THE EFFECTIVENESS OF LIVESTOCK GUARDING DOGS FOR LIVESTOCK PRODUCTION AND CONSERVATION IN NAMIBIA

By

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DECLARATION

I, Gail Christine Potgieter (210122668), hereby declare that the dissertation for the degree of Master of Science is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification.

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Acknowledgments

When I embarked on my mission to obtain my MSc, my goal was fairly simple – to learn more about the use of livestock guarding dogs in Namibia and, in the process, to obtain a postgraduate degree. I have learned far more than I ever expected, certainly more than could be written within the bounds of this dissertation. I therefore wish to thank not only those that directly assisted me in the completion of this dissertation, but the many people who have made the few years I have spent in Namibia especially memorable.

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Dedication

This work is dedicated to the farmers that patiently answered my many questions and to the brave livestock guarding dogs of Namibia.

Table of Contents

Abstract

The use of livestock guarding dogs (LGDs) to mitigate farmer-predator conflict in Namibia was evaluated. As farmer-predator conflict has two sides, LGDs were evaluated in terms of livestock production and conservation. The main objectives in terms of livestock production were to document: 1) the perceived ability of LGDs to reduce livestock losses in a cost-effective manner; 2) the farmers' satisfaction with LGD performance; and 3) factors influencing LGD behaviour. The main objectives in terms of conservation were to record: 1) predator killing by farmers relative to LGD introduction; 2) direct impacts of LGDs on target (damage-causing) species; and 3) the impact of LGDs on non-target species.

This evaluation was conducted on LGDs bred by the Cheetah Conservation Fund (CCF) and placed on farms in Namibia. The data were collected during face-to-face interviews with farmers using LGDs. Historical data from the CCF programme were used in conjunction with a complete survey of the farmers in the CCF LGD programme during 2009-2010.

In terms of livestock production, 91% of the LGDs (n = 65) eliminated or reduced livestock losses. Subsequently, 73% of the farmers perceived their LGDs as economically beneficial, although a cost-benefit analysis showed that only 59% of the LGDs were cost-effective. Farmers were generally satisfied with the performance of their LGDs. However, farmer satisfaction was more closely linked to good LGD behaviour than the perceived reduction in livestock losses. The most commonly-reported LGD behavioural problems (n = 195) were staying at home rather than accompanying the livestock (21%) and chasing wildlife (19%). LGD staying home behaviour was linked to a lack of care on subsistence farms, as high quality dog food was not consistently provided. Care for LGDs declined with LGD age on subsistence, but not commercial, farms.

In terms of conservation, predator-killing farmers killed fewer individuals in the year since LGD introduction than previously; this result was only significant for black-backed jackal *Canis mesomelas*. However, 37 LGDs killed jackals, nine killed baboons *Papio ursinus*, three killed caracals *Caracal caracal* and one killed a cheetah *Acinonyx jubatus* (n = 83). Farmers and LGDs combined killed significantly more jackals in the survey year than the same farmers (n = 36) killed before LGD introduction. Conversely, five farmers killed 3.2 ± 2.01 cheetahs each in the year before LGD introduction, whereas LGDs and these farmers combined killed only 0.2 ± 0.2 cheetahs per farm in the survey year. Only 16 LGDs (n = 83) killed non-target species.

The high LGD success rate in terms of livestock production was facilitated by livestock husbandry practices in the study area. In terms of conservation, LGDs were more beneficial for apex predators than for mesopredators and had a minor impact on non-target species.

1. General Introduction

The focus of this study is to evaluate the use of livestock guarding dogs (LGDs) to mitigate conflict between livestock farmers and predators. To provide the context for this evaluation, I highlight the complex, double-sided nature of human-wildlife conflict (HWC) and categorise common mitigation measures. This chapter focuses on the conflict between Namibian farmers and cheetahs *Acinonyx jubatus*, as the LGDs evaluated here are part of the Cheetah Conservation Fund's (CCF) LGD programme in Namibia. Lastly, a set of evaluation criteria are drawn from published human-wildlife conflict mitigation literature to provide the basis for LGD evaluation.

1.1. Human-predator conflict

1.1.1. The ancient, global conflict between humans and predators

The relationship between humans and predators stretches back for millennia and is characterised by conflict arising from the perceptions of humans and the characteristics of predators. Humans perceive predators as a threat to their lives, a competitor for prey (domestic and wild) and, more recently, a threat to their livelihoods (Graham *et al.* 2005; Thirgood *et al.* 2005). Predators, particularly large-bodied species, require a substantial prey base, large tracts of suitable habitat and can be dangerous to people (Sillero-Zubiri & Laurenson 2001; Treves & Karanth 2003).

The conflict between livestock producers and predators has been identified as the most common form of human-wildlife conflict globally (Thirgood *et al.* 2005). The domestication of livestock by people has produced animals that are especially vulnerable to predation (Linnell *et al.* 1999; Thirgood *et al.* 2005). Furthermore, livestock farmers have historically eradicated the natural prey species of large predators due to the perception that wild herbivores compete with domestic species for food (du Toit 2011). In more recent history, habitat destruction, human population expansion, the abandonment of traditional livestock husbandry practices and recoveries of large carnivore populations have exacerbated this age-old problem (Jackson *et al.* 1996; Linnell *et al.* 1996; Messmer 2000; Woodroffe 2000; Musiani *et al.* 2005; Sillero-Zubiri *et al.* 2007).

To develop suitable conflict mitigation measures, it is essential to recognise the two-sided nature of conflict and the complexities arising from both the human communities and predator species involved (Messmer 2000; Treves & Karanth 2003; Madden 2004; Thirgood *et al.* 2005; Woodroffe *et al.* 2005; Sillero-Zubiri *et al.* 2007). Here, I highlight factors that typically complicate conflict mitigation between livestock producers and predators, and link these to the use of LGDs.

1.1.2. The human side of conflict – attitudes, livelihoods and livestock husbandry

Due to the global nature of HWC, human communities involved in conflict are highly diverse with respect to cultures, traditions, values and economic stature (Manfredo & Dayer 2004). Furthermore, the external stakeholders involved in conflict mitigation (e.g. governments, conservation organisations and animal welfare groups), frequently hold different views to those held by the people directly affected by conflict (Madden 2004). Thus, HWC is complicated by interactions between stakeholder groups that vary according to socio-economic backgrounds, perspectives on wildlife management and attitudes towards wildlife. These views can be particularly divergent regarding large carnivores (Bjerke & Kaltenborn 1999; Berg 2001; Røskaft *et al.* 2003).

The stakeholders directly affected by human-predator conflict are most often livestock farmers (Graham *et al.* 2005; Thirgood *et al.* 2005). Although the factors mentioned previously play an integral role in forming farmer attitudes towards predators, the real and perceived threat that predators pose to livestock is the direct cause of farmer-predator conflict (Oli *et al.* 1994; Marker *et al.* 2003b; Graham *et al.* 2005). The loss of livestock, especially when valuable animals or many animals are killed, reduces farmer tolerance and can lead to retaliatory killing of predators (Jackson & Wangchuk 2001; Holmern *et al.* 2007; Kissui 2008).

Worldwide, livestock husbandry has been linked to the severity of the conflict between livestock farmers and predators (Graham *et al.* 2005). This link is exemplified in European countries where carnivore eradication led to the abandonment of intensive livestock husbandry (i.e. enclosing livestock at night and herding them by day) in favour of extensive husbandry (i.e. livestock remain unattended on the open range); livestock are now vulnerable to depredation by recovering predator populations (Cozza *et al.* 1996; Landa *et al.* 1999; Stahl *et al.* 2001; Espuno *et al.* 2004). Studies in African countries have found that farmers practising intensive husbandry lose fewer livestock than those that farm extensively (Ogada *et al.* 2003; Woodroffe *et al.* 2007; Gusset *et al.* 2009).

1.1.3. The predator side of conflict – species conservation and ecological implications

Retaliatory killing of predators by livestock farmers has been described as one of the most pressing concerns for carnivore conservation (Treves & Karanth 2003), even among nominally protected populations (Woodroffe & Ginsberg 1998). However, not all carnivore species are at equal risk to human influences. Cardillo *et al.* (2004) found that carnivore species that naturally occur at low population densities, have slow life-histories, require large hunting areas and large prey species are at greater extinction risk than other species. Additionally, species that attack during the day, pose a threat to human life, prey on expensive livestock and evoke negative, culturally-determined human attitudes are particularly vulnerable to retaliatory killing (Berg 2001; Kissui 2008).

The predators that most commonly cause livestock losses are medium- to large-sized carnivores and are an important component of natural ecosystems (Terborgh *et al.* 1999; Miller *et al.* 2001). The conservation of predators is therefore a priority for restoring and maintaining ecosystems (Soulé 2010). Additionally, the availability of natural prey outside protected areas has been shown to influence the level of livestock depredation, as predators switch to domestic prey when wild prey are scarce (Meriggi & Lovari 1996; Patterson *et al.* 2004; Bagchi & Mishra 2006).

Relationships among carnivores further influence human-predator conflict, as the eradication of apex predators outside protected areas (Woodroffe & Ginsberg 1998) leads to the competitive release of mesopredators (Brashares *et al.* 2010). Mesopredators occurring at high densities can cause severe livestock losses and are generally resilient to human persecution, even when this is well-funded and extensive (e.g. for coyotes *Canis latrans*, Berger 2006; and black-backed jackals *Canis mesomelas*, Stadler 2006). Furthermore, mesopredators may assume the role of apex predators in systems where the latter have been eradicated; the effective control of the new 'apex' predators further compromises ecosystem stability (Brashares *et al.* 2010). Thus, strong ecological arguments exist for the reintroduction of apex predators, but this management action is severely hampered by the real and perceived threats that predators pose to livestock production (Macdonald & Sillero-Zubiri 2002).

1.1.4. The need for two-sided evaluations of conflict mitigation measures

In order to comprehensively address the suite of factors outlined above, management strategies may require long-term sociological, economical and biological studies to be conducted under locally specific conditions (Treves & Karanth 2003). Furthermore, individual conflict mitigation measures must be evaluated with respect to both sides of HWC (Madden 2004). However, mitigation measures are often evaluated from only one side – either in terms of their effectiveness for addressing human needs (e.g. by reducing livestock losses, Smith *et al.* 2000; Marker *et al.* 2005a) or in terms of their conservation benefit (e.g. by reducing retaliatory killing of predators, Mishra *et al.* 2003; Balme *et al.* 2009). In this study, I provide the first evaluation of LGDs as a mitigation tool from both the livestock production and conservation perspectives.

1.2. Lethal and Non-lethal Approaches to HWC Management

1.2.1. Categorising management options

Due to the complex nature of HWC, the methods used to address conflict range from specialized tools used by wildlife management professionals through to simple methods used by individual livestock producers (Treves & Karanth 2003; Shivik 2006). As the main focus of this study is the evaluation of LGDs used by local farmers, I focus on methods of predation control available to individual farmers. These methods can be broadly categorised into those that are designed to kill predators (lethal control) and those that are intended to protect livestock without killing predators (non-lethal control).

1.2.2. Lethal versus *non-lethal control methods*

The use of non-selective lethal control in retaliation to or in order to prevent livestock depredation has contributed to the decline of several carnivore species (Marker-Kraus *et al.* 1996; Woodroffe & Frank 2005; Kissui 2008; Karanth & Chellam 2009; Snow 2009). Nonetheless, individually-selective lethal control could indirectly benefit carnivore populations, if these lead to increased farmer tolerance for non-damage-causing individuals within the population (Treves & Naughton-Treves 2005; Shivik 2006). However, such highly selective methods generally require greater expertise and effort than blanket predator control and are thus typically less practical for use by individual farmers (Mitchell *et al.* 2004).

Traditionally, non-lethal control methods have centred on livestock husbandry, where livestock were guarded by humans and/or dogs by day and kept in enclosures near human settlements by night (Ogada *et al.* 2003). These husbandry practices were often used in combination with lethal control methods, with the primary goal of reducing livestock losses (Breitenmoser *et al.* 2005), and little concern for predator conservation. Nonetheless, carnivore conservationists promote traditional husbandry methods, including the use of LGDs, as a means of mitigating farmer-predator conflict in a non-lethal manner (Ogada *et al.* 2003; Marker *et al.* 2005a; Woodroffe *et al.* 2007; Gusset *et al.* 2009).

