Reported livestock guarding dog-wildlife interactions: implications for conservation and animal welfare

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Abstract

Livestock depredation by carnivores is a key cause of human-wildlife conflict around the world. Recently, the use of livestock-guarding dogs (LGDs) to reduce livestock depredation has been challenged in terms of their impact on wild animal welfare and survival, but the prevalence of LGD-wildlife interactions is poorly understood. Using data for 225 LGDs on South African farms, we determined the prevalence of farmer-reported LGD-wildlife interactions to contextualise the potential concerns. Wildlife interactions were reported for a total of 71 dogs (32%); McNemar's tests revealed non-lethal herbivore interactions (8%) were significantly lower than non-lethal predator interactions (17%; $p < 0.01$), but no significant difference was detectable in the proportion of lethal interactions according to type of wildlife (9% for herbivores and 10% for predators). All reported predator interactions were defensive, compared to only 25% of reported herbivore interactions ($p = 0.016$). Of the dogs for which data on corrective measures were available, 44% were successfully corrected following intervention. Of the remainder, 42% had ceased exhibiting this behaviour independently or were acting defensively, 21% were removed from the programme, and 11% had died. Reported interactions with predators were rare, entirely defensive, and predominantly non-

lethal. However, interactions with non-target species (herbivores) were more prevalent, necessitating remedial interventions. Overall, the conservation benefit of LGDs does not appear to be outweighed by ethical implications of their use; LGDs were shown to be highly targeted and discriminatory towards predators attempting to predate on livestock.

Introduction

Humans and wildlife are increasingly competing for resources such as space and food, often to the detriment of one or both. In particular, the interface between human settlements and the territories of free-ranging wildlife plays host to some of the most intensive cases of human-wildlife conflict. The consequences of domestic farm animal predation by free-ranging carnivores extend beyond the loss of life (or injury) endured by the livestock. Human livelihoods and agricultural sustainability are also at risk (Baker et al., 2008), which typically translates into a significant threat to carnivore species and biodiversity as a whole (Krafte Holland et al., 2018). A popular and apparently successful method of mitigating livestock-carnivore conflict is the use of Livestock Guarding Dogs (LGDs) (Van Eeden et al., 2017). The success of these dogs has primarily been reported in terms of perceived or occasionally empirically measured reductions in livestock loss around the world (Van Eeden et al., 2018) including southern Africa (Marker et al., 2005; Potgieter et al., 2016; Rust et al., 2013), and their use as a conservation tool has recently begun to be assessed in terms of their impact on wildlife (Allen et al., 2017; Spencer et al., n.d.; Van Bommel and Johnson, 2016).

Key LGD breed characteristics which have been enhanced through careful genetic selection and rearing conditions include “attentiveness” towards the livestock being guarded, “trustworthiness” such that they do not compromise livestock well-being or management, and “protectiveness” whereby they react antagonistically towards anything that may harm or disrupt the livestock (Coppinger et al., 1988, 1983; Landry, 2001). Risk aversion strategies employed by predators are considered to result in encounters with dogs being rare, but where they do occur, predators are deterred by the LGDs placing themselves between the herd and the predator, barking and posturing

(Chestley and Whiting, 2015; Landry, 2001). As such, the dogs are classed as a form of "non-lethal" predator control, thereby facilitating the coexistence of livestock, carnivores, and human land-users. Studies have demonstrated the ability of the dogs to defend their herds without physical interaction if approached by a carnivore; preventing livestock depredation whilst simultaneously reporting no wildlife fatalities or exclusion of predators from surrounding farmland (Allen et al., 2017). Moreover, the breeds used as LGDs are considered behaviourally compelled to remain with the livestock they are guarding and are therefore unlikely to chase wildlife beyond a few hundred metres (Chestley and Whiting, 2015; Coppinger et al., 1988; Landry, 2001; Van Bommel and Johnson, 2016).

However, some studies have reported LGD-wildlife interactions which are contraindicated in conservation, such as those involving the chasing or killing wildlife (Black and Green, 1984; Coppinger et al., 1988; Gingold et al., 2009; Hansen and Smith, 1999; Marker et al., 2005; Potgieter et al., 2016; Timm and Schmidtz, 1989). Even scenarios that may be classified as non-lethal at the time of the interaction (e.g. barking at, chasing off of wild animals) may have lethal or sub-lethal long-term consequences for wildlife such as displacement, ecological and physiological impacts of fear, or injuries that subsequently lead to reduced fitness or mortality (Gallagher et al., 2017; Lima and Dill, 1990), the full impacts of which are only just beginning to be understood in regards to predator-prey interactions (Say-Sallaz et al., 2019). All of this has led to the questioning of whether the term "non-lethal" is appropriately applied to these dogs (Potgieter et al., 2016).

Most recently, the negative welfare implications of LGDs interacting with wildlife have been proposed as being potentially greater than traditional lethal methods of control (Allen et al., 2019a). These authors used a panel of experts and the widely accepted 'Five Domains' method for estimating the welfare implications for animals interacting with LGDs; they provide a compelling argument for the potential of LGDs to inflict significant harm via extended chase periods, less than rapid death, and invoking substantial fear in wildlife (Allen et al., 2019a). However, their conclusions have prompted academic debate, focusing on the point that LGDs are effective in reducing human-wildlife conflict with only minimal interactions with wildlife, in contrast to lethal control methods that rely on the ability to substantially reduce target wildlife populations, necessitating a high mortality rate and therefore incurring welfare concerns for large numbers of animals prior to their deaths (Johnson et al., 2019). Moreover, the conclusions of Allen et al. (2019a) were generalised across all LGDs and did not consider the dogs as individuals with varying frequencies of interaction, or behavioural responses to those interactions. The extrapolation of the potential harm inflicted from a hypothetically modelled dog-wildlife interaction to an actual, realised event practised ubiquitously across the population of LGDs or during all LGD-wildlife interactions is unfounded without empirical testing. We emphasise (as have others (Allen et al., 2019b, 2019a; Johnson et al., 2019)) that the welfare implications of LGD-wildlife interactions warrant serious consideration and are not to be dismissed. However, these impacts occur at an individual, rather than a population level, and therefore the prevalence, as well as the characteristics of interactions per individual dog must be included in any assessment of LGD impact. In support of Johnson et al.'s (2019) call for the inclusion of evidence regarding the frequency and characterisation of LGD-interactions, we utilised an existing database comprising data collected over a 12.5-year period for LGDs deployed across commercial farmlands. Our study population of LGDs in South Africa has been shown to reduce livestock depredation by >95% (Rust et al., 2013) and to be widely considered successful by the farming participants (Wilkes et al., 2018), with a neutral (and, in some cases, potentially positive) impact on predator occupancy (Spencer et al., n.d.), and therefore provided an ideal study population for investigating these concerns.

