number of livestock in each herd. If the farm was deemed suitable for a LGD, a puppy was provided to the farmer. Follow-up face-to-face semi-structured questionnaires were then undertaken between by the Dog Officer and the LGD owner during the LGD monitoring visits to the farm. All farmers with LGDs provided by Cheetah Outreach were interviewed. Questions included the total amount of depredation experienced since dog placement, any behavioral problems experienced, whether the dog was removed and the reason(s) for this, if the dog had died and how, and the length of LGD

placement. Unfortunately, data were not recorded on the age of the dog in relation to when livestock depredation took place therefore no analyses could be performed on this variable. A random sample of the farmers visited during the regular LGD monitoring trips were asked if they thought that cheetah populations had increased in their local area and if their tolerance towards cheetahs had changed since becoming part of the program. This perception was rated on a 5-point scale of strongly agree (5) to strongly disagree (1), with 3 corresponding to neutral or no change.

We determined any changes in perceived annual depredation upon LGD placement by using values of perceived depredation noted from results of the initial suitability questionnaire prior to placement, along with data from the follow-up monitoring questionnaires, which were published in the 2 most recent LGD reports that list Cheetah Outreach's LGDs (D. Cilliers, Endangered Wildlife Trust, unpublished report; C. Stannard and L. Smith, unpublished report). Perceived values were used as it was logistically infeasible to verify depredations in the field as the study area was too large for the Dog Officer to monitor. The reports included results from all LGD placements from the entire study range from May 2005 to July 2011. Depredated livestock values prior to LGD placement were based upon study farmers' perceptions of depredation for the year preceding placement. Given the structure of the follow-up questionnaire, depredation values upon placement were recorded for the entire duration of dog placement rather than per year. We therefore calculated annual depredation rates upon LGD placement by dividing the total confirmed depredations during the entire timeframe of LGD ownership by the number of years the dog had been present. It is not clear whether the reported annual depredation prior to LGD placement was a typical value for that farm, thus the calculated effectiveness of LGDs for reducing depredation was based on the assumption that this was indeed typical.

We determined the ability for LGDs to protect certain stock species more effectively than others by comparing depredation frequencies during LGD placement as calculated above dependent on whether either large (cattle) or small (goats and sheep) stock species were guarded. Where both large and small stock were guarded, these data points were not included in the analysis ($n = 1$). The reported LGD behavioral problems, cause of pre-senile mortality, and cause of removal data were analysed from data collected by the follow-up questionnaire.

Using 5 June 2011 market prices for livestock sales in South Africa (B. Smuts, Landmark Foundation, personal communication), we calculated direct annual cost of depredation i.e., the annual number of livestock depredated upon multiplied by the market value per animal, for each stock species using the above annual depredation values prior to and during LGD placement. Annual financial savings during LGD placement were calculated by subtracting the mean annual costs of depredation during LGD placement from the mean of annual costs of depredation of all stock species prior to LGD placement. Annual costs of running the program included upkeep of the LGD (vaccinations, parasite medication and food), salary costs of the Dog Officer (total salary divided by total number of working LGDs in field by end of 2010, $n = 66$) and travel and maintenance costs (total costs divided by total number of working LGDs in field by end of 2010). The cost of purchasing a dog was not included as Cheetah Outreach uses dogs that have been bred at its facility and dogs are donated free of charge to farmers. However, an Internet search for sales of Anatolian puppies is approximately \$200, which was factored into the real costs for theoretically running a LGD scheme. All costs were calculated in South African Rand and converted into US dollars as per the exchange rate on 5 June 2011.

We carried out all analyses using MINITAB VERSION 16 (Minitab Inc., Quality Plaza, 1829 Pine Hall Road, State College, PA). Data were tested for normality using the Anderson-Darling test and non-parametric tests were used for data that were not normally

distributed. A 1-way paired t -test was used to test for a directional difference between the means of the 2 populations, i.e. annual depredations before compared with during LGD placement. A Kruskal-Wallis test was used to test whether depredation values varied during LGD placement depending on species of stock guarded. Due to the small number of instances of reported livestock depredation after LGD placement ($n = 5$), it was not possible to conduct statistical analyses on factors that may have influenced livestock depredation during LGD placement. Due to the small sample size of responses to questions regarding perceived cheetah population numbers and tolerance towards cheetahs, these two variables were analysed descriptively. The significance level for all tests was set at 0.05. Data were reported as mean ($\pm$ SE) unless otherwise stated. Questions not answered by respondents were deemed non-responses and were therefore eliminated from the analysis, hence why sample sizes varied throughout analyses.