Although the use of LGDs is generally considered non-lethal (Shivik 2004; Breitenmoser *et al.* 2005; Gehring *et al.* 2006), traditional Eurasian shepherds actively selected LGDs that showed aggression towards canids and would therefore attack wolves (*Canis lupus*) that approached the livestock (Urbigkit & Urbigkit 2010). Furthermore, domestic dogs are known to have negative impacts on the environment by killing wild carnivores and other wildlife (Lenth *et al.* 2008; Vanak & Gompper 2009). The evaluation of LGDs presented here challenges the rigid classification of LGDs as a non-lethal method of predator control and explores their potential impacts on non-target species.

1.3. Farmer-Cheetah Conflict in Namibia

1.3.1. Farming practices and predators in Namibia

Namibian farmers have historically removed predators (by trapping and/or shooting) occurring on farmlands as a real and perceived threat to their livelihoods (Marker-Kraus *et al.* 1996). Consequently, the largest carnivores – lion *Panthera leo* and spotted hyaena *Crocuta crocuta* – have largely been eliminated from private farmlands, except those immediately adjacent to protected areas (Stander & Hanssen 2003). This has created a refuge for cheetahs, which are subordinate competitors to lions and spotted hyaenas; these species cause high levels of cheetah cub mortality (Laurenson 1995) and frequently steal cheetah kills (Hunter *et al.* 2007).

Another relatively recent change on Namibian farmlands is the increase in game numbers on freehold and communal land. Due to changes in government policy, commercial farmers and, more recently, communal farmers (in gazetted communal conservancies) have been granted utilisation rights over game species (Skyer 2003). Thus, in areas where wild herbivores were formerly eradicated due to alleged competition with livestock, wildlife are now tolerated, encouraged and even reintroduced on Namibian farmlands (Richardson 1998; Naidoo *et al.* 2010). Many of the game species now recovering in Namibia are the natural prey of cheetahs (Marker *et al.* 2003b). The actions of farmers have thus benefitted cheetahs in Namibia by releasing both top-down and bottom-up controls of the population. Consequently, the Namibian cheetah population is the largest in the world and Namibia is considered to be a conservation stronghold for this species (Purchase *et al.* 2007).

Despite the relatively positive situation of the Namibian cheetah population, the threat of farmer-predator conflict remains. As a semi-social species, cheetahs are frequently found in groups: related males form coalitions and females, although solitary, are often accompanied by litters of cubs (Durant 2007). Additionally, cheetahs (particularly males) use marking trees within their home ranges for intraspecific communication (Marker-Kraus *et al.* 1996). Some farmers in Namibia have become adept at identifying marking trees as sites for cage trap placement, which can lead to the removal of coalitions or family groups in single trapping attempts (Marker-Kraus *et al.* 1996). This is compounded by the fact that several groups use the same marking trees and that cheetah removals on individual farms may cause a population sink that draws cheetahs in from a large area (Marker *et al.* 2003a). Thus, farmers that have identified marking trees and perceive cheetahs as a threat to their livestock or farmed game can kill high numbers of cheetahs annually (Marker *et al.* 2003b). The protection of livestock from the threat of cheetah predation (even if this is mostly a perceived threat) has thus been recommended as a means of reducing indiscriminate killing of cheetahs in Namibia (Marker *et al.* 2005a).

1.3.2. Livestock husbandry and guarding dogs in Namibia

In the north-central region of Namibia, the traditional methods of confining livestock at night and herding during the day are still widely used for sheep and goats (Marker-Kraus *et al.* 1996; Schumann 2009). However, herding practices are declining in communal areas as children that would have been used as herders are sent to school instead (Jones & Elliott 2006). Furthermore, most commercial farmers in the north-central region of Namibia keep small stock on a non-commercial basis; the employment of herders is therefore not always cost-effective (Marker-Kraus *et al.* 1996). Nevertheless, Schumann (2009) found that emerging commercial (farmers that have bought entire commercial farms since Namibia's independence) and resettled (farmers that have been placed by the Namibian government on portions of commercial farms) farmers in this region view small stock production as a significant source of income; thus, two-thirds of the farmers in Schumann's (2009) survey employed herders.

In addition to using herders, many Namibian farmers use domestic dogs to guard their small stock. Marker-Kraus *et al.* (1996) found that 35% of the commercial farmers in their survey had dogs with their livestock and Schumann (2009) found that 72% of the emerging commercial farmers they surveyed used dogs. However, in both studies it appeared that the dogs had limited effectiveness for reducing livestock losses (no apparent reduction in losses, Marker-Kraus *et al.* 1996; 30% of the farmers with dogs reported some reduction in losses, Schumann 2009). These authors suggested that the reported lack of LGD effectiveness was due to the type of dog used (herding-type, rather than guarding-type) and/or incorrect training methods. Among subsistence farmers, the Damara people of north-western Namibia have traditionally used dogs to guard their small stock (Coppinger & Coppinger 2001), but no study to date has evaluated the effectiveness of these dogs for reducing livestock losses.

As is typical for human-predator conflict management, mitigating farmer-cheetah conflict in Namibia will require a long-term, multi-disciplinary approach that considers the complex human socio-economical and predator biological factors involved (Marker & Dickman 2004). However, the focus of this study is not to examine the entire conflict management strategy, but rather to closely evaluate the use of a specific conflict mitigation method – livestock guarding dogs.

1.4. Livestock Guarding Dogs

1.4.1. Raising and training livestock guarding dogs

Protecting livestock from predators is perhaps the oldest use that humans have for domestic dogs (Coppinger & Coppinger 2001). The practice of raising and training LGDs is best known from eastern Europe and Asia, where dogs accompany shepherds with several thousand livestock on seasonal migrations (Coppinger & Coppinger 2001). Dogs on these migrations have historically been subjected to intense selection pressure due to the harsh environment in which they worked and the preference of shepherds for dogs with good instinctive behaviour (Coppinger & Coppinger 2001). In addition to producing the known breeds of LGDs, Eurasian shepherds passed down their traditional knowledge of using LGDs, which provided the basis for LGD training guidelines worldwide (Rigg 2001).

Although training and breeding LGDs originated in the Old World, using LGDs with the specific purpose of mitigating farmer-predator conflict has been popularised in the USA (Smith *et al.*

2000). American researchers involved in animal damage control travelled to European countries to learn about the traditional use of LGDs in those countries (reviewed by Smith *et al.* 2000). These training methods have since been refined with additional knowledge on dog behaviour (Coppinger & Coppinger 2001) and guidelines have been produced for farmers using LGDs under various management conditions (Lorenz & Coppinger 1986; Green & Woodruff 1990; Dawydiak & Sims 2004; van Bommel 2010). The basic training methods for LGDs are outlined below.

Ideally, LGDs should be bred from known lines of working dogs and the parents should be active working LGDs (Dawydiak & Sims 2004). The key element in training LGDs is bonding them to the livestock, which is only possible during the critical social bonding period of domestic dogs, between 4-16 weeks of age (Coppinger & Coppinger 2001). To facilitate interspecific bonding, puppies should be exposed to the smells, sights and sounds of a livestock kraal (night-time enclosure) from as young as possible (Coppinger & Coppinger 2001). The puppy should be introduced to livestock (i.e. placed in the same pen) immediately prior to or soon after weaning (6-8 weeks old) and should remain penned with livestock until it is strong enough (usually 3-5 months old) to accompany them into the field (Lorenz & Coppinger 1986; van Bommel 2010). In order to ensure a strong social bond to livestock, human handling of LGD puppies should be limited during the critical period and the dog should never be treated as a pet (Lorenz & Coppinger 1986).

During the critical social bonding period, LGD puppies should be corrected for excessively playing with livestock, although gentle play is a sign of successful social bonding (Coppinger & Coppinger 2001; Dawydiak & Sims 2004). Although LGD breeds tend to have limited predatory instincts, many LGDs develop incomplete predatory behaviours (e.g. grab-biting) after the critical bonding period (Coppinger & Coppinger 2001). Immediate correction of this behaviour will ensure that it is eliminated from the dogs' behavioural repertoire (Coppinger & Coppinger 2001; Dawydiak & Sims 2004). Lastly, supervision of juvenile LGDs whilst they accompany livestock into the field will ensure that they remain with the livestock and allow for immediate correction of wildlife-chasing and other undesirable behaviour (Lorenz & Coppinger 1986; Schumann 2003).

1.4.2. The Cheetah Conservation Fund LGD programme in Namibia

In response to the need for farmer-cheetah conflict mitigation, CCF established a LGD breeding programme near Otjiwarongo in north-central Namibia in 1994 (Marker *et al.* 2005a). The programme provides farmers with Anatolian Shepherd or Kangal dogs, along with information on raising and training LGDs. Farmers apply to CCF for LGDs and are placed on a waiting list; priority is given to those farmers reporting livestock losses to cheetahs, although farmers reporting other predator problems are also considered (Marker *et al.* 2005a). The puppies are given to farmers at eight weeks old; at this time the farmers attend a training session at CCF where the raising and training of LGDs is covered in detail (Marker *et al.* 2005a). Each farmer pays a minimal fee for the LGD (see Chapter 2) and signs a contract, stating that if the LGD is not cared for according to CCF guidelines, CCF retains the right to resume ownership of the LGD.

LGDs bred by CCF are widely distributed on farms in Namibia (Fig.1.1), which is characterised by a semi-arid climate (Mendelsohn *et al.* 2002). The areas in which most LGDs were placed vary in vegetation structure from thornbush, highland and *Mopane* savanna, to the central and northern Kalahari and the Karstveld (Mendelsohn *et al.* 2002). Fewer LGDs were placed in the southern regions of Namibia (characterised by the Nama Karoo, Mendelsohn *et al.* 2002), as cheetahs have been extirpated from this region (Purchase *et al.* 2007) and the small stock are not herded or kraaled at night (Mendelsohn 2006). Thus, the evaluation of LGDs presented here applies to their use in various habitats within a semi-arid climate, but is limited to the use of LGDs with intensive small stock husbandry.