Methods

All LGDs included were placed by Cheetah Outreach Trust (COT) between 2005 and 2017; placements occurred across South Africa but were concentrated along the northern provinces (Figure 1).

<Figure 1 here>

Upon initial placement of an LGD by COT, farmers agree to cease all lethal predator control activities on their property and to allow regular monitoring of the dog by COT. All food and veterinary care is provided by COT during the training period (up to approx. 1 year of age), after which time these responsibilities are assigned to the farmers (assuming the dog is deemed fit to work by COT project managers).

Dogs were considered to be "working" once they were leaving the kraal with the herd of their own accord and therefore appeared bonded to the herd. All dogs are monitored by COT on an approximately monthly basis up until 12 months of age, and thereafter monitored regularly on a case-by-case basis. During each monitoring point (including on-farm visits and phone communications), COT staff discuss the dog's behaviour and effectiveness with the farmer and a questionnaire is intermittently completed as part of this monitoring process (Table 1). Additionally, in 2014 one researcher (X) conducted face-to-face or telephone interviews with 108 farmers for a separate project (Wilkes et al., 2018); these semi-structured interviews included discussion aligned with monitoring point questions. As such, data relevant to questions included in Table 1 obtained during these interviews were also included. Farmers were not asked about their own behaviour towards wildlife; questions were restricted to the dog's behaviour and performance. Likewise, the concurrent use of herders or other husbandry factors were not investigated, although the use of full-time herders is known to be rare and typically LGDs are obtained with the intention of using them without human company. All dogs were working as solitary guarders, with the exception of rare cases where juvenile dogs were being trained alongside an existing working dog. Non-LGD farm dogs were present on a number of farms but were not consistently included in the reporting process so cannot be quantified here. Data pertaining to reported wildlife interactions were quantified as events only; farmers were not asked to estimate the number of animals involved in each interaction, and dogs were defined as either having had, or never having had an interaction reported (i.e. the data were binary for each interaction type per dog). Where no response was provided, this was treated as missing data, whilst responses from farmers which could not be confidently assigned to a post-hoc category were classed as “unclear”.

<Table 1 here>

Working status was recorded by the COT project managers, including working, removed, retired, moved and not yet working, or moved and working. Moving the dog from one placement to another occurs for various reasons (dog and farmer-related) but is typically a form of corrective training, or the result of an owner retiring from farming. Given the variable reasons for dog movement, which were not always clearly defined in monitoring questionnaires, analysis was performed by dog rather than by placement. However, all status classifications refer only to the dog’s status at the time of study completion. Working life was calculated as the period between the date of placement and either the end of the study period, the death of the dog, or the removal or retirement of the dog.

Responses to open ended questions, or any comments volunteered by farmers and recorded during the monitoring meeting or interview were analysed for content and coded to determine circumstances surrounding any wildlife interactions reported. Farmer-reported (herein referred to as “reported”) wildlife interactions were coded as lethal (resulting in the observed death of wildlife) or non-lethal (physical or direct interaction with no detectable fatality of wildlife), and also according to the type of wildlife involved (herbivore or predator; Table 1). The lethal interactions reported by farmers were investigated by project managers to confirm cause of death where possible; reports and events were occasionally temporally distinct such that no carcass was available for inspection. Reported non-lethal interactions may include some lethal interactions which were undetected (e.g. if wildlife death occurred after the interaction had ceased or carcass was not recovered); estimation of this was not possible in our retrospective analysis.

Reported interactions were classed as “defensive” if the wildlife approached the herd and the dog was considered (by the farmer) to be protecting the herd. “Non-defensive” interactions were those that were observed to be unprovoked by wildlife, i.e. to be instigated by the LGD without any apparent role in protecting the livestock. Farmers were not asked directly whether their LGD had interacted with a predator species, nor whether they perceived the behaviours to be defensive or non-defensive (for any wildlife species), thereby reducing the risk of social desirability bias, especially regarding predators since the project was managed by an organisation with known predator conservation objectives. As such, classification was performed post-hoc by independent researchers (X) using transcribed notes from each monitoring report. Predators included any carnivorous species of wildlife (regardless of size or known depredation on livestock), as well as any non-carnivorous species known to occasionally attack livestock (e.g. baboons). Humans (e.g. thieves, trespassers) were also included in the “predator” category.

Of the included dogs, only records for periods when dogs were ≥7 months of age were analysed; prior to this, dogs were not consistently free-living with livestock and were still undergoing training involving close association with farm staff and therefore not considered relevant for this study. Furthermore, interactions between wildlife and juvenile dogs were rare; data was available for 6 dogs prior to 7 months of age; of these only one report of wildlife interactions (chasing game) was recorded). This dog was subsequently reported to interact with wildlife as an adult and was consequently included in our analysis on that basis. Therefore, exclusion of data from juvenile periods was considered unlikely to have affected analytical outcomes. Dogs that were still juvenile at the final sampling point were excluded entirely as they lacked sufficient monitoring reports.