RESULTS

Changes in Level of Perceived Depredation

Perceived annual depredation rates were lower during LGD placement when compared with before placement (Fig. 2 [$P \leq 0.001$, $n = 70$, $T = 10.48$, x^2 difference between pairs = 19.85]). Perceived annual depredation was reduced by a range of 33.3-100% during LGD placement ($x^2 = 98.3 \pm 1. \%0$) across all farms.

The percentage of annual stock lost to predators prior to LGD placement ranged between 2-50% ($x^2 = 17.4\%$, $n = 28$); during LGD placement this ranged from 0-2% ($x^2 = 0.1\%$, $n = 26$). No farm experienced an increase in depredation upon LGD placement.

Livestock Guarding Dog Application

The mean length of LGD placement was 2.3 years (range 1 – 6 years). Of 74 LGD placements with data provided on the stock guarded by dogs, 57% ($n = 42$) guarded sheep, 31% ($n = 23$) goats, 11% ($n = 8$) cattle, and 1% ($n = 1$) guarded a mix of goats and sheep. No

difference was found between perceived depredation of different species during LGD placement ($P = 0.958$, $df\ 2$, $n = 70$, $H = 0.31$), therefore we concluded that livestock species has no effect on efficacy of the LGDs.

Financial Costs and Benefits

Mean financial loss from depredation decreased following LGD placement (Table 1). Annual food costs of one LGD by Cheetah Outreach for the dog's first year of life were \$1,884; veterinary costs were \$392, which included one-off vaccinations at a cost of \$92. Annual salary costs and associated vehicle maintenance and travel costs for the Dog Officer was \$504 per LGD. Total annual costs of running the LGD program by Cheetah Outreach in the dog's first year of life were \$2,780 per dog. These costs were not borne by the farmer, therefore each farmer saved on average $\$3,189 \pm \302 per farm annually due to a reduction in depredation for all livestock species (Table 1). Including the theoretical cost to purchase an Anatolian puppy (\$200), the financial savings of the first year of life of the puppy equate to a net benefit of reduced depredation of $\$209 \pm \302 per dog. After the first year of the puppy's life where the cost of purchasing the dog and one-time vaccinations were absent and the dog food and veterinary bills were relayed to the farmer, annual gross savings for the farmer equated to $\$1,005 \pm \302 per dog; the net saving from reduced depredation annually per dog after the first year of the dog's life was $\$501 \pm \302 .

Behavioral Problems and Removal

Out of 97 dogs analysed, 27 (28%) were reported to have behavioral problems at least once during the study period (Fig. 3). 'Owner-related' problems refer to non-compliance from the farmer to adhere to recommended training procedures. An 'unknown' behavioural problem referred to a LGD recorded to have behavioral problems with no further information provided in the Dog Officer's reports.

Five out of the 27 (19%) LGDs that previously had behavioral problems responded well to corrective training and the problems disappeared. Of those dogs with recorded behavioral problems, 44% ($n = 12$) were removed from the program because corrective training had proven ineffective. As of December 2010 there were 6 LGDs (10%) under corrective training for behavioral problems out of 58 working LGDs.

Out of 97 dogs analysed, 16 (17%) were removed (Fig. 4). The most common cause of removal was due to unresolved behavioral problems ($n = 10$, 63%). The remaining four dogs were removed for reasons not related to behavior.

Pre-senile Mortality

Twenty-one of 97 LGDs (22%) died prematurely, 5 (24%) of which were accidentally killed. These accidental deaths were caused by snaring, falling off a vehicle, heavy metal poisoning, a puppy being stepped on by a goat, and electrocution from chewing on an irrigation system's electric cable. Eleven LGDs (52%) died of snake bites. Two dogs were intentionally killed by individuals other than the owner; one was shot by a neighbor, another poisoned by a farm worker. Two dogs were predated upon; one by a hyena, another by a leopard (*Panthera pardus*). One dog's cause of pre-senile death was unknown.