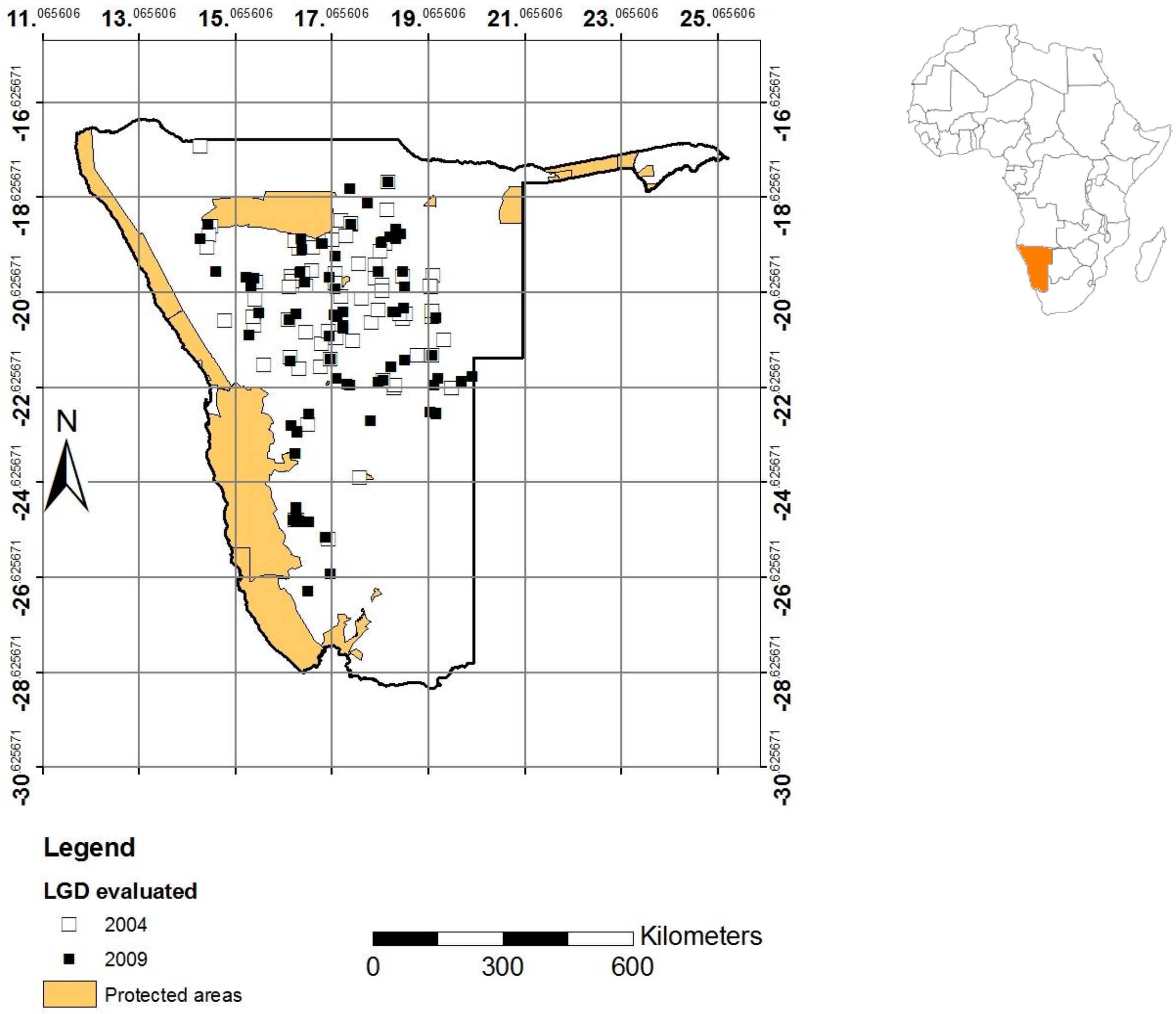

Fig. 1.1. The locations of the LGDs evaluated in this study in Namibia (highlighted in the map of Africa), represented here are those LGDs evaluated using the 2004 and 2009 versions of the questionnaire.

1.5. Evaluating Livestock Guarding Dogs

1.5.1. Evaluation criteria

In this study, I aimed to provide an evaluation of LGDs that would be comparable to evaluations of other methods used to mitigate human-predator conflict. To this end, I sought criteria in published scientific literature for evaluating both lethal and non-lethal methods. Mitchell *et al.* (2004) and Shivik (2006) provided such criteria; the former approached conflict mitigation from the perspective of livestock production and the latter from the perspective of predator conservation. Each set of criteria provided by these authors were categorised according to those most important for livestock producers – the focus of Chapter 2 – and those most relevant in terms of conservation – the focus of Chapter 3.

Mitchell *et al.* (2004) examined the management options for a widespread predator (coyote), with the overall objective of reducing livestock losses suffered by producers in the USA. They suggest that ideal methods of predation management (both lethal and non-lethal) are those that 1) selectively control predation by dealing with individual problem-causing predators, 2) effectively reduce livestock depredation for the maximum length of time, 3) are cost-effective relative to the livestock losses experienced, 4) have a minimal impact on the environment and 5) are socially acceptable to the public. Criteria 2 and 3 are used in Chapter 2 and criteria 1 and 4 are adapted in Chapter 3 to evaluate LGDs in terms of livestock production and conservation, respectively. Although LGDs evaluated in this study killed predators (see Chapter 3), LGDs are currently considered to be non-lethal and thus socially acceptable (Breitenmoser *et al.* 2005); criterion 5 was therefore not included in this evaluation.

Shivik (2006) proposed that the effectiveness of non-lethal methods be evaluated according to their biological and economic efficiency and the farmers' psychological assuagement. An economically efficient method is defined by Shivik (2006) as one that has minimal cost and complexity and lasts for an extended period of time. He defined farmer psychological assuagement as the degree to which farmers perceive a method to be effective. The economic efficiency and psychological assuagement criteria were used in Chapter 2 of this study. Shivik (2004) defined biological efficiency as the relationship between the conservation benefit and economic efficiency of non-lethal methods with respect to the population size of the target predator species. Thus, individual-based methods that are complex and expensive would be biologically efficient for endangered species, whereas population-based methods that are cheap and simple would be favoured for managing locally abundant species (Shivik 2004). The biological efficiency criterion was adapted in Chapter 3 to evaluate LGDs in terms of their effects on different target predator species in Namibia.

1.5.2. Primary research goals and key questions

The primary goal of Chapter 2 was to evaluate the use of LGDs as a means of reducing livestock losses. This chapter builds on previous research on the CCF programme (see Marker *et al.* 2005a) by investigating reasons for LGD effectiveness and behavioural problems. Chapter 2 was designed to answer the following key research questions.

- Do LGDs perform satisfactorily in the farmers' opinions and which LGD behaviours influence farmer satisfaction the most?
- Are LGDs perceived as cost-effective by Namibian farmers and how does this compare with an economic cost-benefit analysis?
- Are LGDs equally applicable for use by commercial and subsistence farmers and do these farmers interact with their LGDs differently?
- What is the effective maximum working lifespan of LGDs in Namibia?

- Can adult LGD success and/or behavioural problems be predicted from evaluations of young LGDs?
- Are common LGD behavioural problems linked to supervision of and/or care provided for LGDs by the farmers?

The primary goal of Chapter 3 was to provide an evaluation of LGDs as a method for reducing predator killing on farmlands, and to document their potential impacts on target and non-target species. Chapter 3 was designed to answer the following research questions.

- Do farmers control predator species in accordance with livestock losses they attribute to those species?
- Do commercial and subsistence farmers that receive LGDs respond by reducing the number of predators they kill on their farms?
- Do LGDs kill any predators themselves and, if so, how does this compare to the number of predators killed by farmers?
- Which predator species are afforded the greatest conservation benefit by the introduction of LGDs?
- Do LGDs kill non-target species and, if so, what is the prevalence of this behaviour among LGDs in the CCF programme?
- What are the behavioural and circumstantial reasons for LGDs killing non-target species?

In the concluding chapter, the effectiveness of LGDs for livestock production and conservation are synthesized to provide a balanced evaluation of LGDs. The overarching goal of the current study is thus to critically examine the use of LGDs to mitigate farmer-predator conflict.

2. The Effectiveness of Livestock Guarding Dogs for Livestock Production

2.1. Introduction

2.1.1. The conflict between livestock farmers and predators

Livestock depredation is one of the main sources of conflict between people and predators worldwide (Sillero-Zubiri & Laurenson 2001; Graham *et al.* 2005; Thirgood *et al.* 2005; Inskip & Zimmermann 2009). This conflict affects farming communities, which bear the direct and indirect costs of coexisting with predators (Butler 2000; Distefano 2005; Rabinowitz 2005; Bagchi & Mishra 2006). Thus, in mitigating farmer-predator conflict, it is important that the suggested mitigation techniques are cost-effective, acceptable and applicable to the farming community (Breitenmoser *et al.* 2005). This chapter focuses on evaluating the use of LGDs from the livestock farmer's perspective.

2.1.2. Direct costs of conflict for livestock farmers

The direct cost of conflict for farming communities is the loss of livestock that are utilized for their meat and other products (Jones 2004; Thirgood *et al.* 2005). Although these costs appear relatively easy to calculate in monetary terms, not all animals lost are of equal value to the farmer (e.g. prized breeding animals vs. substandard animals) and the potential value of young animals lost to predators is difficult to estimate (Shwiff & Bodenchuk 2004; Nyhus *et al.* 2005). Moreover, livestock losses affect commercial farmers differently to subsistence farmers; these differences must be taken into account when considering their responses to livestock depredation (Romañach *et al.* 2007).

For commercial farmers, the economic losses can cause individual farmers to halt or change their farming operations in response to livestock depredation (Shelton 2004). Livestock farming as a business enterprise is typically run with narrow profit margins that are vulnerable to even slightly above-average livestock losses to any cause (Mitchell *et al.* 2004). The impacts of livestock depredation on commercial farming can negatively influence agricultural production and hence the economy at local and regional levels (Jones 2004; Patterson *et al.* 2004). Namibia depends heavily on the commercial livestock industry for its agricultural output (Bowles *et al.* 2005); thus, livestock depredation has the potential to negatively affect the economy of the country.

Although predator damages to commercial farming may influence the economy negatively, the loss of livestock is more devastating for small-scale subsistence farmers and their families (Oli *et al.* 1994; Wang & MacDonald 2006; Romañach *et al.* 2007). Studies in other African countries have shown that losses due to depredation can represent a significant percentage of subsistence farmers' net annual income (Butler 2000; Holmern *et al.* 2007). For countries such as Namibia, with large rural populations depending on livestock for their livelihoods, reducing livestock depredation is important as part of rural development and poverty alleviation goals (M.E.T. 2005).

2.1.3. Indirect costs of conflict for livestock farmers

The price of coexistence with predators is generally higher for farmers than the loss of livestock alone, which does not include the indirect costs suffered (Hill 2004; Jones 2004). Indirect costs mainly comprise the time and money spent by the farmer on reducing livestock losses to predators (Jones 2004; Thirgood *et al.* 2005). Other indirect costs are poorly studied, such as the reduction in livestock production due to changes in livestock behaviour in the presence of predators (Howery & DeLiberto 2004). The time and money spent using LGDs to reduce livestock losses can be considered an indirect cost of the conflict between farmers and predators.

2.1.4. Evaluating LGDs within the CCF programme

The CCF dog programme is designed to reduce the costs of LGDs through discounting the purchase price of the dogs and dog food, which allows the inclusion of subsistence farmers that would otherwise struggle to afford LGDs. Furthermore, CCF aims to reduce the complexity of using LGDs by providing farmers with training materials developed from the literature (see Chapter 1 for an overview of these methods). These materials focus on providing the correct care for the LGD and training to reduce the most commonly reported LGD behavioural problems, i.e. chasing wildlife, biting livestock, staying at home and attacking people (Marker *et al.* 2005a).

Chasing wildlife is the most commonly reported behavioural problem among LGDs in the CCF programme (Marker *et al.* 2005a). This is of particular concern for Namibian farmers, as wildlife utilization can be an important source of income (Richardson 1998). Among emerging commercial farmers, one of the main reasons given for not using LGDs is that they may harass wildlife (Schumann 2009). Furthermore, a dog that chases wildlife is less attentive to its livestock, which may be preyed upon in the dog's absence.

To prevent the above behavioural problems, CCF recommends that the dog is monitored by a herder who is instructed to reprimand the dog in the developmental stages of these problems (Schumann 2003; Marker *et al.* 2005a). Furthermore, several authors suggest that LGDs work better with a herder (Linnell *et al.* 1996; Hansen & Smith 1999; Breitenmoser *et al.* 2005; Distefano 2005), though from the farmers' perspective the use of a herder is not always cost-effective and can therefore be part of the cost of using LGDs (Shivik 2004).

Although training LGDs from a young age (8-16 weeks) is essential for developing good working LGDs (see Chapter 1), aptitude tests of eight-week-old puppies in the CCF programme did not predict the success of these dogs as adults (Marker *et al.* 2005a). From CCF experience, the effectiveness of LGDs is often determined by the owner, herder and the situation in which the LGD works (Schumann 2003) rather than the characteristics of individual LGDs. Additionally, Coppinger (1991) suggested that the important LGD behaviours of attentiveness and trustworthiness tend to emerge from 4-12 months of age, at which point the LGDs in the CCF programme are operating on the farms at which they are placed. In this study, use was made of data produced from juvenile (3-5 months old) LGD evaluations to determine whether early LGD behaviour could be used to predict adult LGD effectiveness.

An important cost and potential limiting factor of the effectiveness of LGDs is the food provided by the farmer. Within the CCF training materials, the importance of providing high quality food to ensure LGD effectiveness is stressed (Schumann 2003). Hypothetically, malnourished LGDs would provide less protection to the livestock as they lack the energy to defend their flocks from predators. Furthermore, these LGDs may not be able to accompany the livestock and would tend to stay at home rather than work. Similarly, a LGD that is underfed may start chasing wildlife in an attempt to kill animals as a source of food. However, those dogs that are too weak to accompany their livestock would not have the energy to chase wildlife. These alternative hypotheses will be examined in this chapter.

The cost and complexity of using LGDs outlined above were balanced with the direct benefits of the LGDs to farmers by reducing livestock losses. The effects of herders and LGD diet were analysed to examine whether these costs associated with LGDs are linked to the benefit received from them, as suggested in the CCF training materials.