Reported interactions were not always mutually exclusive (dogs may have been reported with more than one interaction type). The majority of reported herbivore wildlife interactions were considered undesirable from the perspective of the farmer, with the exception of those involving a wild herbivore attempting to integrate with the herd. For dogs reported with undesirable herbivore interactions, the proportion for which corrective training was implemented was calculated; of these, the proportion reported as successfully corrected was calculated. It is acknowledged that herbivore interactions were likely under-reported in the dataset, whereby some farmers preferred to handle the corrective training independently or did not consider the behaviour worthy of reporting. Likewise, corrective training was not always implemented if reported to be a one-off incident. Corrective training for reported predator wildlife interactions was never implemented because all instances of these interactions were considered as being protective of the livestock and therefore not a problematic behaviour (from the farmer's perspective).

McNemar's tests were used to compare related proportional data for interactions with different wildlife (herbivore or predator), and different interaction types (defensive or non-defensive). Differences according to dog sex were tested for significance using a Pearson's Chi-squared test. Data collected between 25 April 2005 and 31 December 2017 were made available for this study and analysed with SPSS (v.24, IBM Corp, 2016) and significance set at $\alpha < 0.05$.

Results

Over the 12.5-year period, a total of 264 dogs were monitored. Thirty-nine of these were removed from analysis because they lacked sufficient monitoring reports; these were either juvenile at the final sampling point (n=9), died within 6 months of age (n=19), or had insufficient data reported for other reasons (n=11), leaving a final sample size of 225 dogs (132 males, 93 females). Of the juvenile dogs excluded, all were listed as "unknown" in regards herbivore interactions and none had any reports of predator interactions. The majority of dogs were Anatolian (n = 189, 84%), with Malutis comprising the remainder (n = 36, 16%). Livestock type guarded was predominantly sheep (55%), followed by goats (31%), cattle (10%), a mixture of small livestock (3%), or game species (1%).

Over the study period, 66 had died (29%), 46 (20%) were removed from farms for dog- or farmer-related concerns (e.g. dog health, welfare, or behaviour, or farmer disengagement from the training programme), 14 (6%) had been retired, and 5 (2%) had been moved from one farm to another. Of the dogs alive at the end of the study (n=159) and classed as "working" (n=96; 60%), the average time spent on placement to date was 45.8 ± 2.98 months, whilst those that had been removed or retired during the study period had an average working life of 34.27 ± 4.54 months (n=60). Three dogs had been moved and were not yet working so were not included in the temporal analysis. The average working life for dogs that had died during the study period was 24.97 ± 2.93 months (n=66).

Wildlife interactions (of any type) were reported for a total of 71 dogs (32%), and then categorised according to the type of interaction (Table 2), the species involved and the observed nature of the interaction (defensive or non-defensive) (Table 3).

<Table 2 here>

When data were analysed according to lethality category, the proportion of dogs reported as having interacted with herbivores with a non-lethal outcome (n=18; 8%) was significantly lower than that for reported non-lethal predator interactions (n=39; 17%; p = 0.004; Table 3). However, no significant difference was detectable in the proportion of reported lethal interaction events with herbivores and predators (Table 3).

<Insert Table 3 here>

The type of interaction (defensive or non-defensive) differed according to whether herbivores or predators were involved; excluding reports where the type of interaction was not classifiable, 100% of dogs reported with at least one predator interaction (regardless of outcome; n=44 reports) were classed as cases where the dog was acting defensively, compared to only 28% of cases for herbivore interactions (n=9/32; p = 0.016).

No effect of dog sex was detectable for the proportion of dogs with at least one report including an observed interaction with predators or herbivores (Table 3). Likewise, the proportion of reported lethal interactions did not differ by dog sex for either herbivore or predator (data according to classification of these interactions (defensive vs non-defensive) were also determined (Table 3) but the sample size was too small for statistical analysis).

Examples of comments made by farmers (anonymised and assigned interview numbers) resulting in reported interactions being classed as defensive against predators included “[the dog] kept a brown hyaena away from the herd and followed it until it left the area” [#40], or “[the dog] successfully defended his herd against baboon and leopard” [#61], or “[the dog] chased a caracal but stopped at the fence when it ran away” [#46], or “[the dog was] seen chasing a cheetah away from the herd and keeping a jackal away from the kraal” [#123]. Similarly, dogs were reported to have “successfully stopped the problem of stock theft since his arrival” [#111], or defended herds against herbivores when “she has chased a bushbuck that was between her flock. She did not kill it” [#212].

Reported lethal interactions with herbivores that were classed as defensive included scenarios where “some new impala were loaded off on the farm and one ran into herd, which the dog saw as a threat to the sheep so killed it” [#30]. Reported non-defensive herbivore interactions were supported by statements such as “the herdsman taught the dog to hunt and he was hunting Kudu” [#14], or “he chased game for several months before killing a nyala bull” [146], or “as the herd got smaller, the dog started to worry the cattle. Then the dog started hunting game” [#16].

Interventions arising from reports of behavioural problems included “the dog was seen chasing a guinea fowl and after being reprimanded it did not happen again” [#46], or “she chased game when they got too near the herd but was verbally reprimanded and did not do this again” [#173]. Less commonly, dogs were “moved to a second farm. The dog was very thin on arrival at the new farm but improved in condition - this reduced its hunting of guinea fowl” [#28].

Of the 34 dogs reported with herbivore interactions, undesirable behaviours were reported as corrected for 15 dogs (44%) but uncorrected for 4 (12%), not attempted in 12 (35%) and the outcomes of training in 3 dogs (9%) were not unclear. Of the 4 dogs exhibiting undesirable behaviour that was not corrected, all were removed from the programme; 3 were removed because of their hunting behaviour, and the fourth was removed for a combination of behavioural problems. The 12 dogs for which no corrective training was attempted were explained as follows: 5 had not been reported to COT during routine monitoring but voluntarily divulged during the interview conducted by one researcher, a further 5 were considered to be one-off events with no further evidence of these behaviours being observed, and in 2 cases the dog was considered to be performing a defensive role. Of the dogs with undesirable behaviours for which records of corrective training were unavailable or unclear, 1 dog was still working, and the farmer reported that although the dog used to chase game it no longer did (no details were available to determine whether corrective training had been implemented). The remaining 2 dogs were both dead at the final sampling point but neither had been reported as chasing game to COT (one farmer divulged he was handling the behaviour independently, but no details were available for the training of the other dog).