Perceptions of Cheetahs

Fifteen per cent ($n = 14$) of farmers were sampled to ask if they thought that cheetah numbers had increased since becoming involved with the LGD program. Of these, 57% ($n = 8$) strongly agreed that there was an increase in cheetah numbers in their area, with the remainder seeing no change. Seventy-nine per cent ($n = 11$) thought that their tolerance towards cheetahs had greatly increased since being involved in the LGD program, with 7% ($n = 1$) thinking their tolerance had not changed and the remaining 14% ($n = 2$) thinking their tolerance had somewhat decreased.

DISCUSSION

Livestock guarding dogs were successful in completely eliminating reported livestock depredation on over 90% ($n = 66$ out of 70 farms with usable data) of the South African farms investigated. Moreover, in cases where livestock losses were not completely eradicated following the placement of a LGD, perceived losses due to predation were reduced by at least 80%, with only one exceptional case experiencing a reduction of only 33% due to a very low rate of depredation both before and during LGD placement. Reported decreases in livestock depredation were noted on many farms that had owned LGD puppies for less than a year, showing anecdotal evidence that even young dogs were able to deter predators.

The overall perceived financial benefits of the reduced depredation achieved on the majority of farms were substantial, with one farmer estimated to have saved \$14,415 per year (Table 1). An average annual saving for each farmer across the study population was calculated at \$3,189 per farm, which is similar to that reported previously (Andelt and Hopper 2000). However, when taking into account the cost of running this LGD program, this saving still outweighs the costs for a farmer to hypothetically bear full financial responsibility. It must be made explicit that these running costs are not borne by the farmer in this study and therefore do not alter the efficacy of the economic incentive for the farmer to reduce lethal control of cheetahs by owning LGDs to reduce depredation. These values also do not take into consideration the potentially significant intangible benefits of owning a LGD, such as a reduction in disease transmission between wildlife and cattle (Vercauteren et al. 2008), reduced stress from finding livestock carcasses and an increased feeling of security (Andelt 1984). Other economic incentive schemes to mitigate human-wildlife conflict, such as offering compensation for depredation, are also prone to high running costs, as not only do the schemes have to cover the cost of all depredation, but salaried field officers are also required to verify losses, which can be expensive (Wagner et al. 1997, Maclellan et al.

2009). Assuming that the costs of running the compensation scheme are equivalent to the salary, travel and maintenance costs of running the LGD scheme, the additional cost of compensating for all livestock depredation means that operational costs of compensation schemes are higher than for LGD schemes. Furthermore, compensation schemes do not usually require farmers to improve their livestock husbandry practices and therefore depredation does not generally decrease (Nyhus et al. 2005). As the negative effects of predators still occur on the farm, compensation schemes do not increase tolerance of predators, even if the farmer is fully compensated for the market value of lost livestock (Naughton-Treves et al. 2003). Being that the costs of compensation schemes are higher than LGD schemes and compensation does not increase tolerance to predators or reduce lethal control, the LGD scheme may be a more effective human-wildlife conflict mitigation strategy. Evidence from the present study has shown that tolerance towards cheetahs has improved since implementation of the LGD scheme and indicates that cheetah numbers are increasing on farms with LGDs. It could be that variables not related to the use of LGDs have increased perceived cheetah populations in the area, but the fact that the perceived tolerance of cheetahs has increased due to LGD ownership may demonstrate that farmers are using lethal predator control less often, causing an increase in cheetah populations. The causal relationship between these variables has, however, yet to be proven.

The incidence of depredation of small stock species (sheep and goats) to predators was similar to that of large stock species (cattle) during LGD placement. As such, LGDs appear to be equally successful at reducing depredation of both large and small stock species and may therefore be a viable and relevant form of effective predator control for a range of farmed animal species. This confirms similar findings from Andelt (2004).

The efficacy of a LGD to reduce livestock depredation was dependent upon its successful placement on each farm. However, LGDs may be removed from farms due to a

variety of reasons and the proportion of failed placements in this study resulting in the dog's removal was reasonably high (over 15%, compared with just 8% in a study by Marker et al. [2005b]). The most common reason for removal was due to behavioral problems, which accounted for over 60% of removals in the current study. Pre-senile mortality was also relatively common, with snake bites accounting for over half of such deaths.