The satisfaction of farmers with their LGDs was used in this study as a measure of farmer psychological assuagement (as per Shivik 2006). The level of farmer satisfaction was expected to reflect the degree to which LGDs reportedly reduced livestock losses. Furthermore, farmers are expected to be more satisfied with LGDs that are protective over the livestock, remain with the livestock at all times (attentive) and do not display any behavioural problems (trustworthy). The protectiveness, attentiveness and trustworthiness attributes of LGDs were defined by Coppinger & Coppinger (1980) as the main measures of good LGD behaviour. Thus, farmer satisfaction was used as an overall measure of the usefulness of LGDs for conflict mitigation, as perceived by the livestock farmers in the CCF programme.

2.1.5. Evaluating the effects of LGD age on their effectiveness

The length of time for which LGDs can potentially be effective (the second criterion by Mitchell (2004) and part of Shivik's (2006) economic efficiency) has received little attention in the literature. There are no published studies estimating the age at which LGDs become effective at protecting the livestock from predators (i.e. youngest working age) and the age at which they become less effective (i.e. oldest working age), although Green *et al.* (1994) reported some general trends of LGD effectiveness over their time spent working on farms. The lifespan of a working dog may additionally be influenced by the care provided by the farmer, which was shown to decrease over time by Marker *et al.* (2005a).

With respect to the minimum working age for LGDs, Andelt (2004) reported that LGDs as young as nine months old saved more time in livestock management than was required to spend training the dog. However, LGD breeds such as the Anatolian Shepherd or Kangal dog are estimated to reach maturity between 1.5 to 2.5 years of age (Green & Woodruff 1990; Dawydiak & Sims 2004; Espuno *et al.* 2004). Green *et al.* (1994) suggested that dogs younger than two years of age may not effectively reduce predation by aggressive and persistent predators due to their inexperience and immaturity. None of the above studies compared the effectiveness of young LGDs at reducing livestock losses to that of adult LGDs, which is an objective of the current study.

At the other end of the age spectrum, there has been no empirical determination of the age at which LGDs are too old to effectively protect the livestock. This is likely due to the relatively short lifespan reported for working LGDs due to premature deaths (Lorenz & Coppinger 1986; Green & Woodruff 1990; Marker *et al.* 2005b). Green *et al.* (1994) suggested that LGDs working in harsh conditions (such as those in Namibia) would be expected to have a shorter working lifespan. In his review, Rigg (2001) suggested that a maximum of ten years of work could be expected from a LGD. The CCF LGD programme has been running since 1994 and some older dogs are still working. Thus, an evaluation of the few older working dogs in the study population could give an indication of the maximum LGD working age. This age will then be used in conjunction with the minimum working age to estimate the maximum working lifespan of LGDs in Namibia.

2.1.6. Objectives and hypotheses

The following objectives (numbered) and hypotheses (lettered) emerge from the review provided above.

1) To determine the cost-effectiveness of LGDs as a means to reduce livestock losses and to document the subsequent farmer satisfaction with LGDs.
    a. The majority of LGDs in the CCF programme have reduced the number of livestock lost to predators since being introduced on their respective farms.

   b. Farmers in the CCF programme would be generally satisfied with their LGDs, yielding an average satisfaction score of > 0.7, as reported by Marker *et al.* (2005a) (maximum score = 1.0).
   c. Farmers with LGDs that reduced livestock losses would be more satisfied with their LGDs than the farmers with LGDs that did not reduce their losses.
   d. Farmer satisfaction would be positively correlated with LGD protectiveness, attentiveness and trustworthiness scores on all farm types.
   e. An economic cost-benefit analysis would reveal that the majority of the LGDs in the CCF programme are a net economic benefit for farmers.

2) To determine the interacting effects of farm type, care provided and LGD age on the protectiveness of LGDs in the CCF programme.
   a. The care provided for the LGDs will be influenced by farm type, with commercial farmers expected to provide more care than subsistence farmers.
   b. LGD protectiveness would be positively correlated with care provided.
   c. If hypotheses a. and b. are supported, LGDs on subsistence farms are expected to have lower protectiveness scores than LGDs on commercial farms.
   d. The care provided for LGDs was expected to be negatively correlated with LGD age, as found by Marker *et al.* (2005a).
   e. When separated into age categories, the LGDs in the youngest and oldest categories would be less protective than the LGDs in the intermediate age categories.

3) To investigate the development of good LGD behaviours and the prevalence and potential causes of common behavioural problems.

a. Juvenile LGD (3-5 months) attentiveness, trustworthiness and protectiveness scores will be correlated with the adult behaviour scores for the same LGDs. The juvenile LGD behavioural scores are expected to be similar to their scores as adults.
b. Within the adult population, the LGD attributes of attentiveness, trustworthiness and protectiveness will be positively correlated.
c. The prevalence of behavioural problems will be related to the age of the LGD.
d. LGDs that work with a herder and/or have not experienced a change in herders in their working lifetimes will be more trustworthy (i.e. display fewer behavioural problems) than their counterparts.
e. LGDs that are provided less care by their farmers will be more likely to stay at home due to the lack of energy gained from their diet.
f. LGDs that are provided less care could start chasing wildlife in order to supplement their diets. An alternative hypothesis is that LGDs fed on a low quality diet would tend not to chase wildlife due to the lack of energy from their diet.

2.2. Materials and Methods

2.2.1. Data collection and manipulation

Since the inception of the CCF dog programme in 1994, the LGDs have been monitored by conducting farm visits when the dogs are three months, six months and one year old, and annually thereafter. During each farm visit, the owner or herder/caretaker of the dog is interviewed face-to-face using a standard LGD questionnaire designed to evaluate the dogs in the programme (as per Marker *et al.* 2005a).

The standard LGD questionnaire was adjusted over time, with some questions being omitted, added or refined as it was seen fit to improve the evaluation of the dogs (CCF 1999; 2004a;

2009). Although some minor adjustments were made throughout the programme, three major versions of the questionnaire that differ substantially from one another were used to evaluate the LGDs over time (CCF 1999; 2004a; 2009).

The first of these versions was used from the start of the programme in 1994 to 2000 (CCF 1999); however, most of the evaluations conducted with this questionnaire were done during 1999 (see Marker *et al.* 2005a for the results from this survey). In 2001, a major revision of the 1999 questionnaire was conducted; this version was used until 2008 (CCF 2004a). It was used in conjunction with a complete health survey of the living dogs in the programme in 2004 (CCF 2004b). Finally, in 2009 the questionnaire was further adjusted to answer questions pertaining to the current research (CCF 2009). This version (see Appendix) was then used to conduct a complete survey of the dogs in the programme during 2009 and 2010. Hereafter, the different versions of the questionnaire are named according to the years during which most of the data were collected using each version: 1999, 2004 and 2009. The 1999 and 2004 data used in this study overlap significantly with the data used by Marker *et al.* (2005a). The current study is thus a re-analysis of the previous dataset, which is compared to the data collected in 2009-2010. As the dogs were evaluated repeatedly throughout their lives, each dog may have been evaluated using more than one version and/or have been evaluated several times with any one of the versions.

Consistent with the previous work published on the CCF dog programme (Marker *et al.* 2005a), five scores were used to evaluate the effectiveness of livestock guarding dogs. As in that study, LGD behaviour was defined using the three components given by Coppinger and Coppinger (1980): attentiveness – the tendency of the dog to stay with the flock; trustworthiness – the lack of predatory behaviour towards the flock and the lack of other behavioural problems;

protectiveness – the tendency of the dog to display protective behaviour towards the flock (Table 2.1). The same scores, comprising slightly different questions, were used in the juvenile LGD (3-5 months) questionnaire to evaluate young dogs by investigating early versions of adult LGD behaviours (Table 2.2). Furthermore, the farmer satisfaction and care scores used in this study were similar to those defined by Marker *et al.* (2005a) (Table 2.3).

Table 2.1. The questions used to calculate the scores for each of the three major dog behaviours: attentiveness, trustworthiness and protectiveness.

Total Attentiveness Score 2004 & 2009 only	Total Trustworthiness Score 2004 & 2009 only	Total Protectiveness Score all questionnaires
Is the dog with the herd all the time?	Is the dog submissive to members of the herd?	How would you rate your dog's protectiveness of your stock?
Where is the dog at night?	Does the dog have any behavioural problems?	Have you had livestock losses since the dog?
Does the dog appear to be part of the flock?		
Are the dog and stock bonded together?		

Table 2.2. The questions used in all questionnaires to calculate the scores of juvenile (3-5 months old) dogs for each of the three major dog behaviours: attentiveness, trustworthiness and protectiveness.

Total Attentiveness Score	Total Trustworthiness Score	Protectiveness Score
Is the puppy with the herd all the time?	Is the puppy submissive to the stock?	Does the puppy bark at strange sounds?
Does the puppy appear to be part of the stock?	Does the puppy play roughly with the stock?	Does the puppy bark at strangers?
Is the puppy accepted by the stock?	Does the puppy have any other behavioural problems?	Does the puppy bark at strange things?
Is the puppy investigative towards the stock?		

Table 2.3. The questions used to calculate the scores for farmer care and satisfaction, in all questionnaire versions.

Total Farmer Care Score all questionnaires	Total Satisfaction Score all questionnaires
Please describe what food you give to your dog.	How is your dog working?
How would you describe your involvement with your dog?	Is it doing what you thought it would do?
	Has there been an economic benefit to having the dog?

The questions for all scores were chosen to best represent the scores for which they were calculated; secondly, preference was given to questions that were used in all three questionnaire versions. In instances where important questions for the scores were omitted from some questionnaire versions (as was the case for the attentiveness and care scores), the sample size was reduced for these variables.

To create the scores, the calculations given by Marker *et al.* (2005a) were used. For all questions, the most positive response (e.g. "Excellent" for "How is your dog working?" or "Yes" for "Is it doing what you thought it would do?") was scored as +2 and the most negative response ("Poor" or "No" respectively for the questions above) was scored as -2. For those questions that had a range of options the scores were as follows: Excellent = 2, Good = 1, Fair = -1, Poor = -2. The numbers generated for each of the answers were then combined to produce the mean scores for attentiveness, trustworthiness, protectiveness, farmer care and satisfaction. These mean scores were converted into values between 0 (all answers were -2) and 1 (all answers were 2) following Marker *et al.* (2005a).

In the LGD evaluations, any missing answers to the questions in Tables 2.1-2.3 above were carefully considered, as the absence of one answer from a score that consists of three or more answers would render that score incalculable. In these cases, reasons for the missing data were carefully considered before the decision was taken to impute replacement values for the missing items (de Leeuw *et al.* 2003). When the questions were not asked of the respondent (i.e. where previous questionnaire versions were used), the data were marked as missing and no score could be calculated. These cases were still used for scores where the answers were known, as the data were excluded pair-wise rather than list-wise. This exclusion method maximized the use of the collected data and is the reason for the variable sample sizes in this study, which is a side-effect of this method (Acock 2005).

In cases where the respondent was posed the question, but was uncertain of the answer, the score given was zero and included in the score calculations. This decision was based on the auxiliary data collected by the interviewer as to why the respondent did not answer the question (de Leeuw *et al.* 2003). The reasons for non-response were usually due to the respondent not witnessing the dog behaviour (e.g. the respondent was the owner of the dog, but did not work with the dog directly) or not knowing enough about dog behaviour to make a judgment (e.g. the respondent worked with the dog, but was unable to identify specific dog behaviours). The zero score implies that the dog had a 50:50 chance of displaying the behaviour in question. This may have deflated the scores of dogs that scored highly for the other variables, but would have inflated the scores of dogs that had low scores for the other variables; the net effect of this imputation on the results was therefore deemed minimal.

2.2.2. Data selection for LGD evaluations

To maintain independence among the data, only one questionnaire interview was chosen for analysis per dog. All dogs six months or older at the time of the interview were included in the analyses on adult dogs. Due to the relatively short lifespan of working dogs and the higher intensity of visits when the dogs are young, more evaluations were conducted on younger dogs. To reduce the skew towards young dogs, the last interview was chosen (i.e. when the dog was oldest) for those dogs that were evaluated multiple times. This also applied to dogs that had multiple owners in their lifetimes; the interview with the last owner to have the dog was chosen over interviews with previous owners.