The predator species of conservation concern (i.e. classed as Vulnerable or higher, IUCN Red List) reported as being involved in LGD interactions were cheetah (*Acinonyx jubatus*; 5 dogs reported with non-lethal interactions, 0 lethal interactions), leopard (*Panthera pardus*; 12 non-lethal, 0 lethal), lion (*Panthera leo*; 3 non-lethal, 0 lethal), and brown hyaena (*Parahyaena brunnea;* 8 non-lethal, 1 lethal). Other predator species involved were black-backed jackal (*Canis mesomelas*), caracal (*Caracal caracal*), honey badger (*Mellivora capensis*), baboon (*Papio ursinus*), cats (unspecified), African wild cat (*Felis sylvestris lybica*), civet (*Civettictis civetta*), and humans (*Homo sapiens*). These other species were included in reports of non-lethal interactions (22 dogs) and lethal interactions (23 dogs). Herbivore species reported as involved in LGD interactions included impala (*Aepyceros melampus*), nyala (*Tragelaphus angasii*), blesbok (*Damaliscus pygargus phillipsi*), bushbuck (*Tragelaphus sylvaticus*), warthog (*Phacochoerus africanus*), bush pig (*Potamochoerus larvatus*), ostrich (*Struthio camelus*), guinea fowl (*Numida meleagris*), kudu (*Tragelaphus* spp.), springbok (*Antidorcas marsupialis*), steenbok (*Raphicerus campestris*), and waterbuck (*Kobus ellipsiprymnus*). The data collection method was not conducive to estimation of total number of each wildlife species involved or number of interactions occurring per dog; instead data represents number of dogs with at least one interaction reported for the relevant species.

Discussion

Representing the largest LGD dataset published to date (n=225), and spanning over a decade of regular, repeated monitoring points with farmers using these dogs, our findings reveal a markedly lower prevalence of LGDs reported as having interacted with wildlife compared to existing studies. Previously, concerns regarding the conservation implications of LGDs arose following reports of lethal wildlife-dog interactions (Black and Green, 1984; Hansen and Smith, 1999; Marker et al., 2005; Potgieter et al., 2016; Urbigkit and Urbigkit, 2010) or negative ecological or reproductive outcomes for wildlife (Gingold et al., 2009; Van Bommel and Johnson, 2016). The most recent of these represents reports for 79 dogs over a 12-month period and identified over half of the dogs to have killed a predator species known to prey on livestock; the majority of these were black-backed jackals (88% of lethal predator interactions), but also included one cheetah (Potgieter et al., 2016). Likewise, an earlier survey of LGD owners in North America reported 21% of mixed-breed dogs used by Navajo farmers (n=67) were thought to have killed coyotes (Black and Green, 1984). In contrast, lethal interactions with predators were reported for only 10% of LGDs in our study. The prevalence of dogs with reported non-lethal predator interactions (17%) is similar to some previous studies (Allen et al., 2017; Hansen and Smith, 1999; Van Bommel and Johnson, 2016), but lower than others; chasing predators was reported in 91% of Navajo dogs (Black and Green, 1984) and ~80% of farmers in Namibia reported their LGDs as barking or having had confrontations with predators in Namibia (Marker et al., 2005).

Reports of dogs having had predator interactions may have been under-reported in our study since, although farmers were asked if they perceived dogs to be effective in their guarding role, LGD-predator interactions were not specifically queried during monitoring points (although “chasing game” was). Farmers may have been biased towards reporting behaviours they perceived to be problematic, whereas predator interactions are considered desirable in that they reflect the dog performing its protective role. Additionally, farmers in our study had agreed to cease all lethal forms of predator control following placement of a dog. This may have caused some reluctance to report lethal LGD-predator interactions to the conservation NGO conducting the monitoring interviews. However, reports of lethal predator interactions were not criteria for removal of a dog, and therefore reporting these interactions did not disadvantage the farmers. Moreover, where reported the comments were frank and explicit; as such farmer reports of predator interactions are considered reasonably reliable, with minimal under-reporting of the prevalence of dogs with these interactions.

With that in mind, the lower prevalence of dogs involved in predator interactions in our study compared to others could suggest reduced guarding effectiveness. However, livestock losses following placement of these dogs ceased completely in 91% of cases (reductions of between 33 – 100% across all farms) for the first seven years of our study period (2005 and 2011 (Rust et al., 2013)). This is greater than the 70% of farmers reporting complete cessation of livestock depredation in Namibia (Marker et al., 2005); therefore the dogs are achieving high success rates with minimal predator interactions. Alternatively, lower interactions may reflect lower predator population density in our study area compared to previous study sites, but this was not tested. Likewise, it is possible that predators were avoiding the areas patrolled by the dogs as a result of risk aversive behavioural strategies (Landry, 2001) thereby reducing interactions. This is a key factor in the discussion regarding the welfare impacts of LGDs; on the one hand the effectiveness of LGDs in reducing livestock depredation has largely been attributed to the avoidance of LGD-guarded areas by carnivores (Johnson et al., 2019). Yet on the other hand, the 'landscape of fear' and resultant changes in carnivore behaviour are included as indicators of the potential harm inflicted on carnivores by these dogs (Allen et al., 2019a, 2019b). Unlike previous studies, recent research in our study population has actually demonstrated predator occupancy to be equivalent on guarded and unguarded farms (Spencer et al., n.d.). However, further research is warranted to determine the full extent of LGD impacts on wildlife.