According to Pfeifer and Goos (1982), failure to reduce depredation by LGDs may occur under the following situations: 1) the dog is less than 6 months old; 2) the stock are too dispersed for the dog to guard effectively; 3) the dog is ill; or 4) the dog lacks attentive behavior. These situations were observed in the current study, with the exception of ill-health causing failure to guard. Age appeared to be an important factor when considering failed guarding cases in the current study, as the majority of depredation took place on farms with dogs under the age of 1. Livestock guarding dogs are considered to be most effective once they reach maturity at approximately 2 years of age (Green et al. 1994). Therefore a dog's guarding behavior should not be anticipated to reach peak performance until this age; a number of depredation incidences in the current study took place prior to the LGD reaching adulthood. Additional depredations were observed in one case where the herd split itself into two groups, thereby making it difficult for the dog to guard both herds. In this situation, we advised for the placement of a second LGD on this farm to prevent this from happening again.

Inattentiveness was the most common behavioral problem reported and accounted for a considerable number of dog removals. However, it is unclear whether depredation took place directly due to the dog's inattentiveness. Dogs are reported to exhibit more successful LGD behavior when they are introduced to livestock no later than 6 weeks of age (Pfeifer and Goos 1982, Black and Green 1984). If a dog has not imprinted upon its herd species by this time, it is far more likely to become inattentive when guarding (Pfeifer and Goos 1982, Coppinger et al. 1983). Because the dogs in our study were bonded with herds prior to and

during this critical socialisation period, it is unlikely that this was the cause of the inattentive behavior noted here. Likewise, as all dogs in the present study were neutered at 8 months of age, this indicates that sexual behaviors such as roaming to find mates (R. Lüthi, World Wildlife Fund, pers. comm.) are unlikely to explain the inattentiveness observed here.

The use of Anatolian shepherds in this study may have introduced some breed-specific factors influencing guarding efficacy. For example, other studies have found Anatolian shepherds to be less protective and trustworthy than other breeds (Coppinger et al. 1983, Timm and Schmidt 1989, Green and Woodruff 1990). Other carnivore conservation NGOs in southern Africa are trialling different breeds of LGDs such as Boerboel dogs and mixed breeds to determine whether this affects the success of their LGD programs (Marker et al. 2005c, D. Cilliers, unpublished report). The results of such studies may have substantial implications for future planning of LGD programs.

The relatively high frequency of inattentive behavior reported here when compared with Coppinger et al. (1983) may also be due to lack of engagement with the training program by the farmer. Indeed, although the success of a LGD depends partly on canine genetics and imprinting (Coppinger et al. 1987), Rigg (2005) indicated that the farmer's commitment to the program is a more important factor for determining the success of the dog. In our study we observed one dog which was reported to have behavioral problems and was consequently transferred to an alternative farm. This dog subsequently worked extremely effectively. It remains to be seen if this single case reflects any trend. Furthermore, nearly 1 in 5 of the dogs with behavioral problems responded well to corrective training. This highlights the need for on-going and regular communication and training of dogs and the farmers involved in order to increase the likelihood of a successful placement.

Similar to other studies (Lorenz and Coppinger 1986, Ribeiro and Petrucci-Fonseca 2005), pre-senile mortality was observed in over 20% of LGDs prior to reaching 10 years of

age. Snake bites and accidents were the most common causes of death, which has also been found in other studies (Lorenz et al. 1986, Green and Woodruff 1990, Marker et al. 2005a). In a study of domestic dogs in the United States, snake bites were the most frequent cause of poison-related deaths (Case 2005) and it appears from our study that LGDs are at similar risk. As such, snake aversion conditioning would be a beneficial addition to LGD training programs. Predation may be an unavoidable risk for LGDs and was the cause of 10% of LGD pre-senile deaths in the current study, which is comparable to a previous study (Ribeiro and Petrucci-Fonseca 2005). Protective spiked collars similar to those worn by Anatolian shepherds in Turkey (Rigg 2001), or the placement of puppies on farms with working adults may help reduce such deaths as puppies learn how to avoid dangerous situations quicker (Black and Green 1984). Purposeful killing of LGDs by humans accounted for 10% of LGD deaths in the current study, which is a similar result to that found by Marker et al. (2005a). Limiting inattentive behavior by constructing dog-proof fencing or by using shock collars (Timm and Schmidt 1989) to decrease roaming onto neighboring properties (Lorenz et al. 1986) may also assist in preventing pre-senile deaths caused by humans. However, influencing the behavior of humans rather than that of the dogs is more likely to reduce this type of death. Previous studies have indicated that LGDs have been purposefully killed by neighbors or hunters (Green and Woodruff 1990, Marker et al. 2005a, Ribeiro and Petrucci-Fonseca 2005), possibly as they were regarded as a threat to livestock, game, or pets (Rigg 2005). Community outreach and education programs could be the most effective method of combating this problem.