The final sample of adult LGDs comprised 195 (99 male, 96 female) dogs evaluated from all farm types. Due to the earlier placement of dogs on commercial farms in the initial phases of the CCF programme (Marker *et al.* 2005a), more dog evaluations were in the sample from commercial farms (119) than from communal (37), emerging commercial (29) and resettled (10) farms. Due to the relatively small sample sizes of the other farm types, the data from communal and resettled farms were combined and the data from commercial and emerging commercial farms were combined. These combinations were chosen as the former group represent subsistence farming, whilst the latter group represent commercial farming (Odendaal 2005). The interactions of these farmers with their dogs are therefore expected to be more similar within the groups than between them. All analyses including farm type were conducted using these combinations of farm types, hereafter termed commercial and subsistence farms. In the 1999 data collection period, only one LGD was evaluated on a subsistence farm, compared to 30 LGDs on commercial farms (Table 2.4). Similar numbers of LGDs were evaluated using the 2004 and 2009 questionnaire versions, with similar proportions on commercial and subsistence farms (Table 2.4).

Table 2.4. The numbers of LGDs evaluated on commercial and subsistence farms using the three different questionnaire versions.

	Questionnaire version		
	1999	2004	2009
Commercial farms	30	59	59
Subsistence farms	1	26	20

For some analyses, the evaluations were categorised into one of six age categories according to the age of the dog at the time of the evaluation. Due to the skew towards young dogs in the dataset, the age categories were made to be smaller for younger dogs than older dogs (Fig. 2.1.). Furthermore, the behaviours of the dogs are expected to become increasingly stable as they age; thus, the behaviours of older dogs were expected not to be highly variable, despite the use of broader age categories.

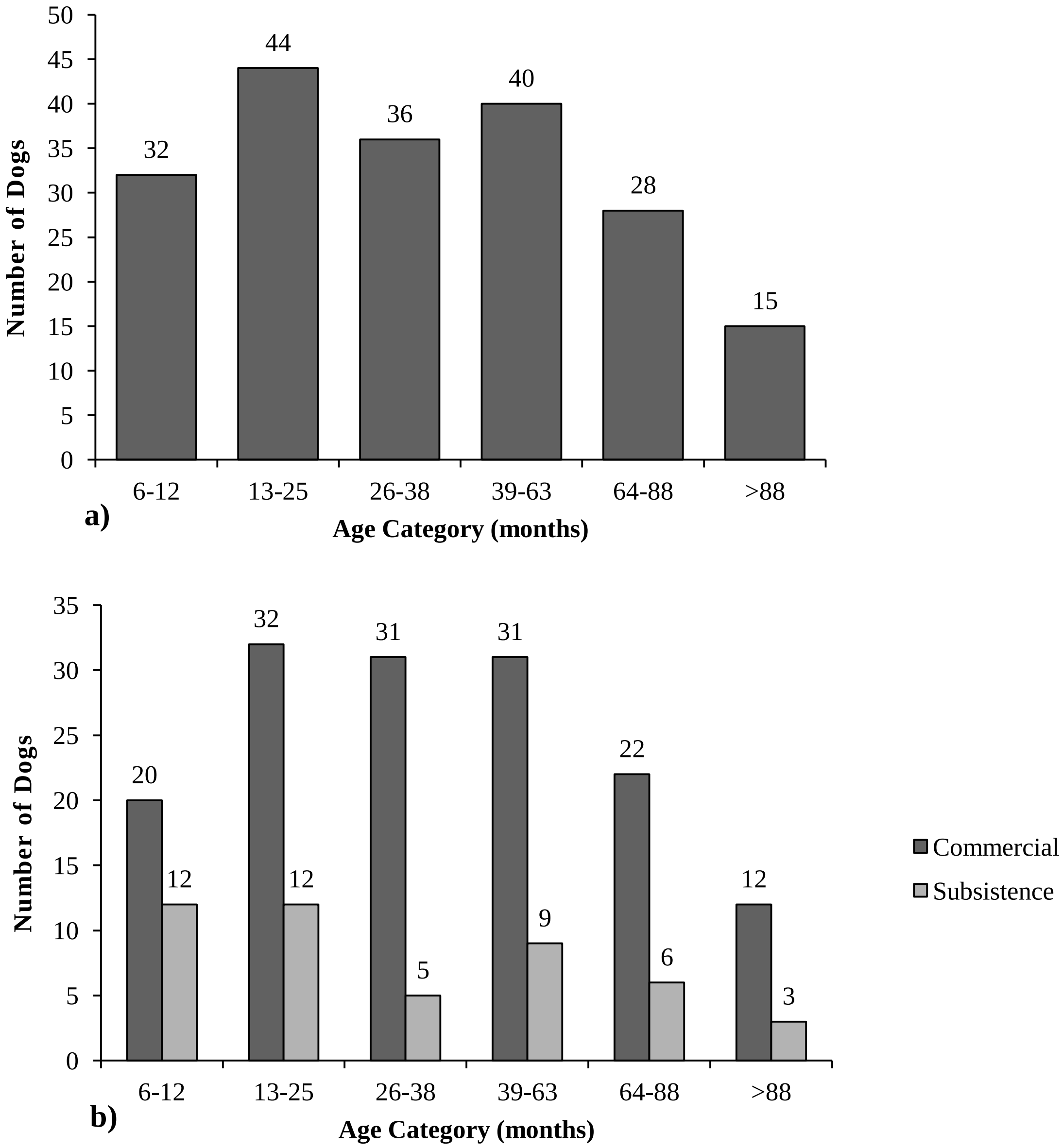

Fig. 2.1. Sample sizes (represented by numbers above the bars) of dogs evaluated within six age categories on **a)** all farms, **b)** commercial and subsistence farms separately.

In the analyses that compared LGD protectiveness according to age category, a Kruskal-Wallis test was conducted among dogs in all age categories, for both farm types. Specific Mann Whitney U tests were then conducted between the first (6-12 months) and second (13-25 months) categories and the fifth (64-88 months) and sixth (>88 months) categories. These were to determine whether the dogs in the first and last age categories were too young or too old to be effective, relative to dogs in older and younger categories, respectively. These tests were repeated for both farm types.

For all questionnaires used, the incidence of livestock losses on farms since the LGD started working was recorded as per Marker *et al.* (2005a). This variable was refined in 2009 to include the level of stock losses experienced in the survey year since the LGD introduction relative to the losses in the year before the LGD. For the 2009 evaluations (where losses before the LGD were recorded), 11 farmers (17% of the total evaluated) that reported no loss in the year since the LGD also reported no losses in the year before the LGD. In determining the protectiveness of the LGD, it was considered that the level of livestock losses in one year before the LGD should not influence the protectiveness score of the LGD. Thus, the LGDs that did not lose any of their livestock in the survey year were given the maximum score for that result, irrespective of the level of livestock losses before the LGD.

To assess potential differences in the farmers' perceptions of the dogs and the actual livestock losses experienced, the satisfaction score of farmers giving different reports of stock losses were compared. As the satisfaction score is designed to assess the farmers' perceptions of LGDs as an economically beneficial method and their overall opinion of the dogs' working abilities (Marker *et al.* 2005a), this score is indicative of farmer psychological assuagement (Shivik 2006).

For the analyses of juvenile and adult LGD scores, dogs were chosen that had been evaluated as a juvenile (3-5 months old) and when they were 13 months or older. Dogs in the 6-12 month category were not considered to be adults (Coppinger 1991). The dogs in the 13-25 month category were not significantly different from the dogs in the next category (26-38 months) for any of the LGD behaviours (attentiveness: $U = 518$, $z = -0.26$, p = 0.79; trustworthiness: $U = 453$, $z = -1.22$, p = 0.22; protectiveness: $U = 723$, $z = -0.53$, p = 0.60). Thus, dogs that were 13 months and older behaved similarly to older dogs and could therefore be included as adult dogs for the purpose of these analyses.

2.2.3. Calculation of the monetary costs of LGDs

The current purchase price of a LGD from CCF is N$700.00 for all farmers. As CCF breeds both purebred Anatolian Shepherds or Kangal dogs and ¾ Anatolian Shepherds (the mother is half Anatolian and half mixed breed, the father is purebred), these dogs differ in size and thus require different amounts of dog food. The smaller ¾ Anatolians can be maintained in good condition with 400 g of high quality dry dog food per day. For the purebred dogs, a diet of 600 g or 800 g dog food per day is required; the needs of larger dogs may differ for individuals, but 800 g per day was set as a reasonable maximum. The dog food provided by CCF is a veterinary diet that CCF sells to the farmers at N$200 per 20 kg bag. Lastly, the price of vaccinations was included in the maximum costs for a LGD, as only commercial farmers with larger dogs are likely to buy vaccinations (rabies and 5-in-1 vaccines) for their LGDs. CCF supplies vaccinations for the LGDs of farmers who cannot afford them. The price of booster vaccinations (CCF gives all puppies the first vaccination) was obtained from a veterinary clinic in Windhoek. Costs due to unforeseen circumstances such as veterinary emergencies were not included in the analyses.

2.2.4. Calculation of the monetary benefits of LGDs

To determine the benefit of LGDs, the relative livestock loss data were used to estimate the number of livestock saved by LGDs, using the 2009 questionnaire data. Unlike the LGD protectiveness score, the economic analysis included the records of no livestock loss before and after the LGD among the LGDs that had no economic benefit. In the questionnaires, livestock losses were recorded in categories (see Appendix), as most of the respondents were not sure of the exact numbers of livestock lost per year and were only able to give estimates. For the analysis of these estimates, the midpoint of each category (e.g. 1-5 = 3) was chosen as an estimate of the livestock lost, and a value of 41 was chosen for the category > 40 livestock saved (Agresti 2007). The differences between the midpoint number of livestock lost before and since the LGDs were then calculated (e.g. 6-10 losses before LGD = 8; 1-5 losses since LGD = 3, thus 5 livestock saved). The estimates of livestock saved by the LGD were then grouped into four categories as follows: category 1 = no livestock saved (differences between stock losses before and since LGD are negative or 0); category 2 = 3, 5 or 8 livestock saved; category 3 = 16, 22 or 25 livestock saved; category 4 = 33, 38 or > 40 livestock saved. The frequencies of LGDs in each of the four categories were then calculated.

The number of livestock saved was converted into monetary terms using the average prices for goat kids and lambs at the Otjiwarongo auction on the 3rd of February 2011 (Anonymous 2011). Goat kid and lamb prices were used as these are most vulnerable to predation and the source of annual cash income for meat producers (Jones 2004). Although this cost-benefit analysis is not as robust as it could be if the exact livestock losses were known and costed, it was used to give the value of LGDs to farmers, using their own estimations of livestock losses. The farmers that regarded their LGDs as an economic benefit during the 2009 questionnaire survey were then compared to the number of LGDs deemed economically beneficial by the cost-benefit analysis.

2.2.5. Analyses of LGD behavioural problems

Analyses on the trustworthiness of adult dogs across the different age categories were conducted using the same 195 dogs selected for other adult dog analyses. The dogs' behavioural problems were evaluated in four main categories: chasing wildlife, biting livestock, staying home, and attacking people (as per Marker *et al.* 2005a). LGDs that displayed a combination of behavioural problems (e.g. chasing wildlife and staying home) were added to both problem categories. All of the dogs in the dataset, including those that displayed staying home behaviour, were working dogs at the time of the evaluation. Staying home behaviour was typically reported as dogs that occasionally refused to accompany the livestock for parts of some days or whole days within the survey year. If a respondent stated that the dog rarely or never went out with the livestock in the survey year, then it was counted as a pet dog and excluded from all analyses.

As the prevalence of behavioural problems and their prevention has been a focus of the CCF programme (Schumann 2003), more detailed analyses were conducted on the possible reasons for these problems. The unexpectedly high prevalence of behavioural problems in the 39-63 months age category in the current study was hypothesized to be linked to the lack of herders and/or a change in herder. It was further hypothesized that the specific problems of staying at home or chasing wildlife may be more prevalent among dogs that receive less care.