Lastly, the lower reported prevalence of dogs with predator interactions may be an artefact of our sampling strategy, namely the exclusion of data from dogs which were still undergoing training. Younger dogs are more likely to engage in play behaviours (Landry, 2001), which may increase the likelihood of them interacting with wildlife during their training period; the inclusion of these younger dogs in other studies may have increased their interaction estimates. However, the low prevalence of wildlife interactions (of any type) in our study dogs during their juvenile period (1 report from 5 dogs with excluded juvenile data) and the fact that this dog was later recorded as interacting with wildlife as an adult so is actually represented in our analysis refutes this as an explanation for our findings. A further nine dogs were excluded entirely as they lacked sufficient lifetime monitoring data and were <7 months of age at the time of our final sampling point, but of the records we had for these dogs none had any reports of wildlife interactions. As such, the low prevalence of predator interactions may be testament to the vigilance of the training and monitoring programme employed, but further research is warranted to confirm this.

Prevalence of dogs with reported interactions with non-threatening wildlife (e.g. ungulates, small mammals) was also low (9% dogs reported with lethal interactions, 8% reported with non-lethal interactions). Wild herbivores are typically assigned high economic and existence values by farmers in this area (many of which include game hunting as a source of revenue) (Child et al., 2012; Snijders, 2012). Interactions between LGDs and wild herbivores are often considered problem behaviours and are therefore unlikely to be under-reported (where observed) by farmers, such that LGD-herbivore interaction data is considered to be more robust than that pertaining to predator interactions. Moreover, reports of these interactions resulted in corrective training (or removal and replacement) of the dog involved by the programme managers, such that this reporting was also not considered to be disadvantageous to farmers. The exceptions to this include farmers who differ in attitudes toward herbivores in general as part of the ecology of the land, variation in attitudes towards different species of herbivore (e.g. kudu valued for hunting, or pests such as damaging-causing warthog), and the degree to which individual farmers are willing to tackle behavioural issues independently as they become more experienced within the culture of LGDs.

In a 3-month observation study of Great Pyrenees LGDs in Norway, wildlife was chased in 85% of cases where wildlife was encountered by the dog (Hansen and Smith, 1999), and reports covering 174 dogs (a range of breeds) over two years included examples of wildlife harassment in 40% of the dogs (Coppinger et al., 1988). Yet individual differences within one LGD breed can be more pronounced than differences between separate LGD breeds (VerCauteren et al., 2014), emphasising the importance of the rearing and bonding phase. Indeed, the Great Pyrenees discussed in Hansen and Smith (1999) were represented by a small sample (10) of improperly bonded dogs that were not from working stock. Other authors have demonstrated the importance of rearing conditions in influencing dog temperament; LGDs reared exclusively with the herd (as per our study dogs) exhibited more human-directed aggression than LGDs reared under more relaxed conditions including some friendly human contact and cohabitation (Marion et al., 2018). This may reflect increased herd-bonding (and subsequently greater protectiveness) in dogs reared without friendly human interaction and could potentially extend to their behavioural response to wildlife encounters. Although it was not possible to determine how often dogs in our study encountered wildlife, reported prevalence of dogs with wildlife-chasing behaviour was encouragingly low compared to these previous studies. Two studies have reported these types of wildlife interactions in Namibia where Anatolian shepherd dogs are also used; the earliest reported much higher prevalence than in our study, with nearly half of LGDs reported to have chased game (Marker et al., 2005), but a more recent study of this population demonstrated a decrease in this to 10%, equivalent to our findings in South Africa (Potgieter et al., 2016).

Aside from the conservation impact of these LGD-wildlife interactions, concern has also been raised regarding the welfare implications for wild animals in LGD-occupied areas (Allen et al., 2019a). Hypothetically, LGDs were described as having the potential to inflict greater harm on wild animals than traditional control methods including poisoning and shooting, either through direct consumptive effects, or indirectly via their role in creating a landscape of fear (Allen et al., 2019a). The welfare implications for wild animals involved in anthropogenic interventions are a valid and poorly represented consideration in conservation (Allen et al., 2019a; Hampton and Hyndman, 2019; Paquet and Darimont, 2010). Researchers acknowledge that very little is known about the disturbance to wildlife caused by free-roaming dogs specifically (Weston and Stankowich, 2014). However, in order to assess the potential risk to the welfare of wild animals interacting with LGDs, dog behaviour-specific and programme-specific knowledge is required.

Specialist breeds of livestock guarding dogs, such as the Anatolian shepherd used here and in Namibia (Marker et al., 2005; Potgieter et al., 2016) have been selectively bred to display particular protective traits, without the functional ancestral predatory behaviours (Coppinger et al., 1988, 1983; Landry, 2001; Marker et al., 2005) and are known to lack a predisposition to chase wildlife (McGrew and Blakesley, 2007). Combined with a strong bond and loyalty towards their herd, this means that these specialist breeds of appropriately trained and managed LGDs are unlikely to engage in interactions with wildlife beyond those arising during the process of herd defence; thus even chasing of non-target species can fall under the definition of protective behaviour in the context of a non-target animal approaching the herd. This is supported by consistent farmer observations of defensive, guarding behaviours such as barking, confronting approaching wildlife, and short chases to ward off predators in our study. Where sufficient detail was available in the records to enable classification of the interaction type, defensive interactions characterised the majority of reported LGD-predator interactions and no non-defensive interactions were reported. As such, although it is possible that some dogs with reported non-lethal interactions resulted in unrecorded fatalities for the wildlife (i.e. as a result of injuries or exhaustion subsequent to the interaction), the documented defensive rather than offensive behavioural characteristics of LGDs (Allen et al., 2017; Chestley and Whiting, 2015; Linhart et al., 1979; McGrew and Blakesley, 2007; Urbigkit and Urbigkit, 2010) indicates LGDs in our study are interacting with predators as part of their protective role, and not indiscriminately.