It is possible that livestock depredations decreased in this study due to other variables unrelated to, or instead of, the LGDs. These alternative explanations may include factors such as an increase in natural prey numbers causing predators to revert to their preferred dietary choice, i.e. from livestock to wild prey (Woodroffe et al. 2005) or a possible bias in

reporting or recording livestock depredation by farmers (Green and Woodruff 1983). It could also be that improved livestock husbandry practices were implemented during the study period. However, given that the intended conservation goal for using LGDs is to reduce lethal control of predators, improving livestock management to reduce depredation should be encouraged, which would concurrently reduce the need to kill predators. Further research will be needed to understand the extent these factors play in influencing depredation.

MANAGEMENT IMPLICATIONS

As many large carnivore populations continue to decline, the development of effective solutions to reduce threats to their existence and improve stakeholder tolerance are needed. The LGD program we studied may be part of this solution as LGDs significantly reduced perceived livestock depredations. The initial running costs of this project were borne by Cheetah Outreach, which meant that farmers realised the gross benefits of LGD ownership without the associated costs. We believe that this economic factor increased tolerance more effectively than either compensation schemes or by encouraging farmers to buy their own LGDs because the negative externalities of cheetah existence, i.e. the depredation they caused, and the positive externalities that farmers produced, i.e. habitat for cheetahs, were paid for by those that value and benefit from cheetah existence. This has reduced the market failure of the previously unmet costs and benefits of cheetah existence; anecdotal evidence suggests that farmers perceive to see more cheetahs on their land and farmer tolerance towards cheetahs are increasing on farms with LGDs in this study, which may signify that human-wildlife conflict has been ameliorated. However, for such a scheme to be implemented elsewhere, sustainable funds must be sourced to finance the subsidised LGDs, which may be obtained by donations, sponsorship or government subsidies. Additional research needs to be conducted to establish causal relationships between participation in the LGD scheme and its effect on cheetah populations. Intangible benefits of the LGD scheme should also be valued,

such as the farmer's feelings of security and reduced anxiety from not encountering livestock depredation. Despite this current lack of knowledge, this study has found that LGDs reduce conflict between farmers and cheetahs in South Africa, which save more money overall via reduced livestock depredation than the hypothetical costs for a farmer to finance the program, creating an economically viable mitigation strategy.

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552 Figure Captions

553 **Figure 1.** Placement by Cheetah Outreach of Anatolian shepherds (black circles) within
554 South Africa, May 2005 – Jul 2011,

555

556 **Figure 2.** Histogram of mean $\pm$ SEM annual depredation frequencies on 70 farms before and
557 during livestock guarding dog (LGD) placement in South Africa,

558

559 **Figure 3.** Histogram of reported frequencies of behavioral problems noted by Cheetah
560 Outreach's Dog Officer in 26 livestock guarding dogs placed on South African farms between
561 May 2005 – Jul 2011,

562

563 **Figure 4.** Histogram of frequencies and causes of 16 livestock guarding dog removals in
564 South Africa between May 2005 – Jul 2011.

565

Table 1. Mean $\pm$ SE (and range ^a) of annual cost [US \$] of depredation before and during livestock guarding dog (LGD) placement on 94 farms in South Africa, May 2005 – Jul 2011 ($n = 70$)

Livestock farm type	Mean annual financial loss due to depredation	
	Before LGD placement	During LGD placement
Cattle	5,127 $\pm$ 1,315 (1,783-11,889)	0
Sheep	3,222 $\pm$ 384 (0-14,416)	5 $\pm$ 3 (0-99)
Goats	2,449 $\pm$ 386 (357-5,945)	8 $\pm$ 6 (0 - 119)
Sheep and goats	1,486 $\pm$ 0 (1,486)	0

^a Range stated in brackets.

Figure 1. Placement by Cheetah Outreach of Anatolian shepherds (black circles) within South Africa, May 2005 – July 2011.

Figure 2. Histogram of mean $\pm$ SEM annual depredation frequencies on 70 farms before and during livestock guarding dog (LGD) placement in South Africa.

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