2.2.6. Statistical analyses

The data for all five scores were negatively skewed and violated the assumption of normality when tested using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Thus, non-parametric tests were used for all analyses. Mann-Whitney U tests were conducted where only two categories were compared. For the analyses with several categories, Kruskal-Wallis tests were performed and Mann-Whitney U tests were conducted *post hoc* on specific categories chosen for the reasons outlined above. Where continuous rather than categorical data were used, Spearman's Rank Order correlation was conducted to test the strength, direction and significance of correlations among the variables. To determine whether juvenile LGD behaviour scores were different to the adult scores of the same dogs, the Wilcoxon Signed Rank Test was used. All statistical procedures were conducted using SPSS 12.0.1 and only the results where $p < 0.05$ were considered significant.

2.3. Results

2.3.1. Livestock guarding dogs and livestock losses

From the evaluations conducted with the 1999 and 2004 questionnaires (n = 111), 63% of the farmers reported no stock losses since the LGD was received (Fig. 2.2.a). A similar percentage of farmers reporting no stock losses since the LGD were found during the evaluation in 2009 (65%, n = 65, Fig. 2.2.b). Furthermore, in the 2009 questionnaire, 26% of the farmers reported that although they still experienced losses, their losses had been reduced since receiving the dog (Fig. 2.2.b). Four farmers (6%) reported that their losses had remained at a similar level to before the dog arrived; two farmers (3%) reported that losses had increased since they received the dogs.

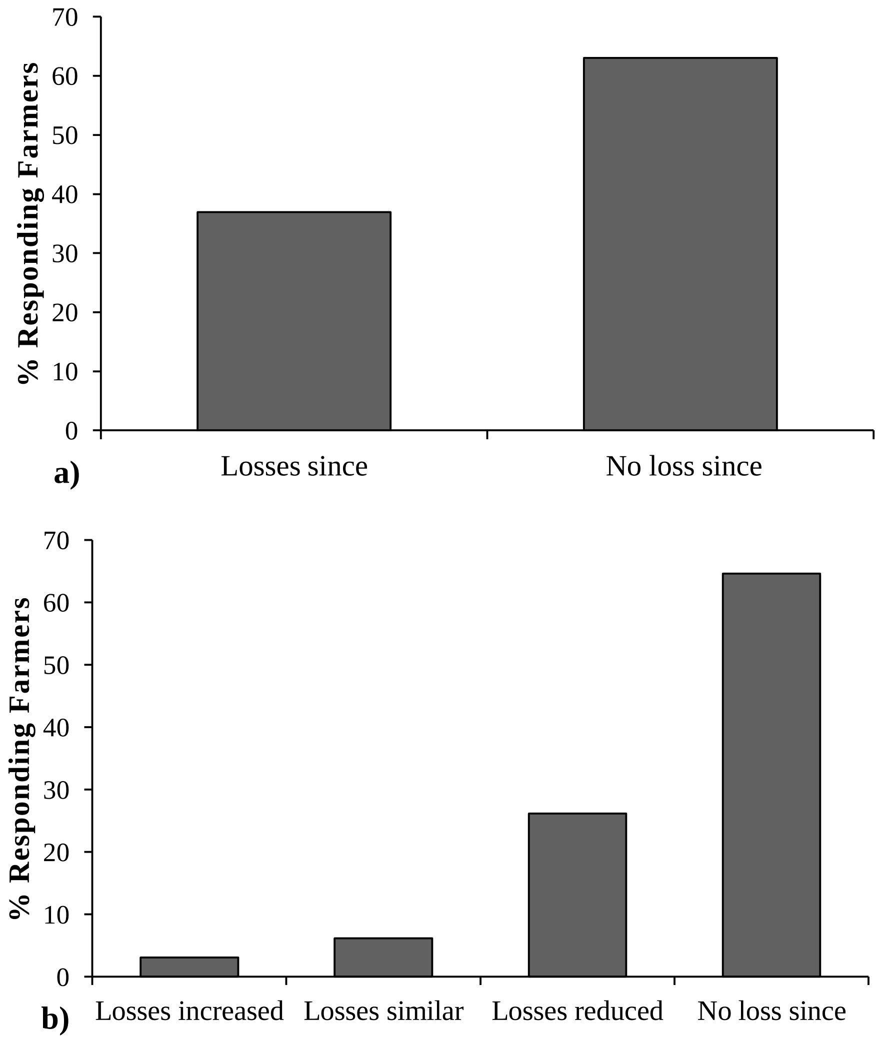

Fig. 2.2. Percentage of farmers reporting different relative levels of livestock losses since receiving a LGD **a)** from the 1999 and 2004 questionnaires (n = 111), **b)** from the 2009 questionnaire (n = 65).

2.3.2. Farmer satisfaction and reduction in livestock losses

The farmers surveyed using any of the three questionnaires were highly satisfied with their LGDs – the average farmer satisfaction score was 0.84 (± 0.238 S.E., n = 195). Farmer satisfaction was significantly lower during the 1999 survey than the 2004 survey ($U = 897$, $z = -2.73$, $p = 0.006$), which was similar to the level of satisfaction in the 2009 survey (Fig. 2.3.a). The protectiveness score had a similar pattern to farmer satisfaction over the survey periods: the score during the 1999 survey was significantly lower than the 2004 survey ($U = 661$, $z = -4.13$, $p < 0.001$), which was similar to the 2009 survey (Fig. 2.3.b).

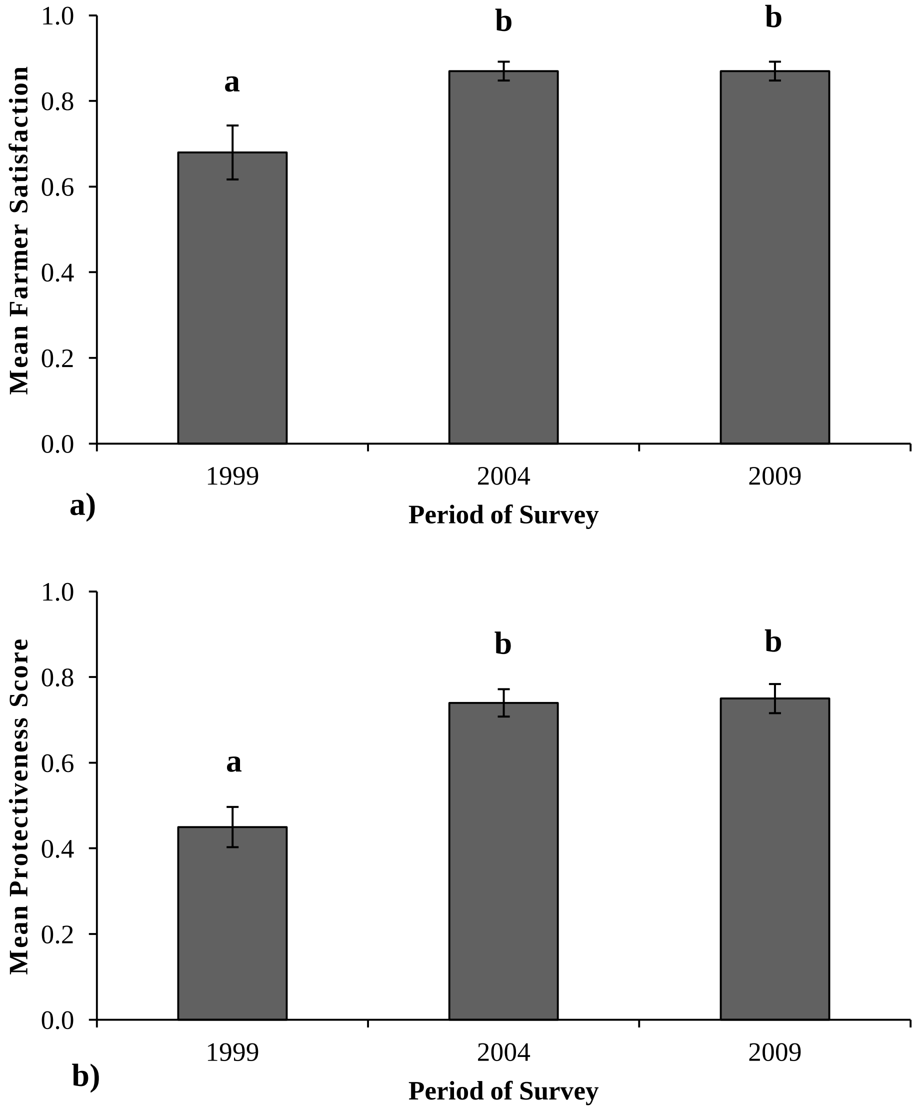

Fig. 2.3.a) Mean farmer satisfaction (± S.E.) with their LGDs and **b)** Mean LGD protectiveness (± S.E.) during the three survey periods conducted. Different letters indicate significance where $p < 0.001$.

Farmers that experienced no loss after receiving a dog were more satisfied with their dogs than the farmers that had experienced losses since their dogs in the 1999 and 2004 surveys ($U = 1022$, $z = -2.64$, $p = 0.008$, Fig. 2.4.a). In the 2009 survey, farmers that had experienced no losses or a reduction in losses since the dog had similarly high satisfaction scores (Fig. 2.4.b). However, those farmers that reported similar or increased losses had variable satisfaction with their dogs (Fig. 2.4.b). Due to this variability and the small sample size of farmers that had increased or similar losses (six in total), there was no significant difference amongst the groups ($\chi^2 = 0.55$, df = 3, p = 0.91). When the farmers were combined into two groups – those reporting reduced or no losses compared to those reporting increased or similar losses – the difference in satisfaction between the groups was still not significant ($U = 150$, $z = -0.65$, p = 0.52).

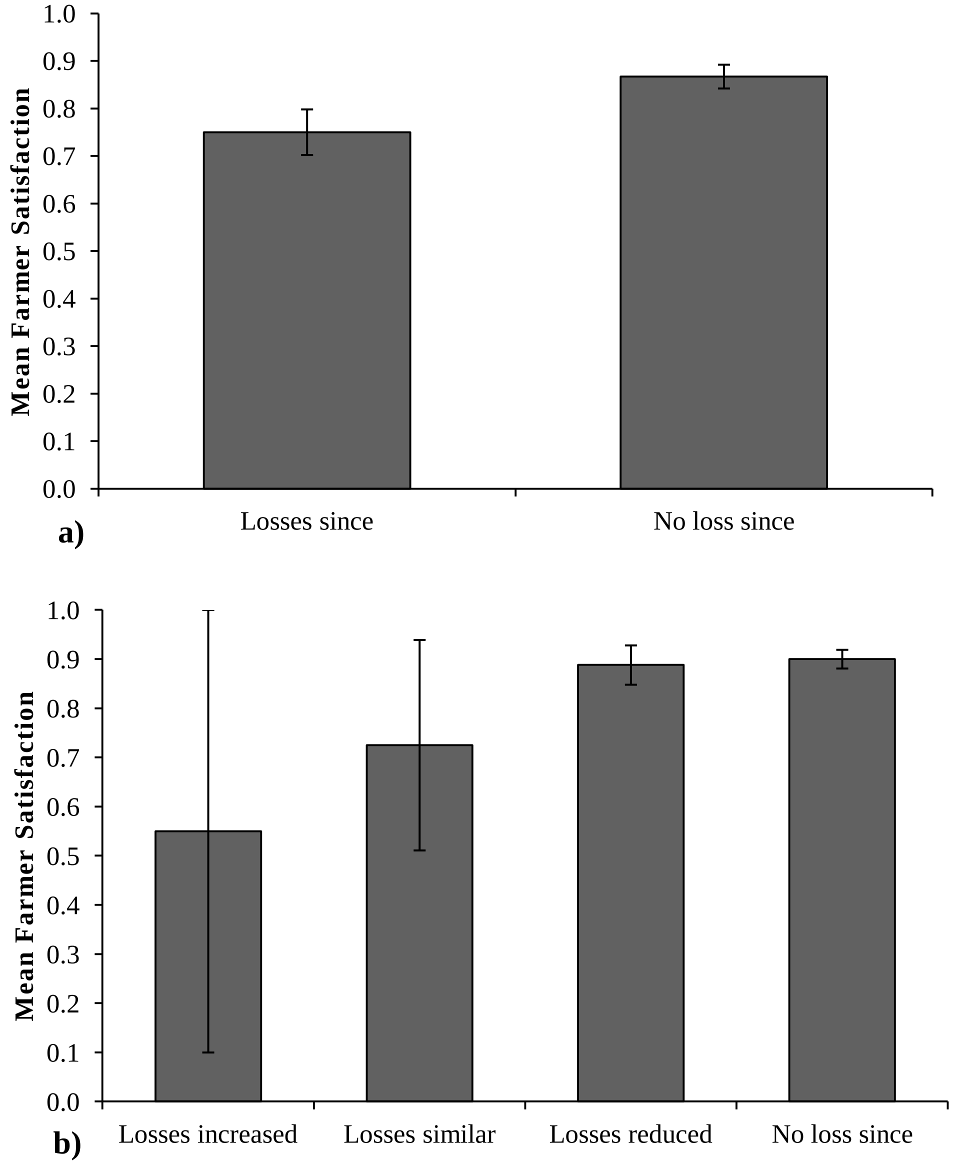

Fig. 2.4. The mean satisfaction scores of farmers (± S.E.) reporting different relative levels of stock losses since the LGD **a)** from the 1999 and 2004 questionnaires (n = 111), **b)** from the 2009 questionnaire (n = 65).