Similar defensive behaviours have also been reported in previous studies, where researchers observed LGDs to put themselves between the herd and predator to deter the predator, and chases rarely extended beyond 50m from the herd (Landry, 2001; McGrew and Blakesley, 2007). Aligning to the protectiveness characteristic specifically selected for in many breeds of LGDs (Coppinger et al., 1988, 1983; Landry, 2001), others have reported LGDs as only chasing predators that approached the herd (Black and Green, 1984; Marker et al., 2005), and to then only chase them up to 300m from the herd before stopping, barking, and then returning to the herd (Black and Green, 1984). Likewise, LGDs have been demonstrated to use their presence and vocalisations alone to deter predators from approaching the herd (Allen et al., 2017; Landry, 2001; Linhart et al., 1979).

Allen et al. (2019a)'s welfare score was in part based on the duration of dog-wildlife interactions, ultimately assigning them as causing "extreme" harm; they estimated dogs would take a minimum of < 1 minute to chase, and the same minimum time again to kill prey, but would take longer to subdue and kill some prey such as cheetahs and baboons. Although our dataset does not include welfare indicators, interactions were reported by farmers to stop once the wild animal retreated from the area, or the dog reached the fence, suggesting they were of short duration. In other studies interactions have been recorded to last for as little as 2 seconds, although longer interactions (i.e. up to 25 minutes) have also been documented (Hansen and Smith, 1999; McGrew and Blakesley, 2007). As such, the minimum harm inflicted by an LGD-wildlife interaction is likely to be lower than the minimum estimated by Allen et al. (2019a), although the maximum harm may indeed be extreme. Taking our findings together with those of previous studies documenting the nature of LGD behaviours towards wildlife, we suggest that LGDs rarely engage in direct interactions with predators. Where they do interact, our findings indicate that the interactions are brief, are not often lethal (in acute temporal terms), and are generally, if not always, defensive in nature. This draws into question the generalisation of welfare scores assigned to all LGD-wildlife interactions and more broadly to LGDs *in toto* as proposed by Allen et al. (2019a).

In contrast, the majority of dogs reported with herbivore interactions were considered to be acting in a non-defensive manner. Although these reported interactions represented a smaller proportion of the interactions than those occurring with predators, they were typically not considered to be performed as part of the dog’s guarding role and therefore raise ethical and conservation concerns. This aligns more with the hypothesis of Allen et al. (2019a) and, if taken at face value, would support an edited version of their suggestion that [a small proportion of] LGDs are acting as anthropogenically introduced predators in these landscapes with associated ethical implications. However, care should be taken to avoid generalising the ecological impact and trophic role of dogs since they are temporally and environmentally context-dependent (Ritchie et al., 2014). Programmes managing these dogs such as those here and in Namibia (Marker et al., 2005; Potgieter et al., 2016) utilise regular monitoring points to detect instances of undesirable behaviours, subsequently implementing corrective measures, or removing the dogs from the farm. Where behavioural problems arise, such as interactions between an LGD and non-target wildlife, prompt detection, addressing, and elimination of these behaviours is necessary (VerCauteren et al., 2014), thus the speed of implementing corrective measures is critical to developing effective LGDs.

For dogs with concurrent data regarding the attempted correction of these behaviours, nearly half (44%) were successfully corrected following behavioural interventions by the project managers and farmers in our study. This is equivalent to the success rate reported for the Namibian programme which experienced higher prevalence of these problem behaviours (Marker et al., 2005). Although undesirable behaviours were not corrected in 12% of affected dogs, all of these were removed from the programme, reflecting the responsiveness of the organisation to ensuring these behaviours did not persist in the programme. Likewise, many of those classed as either “not attempted” or of “unknown outcome” do not appear to have been on-going concerns based on farmer comments (e.g. one-off incidents, the dog acting protectively, or the dog no longer exhibiting the behaviour despite no record of intervention). Nonetheless, 20% of cases (n=7) were not reported to COT as part of routine monitoring and only ascertained during a separate interview. This lack of reporting resulted in no corrective interventions being implemented, or farmers attempting to remedy the behaviours independently. Improving the reporting rate of undesirable behaviours is likely to decrease the incidence and prevalence of dog-herbivore interactions either through corrective training or the removal of the dog and is therefore an important aspect to address for placement organisations.

Among all dogs monitored over the 12.5-year period, 20% were removed for a range of behavioural problems, including (but not limited to) chasing game. These other behavioural problems have also been reported in other studies (Marker et al., 2005; Potgieter et al., 2016; Rust et al., 2013). A potential explanatory mechanism for this failure rate of individual dogs lies in the management approach taken by the NGO in our study, and likely in the Namibian programme as well. Unlike traditional LGD placement programmes in other continents, where only a small number of LGD puppies from each litter are selected for deployment in the field (Landry, 2001; Ribeiro et al., 2017), all puppies from each litter are made available for placement by the COT programme, in an effort to maximise programme efficiency. Pre-placement selection strategies could therefore offer some solution to the problem of undesirable LGD-herbivore interactions and consequently improve programme sustainability (including ethical acceptability).

Having said that, the possibility remains that LGDs may hunt wildlife species (Allen et al., 2019a; Kelly, 2019) and even rare lethal interactions are likely to inflict substantial harm to the individual animals involved.   It has been suggested that wherever they occur, LGDs will kill and consume small rodents, some may even prey on young fawns (Timm and Schmidtz, 1989; Urbigkit, 2016), and small mammal populations may be negatively impacted in pastures with LGDs (VerCauteren et al., 2014). However, small studies using scat analysis have revealed conflicting evidence in regard to the dietary intake of LGDs. In one case, nearly 20% of scats from 6 dogs contained evidence of vertebrate wildlife species (Kelly, 2019), whilst an earlier study demonstrated very minor contributions of hair from scrubhare (*Lepus saxatilis*) and rodent species (multiple) in 1.6% of scats (n = 123 from 5 dogs) and suggested this was more likely reflective of scavenging than hunting (Vliet, 2011). Scavenging behaviour has been observed in our study dogs during farm visits (R. Wilkes, pers. obs.) supporting this latter conclusion. Diet will likely impact on behaviour and it has been postulated that food with a high protein content fed to Anatolian-type dogs, as in this study, may be associated with hyperactivity and undesirable chasing behaviours (Işik, 2014). In Turkey, LGDs are traditionally fed on grain flour mixed with water, milk or tomato sauce, and are claimed to be more herbivorous than other dogs (Işik, 2014), whereas dogs in our study were provided with a commercially prepared dog kibble diet. In contrast, others suggest that providing a complete and balanced diet formulated for dogs enables LGDs to maintain their condition, improves dog welfare and actually reduces the likelihood of their hunting (i.e. in order to supplement an inadequate diet) (Timm and Schmidtz, 1989). Large scale studies are required to elucidate the prevalence of hunting in LGDs, and the welfare of LGDs deserves greater attention in this respect.

Interactions between LGDs and wildlife have severe welfare implications for the animals involved, even if these are infrequent and/or exhibited by a small number of LGDs. As such, they warrant empirical studies along with comparative investigation of the welfare consequences of other predator control methods in order to make informed, evidence-based wildlife management decisions. We therefore support Allen et al. (2019a)'s call to test their hypotheses regarding the welfare outcomes for both predator- and herbivore-LGD interactions, but advocate that outcomes be considered at the scale of the individual animals involved rather than at population level, in keeping with the definition of animal welfare (Fraser and Duncan, 1997). Therefore, any generic conclusions regarding LGD welfare impacts must incorporate the frequency (per dog) and prevalence (within the population of LGDs) of interactions.

As indicated previously, number of limitations are presented in this study which require consideration when interpreting our findings. Firstly, the use of farmer-reported interaction data introduces the likelihood of recall or response bias. However, monitoring occurred within relatively short periods of time (approximately every 4 weeks for the first 12 months of placement and regularly thereafter) such that reported interactions reflect events that occurred in the recent past. This minimises potential error from inaccurately recalled data (i.e. failed or distorted memory) but does not overcome the issue of response bias. However, since predator interactions were not specifically targeted in the questionnaire and only became of interest to us retrospectively, we have perhaps inadvertently reduced the risk or incidence of response bias, along with factors considered above. Moreover, farmers were typically detailed in their description of reported interactions, including whether the dog was positioned amongst or in close proximity of the herd at the time of the interaction, and the behaviour of the wild animal observed, such that we were able to place some level of confidence in their reports. Any statements which were unclear in regards the type of interaction were recorded as such without speculation. Additionally, by investigating prevalence of dogs with at least one interaction among the LGD population, rather than interaction frequency per dog, our analysis was less reliant on the ability of farmers to recall each and every interaction event. From a welfare perspective one interaction is equally as concerning as >1 interaction, although admittedly from an ecological perspective, frequency of interactions per dog would provide a better understanding of LGD impact on wildlife populations and we encourage future studies to accommodate this.

In contrast, the possible under-reporting of herbivore interactions (discussed above) is perhaps the most concerning; the proportion of dogs reported with herbivore interactions was relatively high given that these are non-target species, such that the actual impact of LGDs on herbivores is of critical concern, and even more so if our findings are an under-estimation. Further research is warranted to empirically measure the frequency of these interactions (e.g. using camera collars and GPS tracking or other similar technologies), whilst interventions to markedly reduce these interactions must continue to be prioritised. Likewise, independent empirical data collection is required to characterise interaction types for all wildlife species, and the number of wild animals involved in each interaction event must also be quantified. Such studies will require considerable investment in time and effort; even if our findings under-estimate interactions by half they will still not be common or frequent. Therefore, the number of dogs (e.g. >100) and extended period of time (e.g. >36 months) required for fieldwork before a representative and reliable dataset could be compiled is likely to explain its absence in the literature thus far.

Secondly, we excluded data for dogs during their early training period as this period involves human supervision of the dogs. Whilst our data indicates that LGD-wildlife interactions were extremely rare for this training period, the possibility exists that juvenile dogs under different training regimes may engage in greater wildlife interactions than adult dogs; this warrants investigation. Other potential issues identified with this dataset were the unknown long-term outcome of non-lethal interactions for wildlife (i.e. those interactions which may subsequently result in death for the wild animal due to injury or exhaustion), and the possibility that human behaviour towards wildlife could have influenced dog-wildlife interactions. These will be less easily resolved in future studies but require acknowledgement and consideration. Though these issues may infer some weakness in the quantitative data we present, we assert that our results provide a reliable qualitative indication that LGDs rarely cause harm to wildlife, and are much less prevalent than might be supposed from their hypothetical potential (i.e. as inferred by Allen et al. (2019a)).

Overall, findings from the current study support the carnivore conservation benefit of LGDs; interactions with predators were uncommon, and entirely defensive (where classifiable), indicating this method is highly targeted and discriminatory towards predators attempting to predate on livestock. Furthermore, the majority of these interactions were non-lethal and predicted to be of short duration based on farmer observations and previously documented accounts of LGD guarding strategies. Although lethal interactions did occur with both predators and herbivores, therefore supporting the suggestion that LGDs should not be termed "non-lethal" (Potgieter et al., 2016), and necessitate consideration of the welfare implications for wild animals (Allen et al., 2019a), their occurrence was rare. However, non-defensive behaviours were observed towards non-target species, and corrective measures or the removal of the dog from the programme must be implemented in these cases so as to minimise harm to wildlife. Nonetheless, within the context of the highly discriminatory behavioural response of the dogs towards wildlife posing a threat to livestock, and the previously determined effectiveness of livestock protection conferred by these dogs (Rust et al., 2013) (subsequently facilitating human-carnivore coexistence), the continued use of LGDs appears to offer great conservation benefit with costs to wildlife being the exception, rather than the rule.