To investigate the variability in farmer satisfaction, the records of the six dogs on farms where stock losses were reported to have increased or remained the same were examined in more detail.

Three of these farmers were highly satisfied with their dog's performance – the satisfaction score for all three dogs was the maximum value of 1.0. Two of these farmers said that the continued livestock losses were not the dog's fault, with one of them blaming the herder for the losses. The third farmer had a dog previously that reduced losses and stated that the current dog worked equally well and was pleased that it kept the losses at the same level. One farmer was slightly less than satisfied (score 0.8) with the LGD, stating that the dog was not economically beneficial; this particular dog was still somewhat debilitated after being hit by a car three years prior to the evaluation. The two least satisfied farmers (score 0.1) claimed that the dog no longer worked properly; in both cases, this was due to a lack of care on the part of the farmer – both dogs were subsequently confiscated due to malnourishment.

2.3.3. Farmer satisfaction and LGD behaviour

Using the data from all questionnaire periods, the farmers' satisfaction score was positively correlated (medium strength) with the LGD protectiveness score ($\rho = 0.368$, $n = 193$, $p < 0.001$). The lack of strength between these variables was due to the spread of the data; some farmers' (irrespective of farm type) satisfaction with their dogs was not linked to the dogs' protectiveness scores (Fig. 2.5). Farmer satisfaction for all farm types showed the strongest positive correlation with LGD attentiveness ($\rho = 0.496$, $n = 164$, $p < 0.001$), followed by trustworthiness ($\rho = 0.403$, $n = 164$, $p < 0.001$).

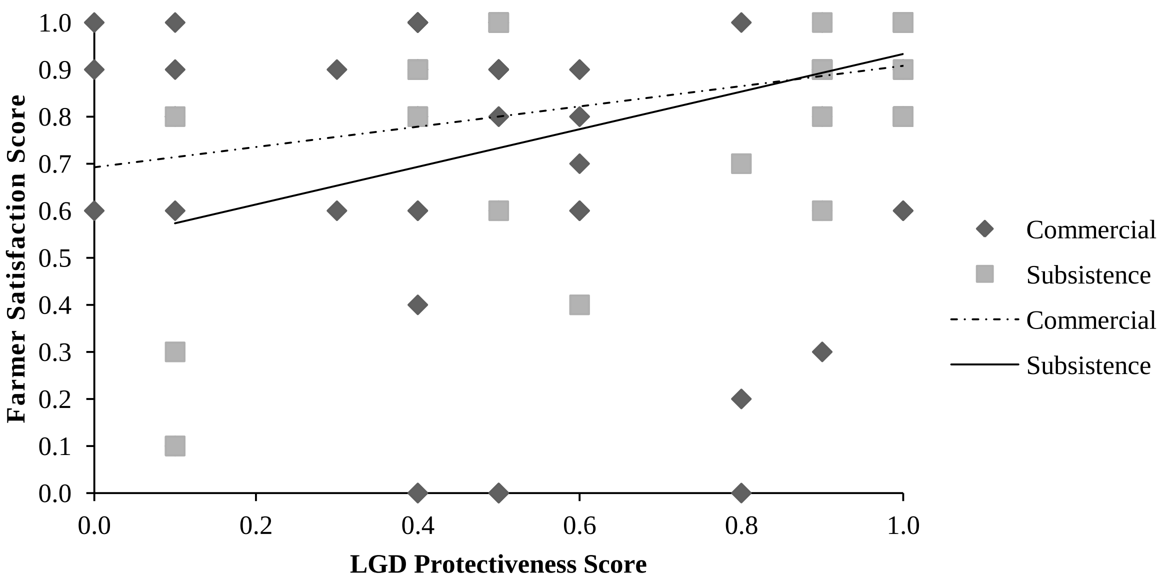

Fig. 2.5. The relationship between farmer satisfaction and LGD protectiveness for different farm types. The dashed line represents the correlation between commercial farmer satisfaction and LGD protectiveness ($\rho = 0.366$, $n = 147$, $p < 0.001$). The solid line represents the correlation between subsistence farmer satisfaction and LGD protectiveness ($\rho = 0.384$, $n = 46$, $p < 0.05$).

2.3.4. Economic cost-benefit analysis of LGDs in the CCF programme

The minimum cost of obtaining and maintaining a ¾ Anatolian Shepherd on a 400 g/day diet for the first year is N$2160.00 and N$1460.00 for every year thereafter (subsequent years exclude purchase price). For a purebred Anatolian on a 600 g/day diet, with vaccinations supplied by CCF, the first year cost is N$2890.00 and N$2190.00 annually thereafter. The maximum cost of a large purebred Anatolian Shepherd on the 800 g/day diet with the farmer supplying the annual vaccines is N$4004.00 for the first year and N$3304.00 thereafter.

Using the costs calculated above and current small stock auction prices (Anonymous 2011), the minimum number of small stock that a LGD would need to save in the first year and annually to be economically beneficial was calculated (Table 2.4). Thus, a medium cost LGD (which is the most common in the programme), should save a minimum of five goats or six sheep annually to be cost-effective. At the minimum LGD cost, only four small stock animals would need to be saved annually. At the maximum LGD cost, seven goats or nine sheep would need to be saved annually for cost-effectiveness (Table 2.4).

Table 2.5. Costs of purchasing and maintaining LGDs from the CCF programme, including an estimate of the minimum number of goats or sheep that LGDs should save to be economically beneficial to farmers. All numbers quoted in N$; the livestock prices were N$454/goat kid and N$370/sheep lamb according to recent regional auction prices (Anonymous 2011).

Cost of LGD	3/4 Anatolian with minimum maintenance	Full Anatolian with medium maintenance	Full Anatolian with maximum maintenance
Purchase price	700	700	700
Food/year	1460	2190	2920
Vaccinations	0	0	210
Total cost 1st year	2160	2890	3830
Total cost annually	1460	2190	3130
	Minimum number of livestock the LGD must save		
In the first year	5 goats or 6 sheep	6 goats or 8 sheep	9 goats or 11 sheep
Annually thereafter	4 goats or 4 sheep	5 goats or 6 sheep	7 goats or 9 sheep

When asked whether their LGDs were an economic benefit to their farming operations, 73% of the farmers in the 2009 survey (both commercial and subsistence, n = 79) said that the LGDs had been a benefit. The economic benefit was calculated apart from the farmers' opinions by estimating the number of livestock saved by LGDs in the programme. This was done by comparing losses in one year before the LGD to the losses in the year of the LGD evaluation (Fig. 2.6, n = 64). These data reveal that 79% of the LGDs reportedly saved some livestock in the year of evaluation. From the LGD costs in Table 2.4, all of the LGDs that saved 16-25 and 33 to > 40 livestock (47%) would be economically beneficial to their farmers, irrespective of the cost (as per Table 2.4) to maintain them. Eight of the LGDs (13%) in the 3-8 category saved 5 or 8 livestock, these would be marginally beneficial to the farmers if they cost the minimum or medium cost to maintain, respectively. The eight dogs (13%) in this category that saved only 3 livestock would not be beneficial even at the minimum cost. The LGDs that did not save livestock (28%) were not economically beneficial for farmers in the evaluation year.

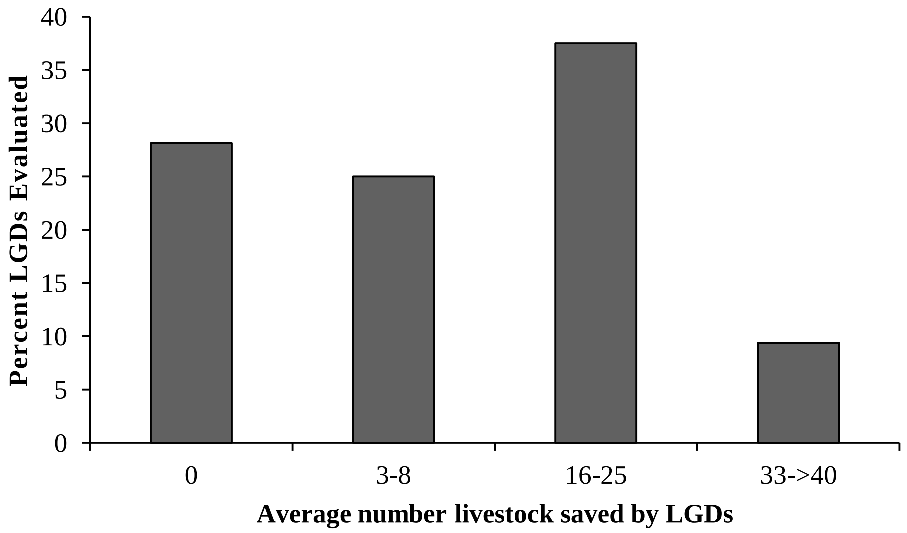

Fig. 2.6. Percentage of LGDs in four categories of livestock saved in 2009 (n = 64).

The economic calculation above appears to underestimate the farmers' perceptions of the LGDs as economically beneficial. Closer inspection of the data revealed that LGDs that reduced livestock losses by any margin were considered economically beneficial by some of the farmers. The farmers that regarded their LGDs as beneficial despite the livestock losses remaining at the same level were the same farmers that expressed high satisfaction with dogs that did not reduce losses, as described in section 2.3.2.

2.3.5. The influence of farm type, care provided and LGD age on LGD protectiveness

The relatively low satisfaction and protectiveness scores in 1999 (see Fig. 2.3) are most likely due to the initial teething problems of the dog programme, as the training methods were not yet refined. As the 1999 survey was conducted almost entirely with commercial farmers (only one subsistence farmer in the dataset), the data from the 1999 survey was excluded from the farm type comparisons to eliminate the bias caused by the youth of the programme in 1999.

Commercial farmers provided significantly more care for their LGDs than subsistence farmers (U = 1264 z = -3.25, p = 0.001). LGD protectiveness was not, however, correlated with the care provided (ρ = -0.51, n = 145, p = 0.54). Consequently, the protectiveness score of the LGDs was not significantly different between the two farm types (U = 2563, z = -0.27, p = 0.78).

For both commercial and subsistence farmers, a weak negative correlation between the farmer care and the age of the dog was found, but this was not significant (ρ = -0.14, n = 146, p = 0.093, Fig. 2.7.a). Due to the significant difference in care provided between the farm types shown above, this trend was re-examined according to farm type. On subsistence farms, a significant negative correlation between care provided and the age of the LGD was found (ρ = -0.34, n = 35, p = 0.04, Fig. 2.7.b). By contrast, no significant correlation was found between care and LGD age on commercial farms (ρ = -0.081, n = 111, p = 0.40, Fig. 2.7.b).