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Declaration of Interests

Three authors (CS, DW, and DC) are employed by (or volunteer for) the organisation responsible for placing the LGDs. Although these authors were involved in the collection of data used in this study, they had no involvement in data analysis; moreover, data collection was conducted prior to this study being launched and therefore collected for the purpose of LGD monitoring only; our analysis of existing data was conducted retrospectively. The other two authors (KWT and RW) are independent researchers and were responsible for the data analysis.

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Figures and Tables

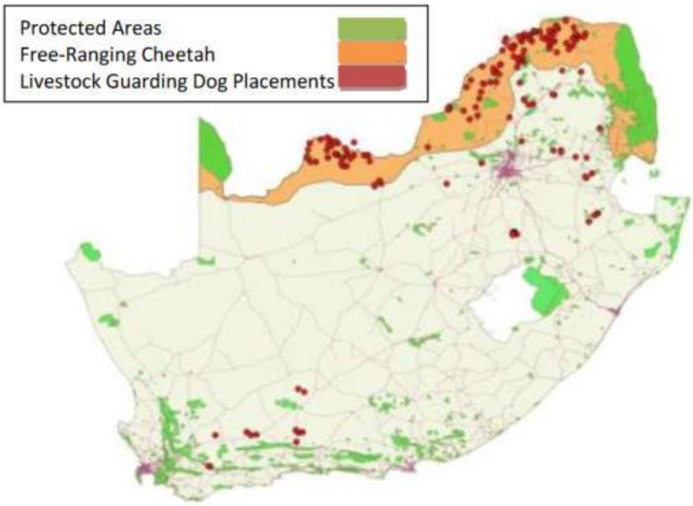

Figure 1. Placement of livestock guarding dogs by Cheetah Outreach Trust in South Africa (dog placements represented by red dots).

Table 1. Questionnaire statements used to collect data from farmers participating in the Cheetah Outreach Trust Livestock Guarding Dog Programme between 2005 and 2017. Only statements relevant to this study are described.

Question or statement	Response options	Use in data analysis
Is the dog having the following behavioural problem?	Chasing game	Non-lethal wildlife interaction (herbivore)
Was corrective training for the behavioural problems implemented?	Yes/No If yes, please describe the corrective training	Corrective training
Was the corrective training effective for the problem?	Yes/No	Corrective training effectiveness
Has any hunting behaviour been observed towards predators and/or any other wildlife?	Yes/No If yes, please describe	Lethal wildlife interactions (herbivore and predator)
Has the dog effectively guarded against predators?	Yes/No Please describe	Predator interactions
Is there anything you would like to bring under our attention?		As relevant

Table 2. Types and prevalence of livestock guarding dog-wildlife interactions reported between 2005 – 2017 in South Africa, representing 225 dogs.

Interaction type (categories are not mutually exclusive)	Number of dogs with each type of interaction reported at least once
Dog-predator interactions	52
Dog-herbivore interactions	34
Interactions with a lethal outcome (for the wildlife)	37
Interactions with a non-lethal outcome (for the wildlife)	52
Interactions in which the dog was considered to be acting in defence of livestock (n=63 classified)	47
Interactions in which the dog was not considered to be acting in defence of livestock (n=63 classified)	16
Male dog-wildlife interactions	45
Female dog-wildlife interactions	26

Table 3. Characteristics of the dog-wildlife interactions reported for Livestock Guarding Dogs (n = 226) between 2005 – 2017 in South Africa.

		Events recorded*		
	Sample size*	**Total***	**Defensive**	**Non-defensive**
All interaction outcomes combined				
Any wildlife-any dog	225 dogs	71 dogs (32%)		
No interaction reported	225 dogs	154 dogs (68%)		
All interaction outcomes combined by wildlife type				
Herbivore-any dog	71 dogs	34 dogs (48%)		
Predator-any dog	71 dogs	52 dogs (73%)		
All reported interaction outcomes with classifiable interaction type (i.e. excluding any unclear reports)*				
Herbivore-any dog	32 dogs		9 (28%)[a]	23 (72%)
Predator-any dog	44 dogs		44 (100%)[b]	0 (0%)
All herbivore interaction outcomes combined according to dog sex*				
Herbivore-male dog	34 dogs	19 dogs (56%)[a]		
Herbivore-female dog	34 dogs	15 dogs (44%)[a]		

All predator interaction outcomes combined according to dog sex*				
Predator-male dog	52 dogs	35 dogs (67%)[a]		
Predator-female dog	52 dogs	17 dogs (33%)[a]		
Categorised as lethal interaction outcome regardless of interaction type*				
Lethal interaction herbivore-any dog	225 dogs	21 dogs (9%)[a]		
Lethal interaction predator-any dog	225 dogs	23 dogs (10%)[a]		
Categorised as non-lethal interaction outcome regardless of interaction type*				
Non-lethal interaction herbivore-any dog	225 dogs	18 dogs (8%)[a]		
Non-lethal interaction predator-any dog	225 dogs	39 dogs (17%)[b]		
Categorised by interaction outcome according to dog sex with classifiable interaction type				
Lethal interaction herbivore-male dog	14 dogs		4 dogs (29%)	10 dogs (71%)
Lethal interaction herbivore-female dog	6 dogs		1 dog (17%)	5 dogs (83%)
Lethal interaction predator-male dog	11 dogs		11 dogs (100%)	0 dogs (0%)
Lethal interaction predator-female dog	8 dogs		8 dogs (100%)	0 dogs (0%)

*Categories were not always mutually exclusive such that each dog could have more than one report or be included in more than one category. For example, a dog could be reported as having both a lethal and non-lethal interaction, or as having interacted with both a herbivore and a predator.

[a,b] Different superscripts between rows indicates differences were significant ($p < 0.05$). This only applies for comparisons among pairs of data within each section of the table, and statistical analyses were not feasible between all rows. No superscripts are presented where no analysis was performed.