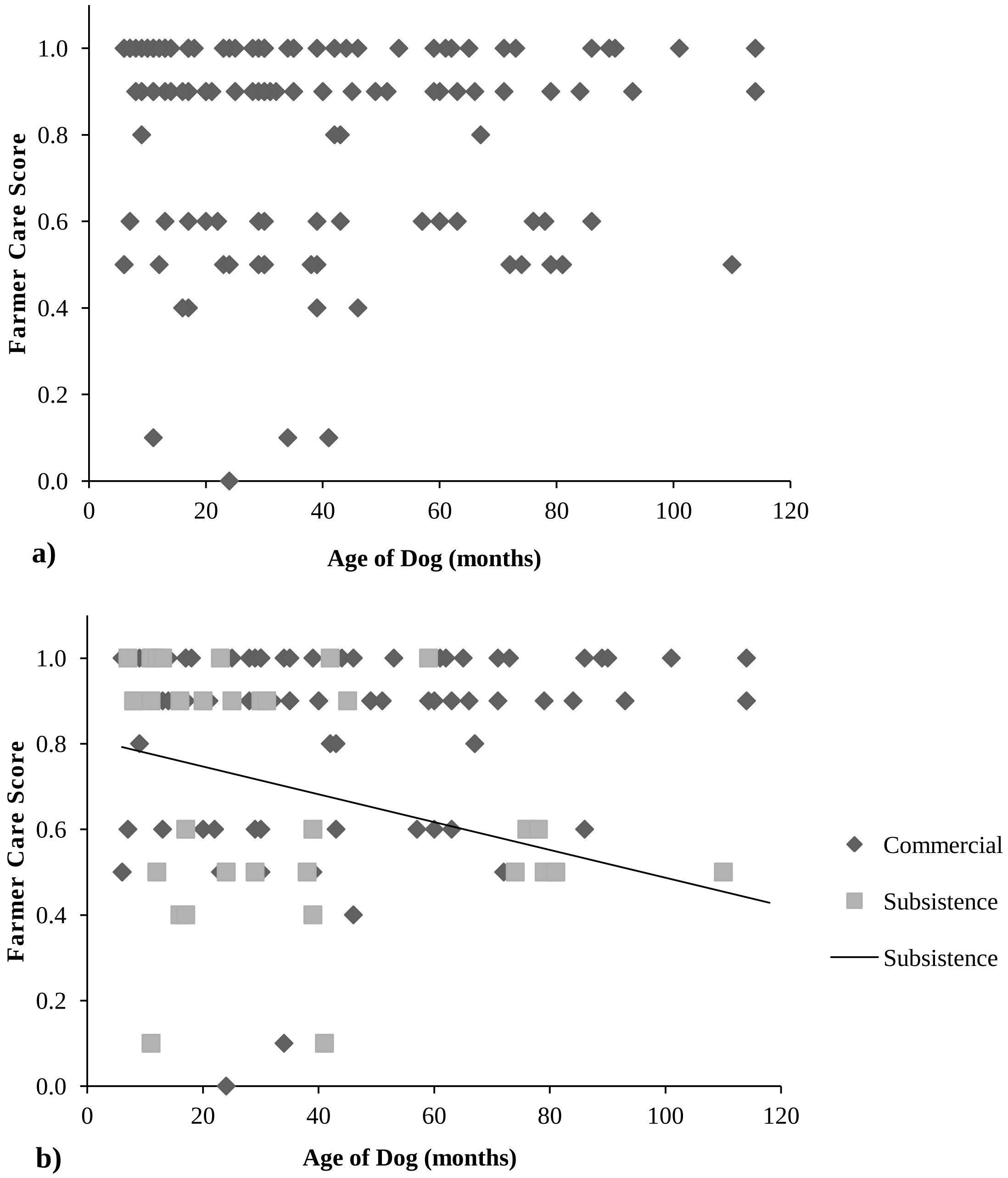

Fig. 2.7. The relationship between mean farmer care score and the LGD age for **a)** all farm types and **b)** separated according to farm type, the line represents the correlation for subsistence farms only, where p = 0.04.

The mean protectiveness scores of the dogs in the six different age categories were not significantly different (χ^2 = 5.48, df = 5, p = 0.359). As the care provided for LGDs declined according to the age of the dog on subsistence, but not commercial farms (see above), the data were separated by farm type. However, a Kruskal-Wallis test on the separated data revealed no significant differences in mean LGD protectiveness among the age categories (commercial: χ^2 = 5.51, df = 5, p = 0.357; subsistence: χ^2 = 4.40, df = 5, p = 0.493, Fig. 2.8).

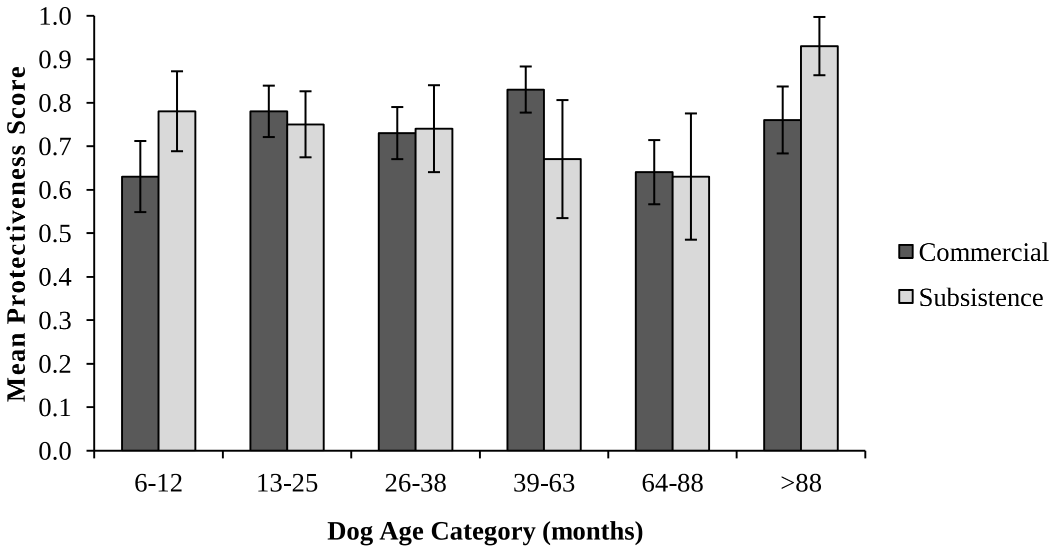

Fig. 2.8. Mean LGD protectiveness scores (+/- S.E.) of dogs on different farm types from the 2004 and 2009 surveys in six different age categories; for commercial: 6-12 months, n = 14; 13-25 months, n = 26; 26-38 months, n = 23; 39-63 months, n = 24; 64-88 months, n = 18; >88 months, n = 12 and subsistence: 6-12 months, n = 11; 13-25 months, n = 11; 26-38 months, n = 5; 39-63 months, n = 9; 64-88 months, n = 6; >88 months, n = 3.

To test whether young dogs (category 1, 6-12 months) were as protective as dogs in the next category (category 2, 13-25 months), a Mann-Whitney U test was conducted between these categories. This test revealed no significant difference in dog protectiveness between age categories 1 and 2 (U = 515, z = -1.71, p = 0.087) for all farm types. Similar results were obtained once the farm types were separated (commercial: U = 123, z = -1.74, p = 0.081; subsistence: U = 58, z = -0.17, p = 0.87).

Contrary to expectations, the dogs in the oldest category (>88 months) appeared to have higher protectiveness scores than those in the previous category (64-88 months). However, this difference was not significant (U = 135, z = -1.35, p = 0.18). Similar results were obtained for the separate farm types (commercial: U = 92, z = -0.72, p = 0.47; subsistence: U = 4, z = -1.32, p =

0.19), although the results for the subsistence farms were hampered by the small sample size of old dogs. Ten of the 15 dogs in the >88 months age category were reported to have eliminated livestock losses in the year of evaluation. Furthermore, eight of these dogs were older than 9 years/108 months of age. Five of these oldest dogs (two of which were working on subsistence farms), including the oldest dog in the dataset (129 months), were given the maximum protectiveness score of 1.0.

2.3.6. Predicting adult LGD behaviour and examining relationships between LGD behaviours

The attentiveness, trustworthiness and protectiveness scores of guarding dogs as puppies were not correlated with the respective behaviour scores of the same dogs as adults (attentiveness: ρ = -0.04, p = 0.81, n = 45; trustworthiness: ρ = 0.11, p = 0.40, n = 57; protectiveness: ρ = -0.10, p = 0.52, n = 47). However, the Wilcoxon Signed Rank Test revealed that juvenile trustworthiness scores (μ = 0.67) were significantly lower (z = -3.48, p = 0.001) than the paired adult scores (μ = 0.80). In contrast, the juvenile attentiveness scores (μ = 0.94) were equivalent to the paired adult attentiveness scores (μ = 0.94; z = 0.00, p = 1.00). Lastly, juvenile protectiveness scores (μ = 0.79) were not significantly different (z = 0.17, p = 0.87) to the paired adult protectiveness scores (μ = 0.76).

Among the adult LGD population, attentiveness was positively correlated (medium strength) with trustworthiness (ρ = 0.451, n = 164, $p < 0.001$) and weakly correlated with protectiveness (ρ = 0.245, n = 162, $p < 0.01$). LGD trustworthiness and protectiveness scores were not correlated (ρ = 0.151, n = 162, p = 0.056).

2.3.7. LGD behavioural problems and potential causes of problems

The prevalence of behavioural problems among LGDs was highest in the 1999 survey (71% dogs with problems, n = 31); this dropped in the 2004 survey to 33% (n = 85) and rose slightly in the 2009 survey to 43% (n = 79).

From the sample of 195 LGDs evaluated during all of the surveys, 84 (43%) displayed behavioural problems. The most prevalent LGD behavioural problems were staying home (20%), chasing wildlife (19%) and biting livestock (11%); only three (2%) dogs were reported to attack people. Over the age categories, a higher percentage of dogs in the 39-63 months (3.25-5.25 years) category chased wildlife (33%, 13 dogs) and/or stayed home (45%, 18 dogs) than dogs in any of the other categories (Fig. 2.9). Biting livestock was more prevalent in the youngest category (6-12 months, 25%, 8 dogs) than the other categories (Fig. 2.9).

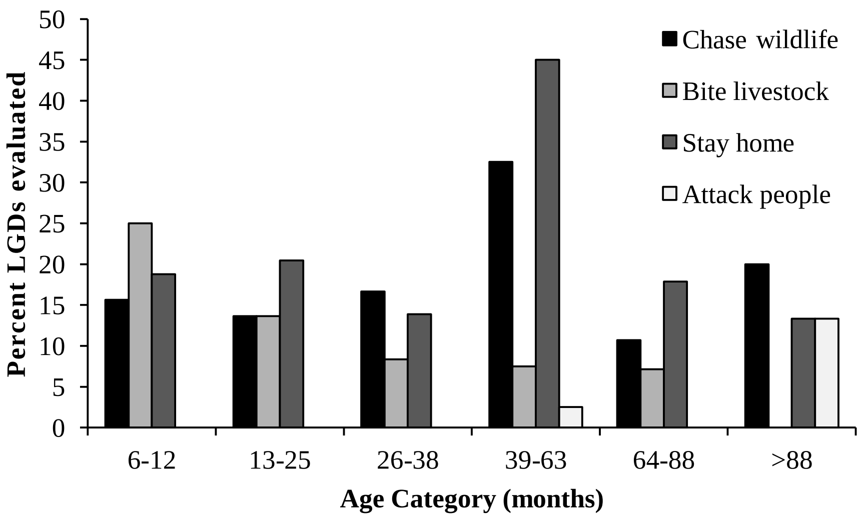

Fig. 2.9. The percentage of LGDs within each age category that were reported to display behavioural problems; 6-12 months, n = 32; 13-25 months, n = 44; 26-38 months, n = 36; 39-63 months, n = 40; 64-88 months, n = 28; >88 months, n = 15.

The trustworthiness score for the dogs in all age categories was not affected by the presence of a herder (U = 2626, z = -0.06, p = 0.95, n = 164), nor whether the herder was changed or not during the dogs' lives (U = 2750, z = -1.72, p = 0.085, n = 162). Five respondents stated that their LGDs' performance was either negatively affected by the change in herder or changed in accordance with herder quality. Fifteen respondents stated that the change in herders was good for the dog, as the new herder was better than the previous one. LGDs in the former group appeared less trustworthy than those in the latter group, however this difference was not significant (U = 25, z = -1.28, p = 0.20). A further 20 respondents stated that the change in herder did not affect the performance of the LGD either negatively or positively.

For the LGDs on all farm types, there was no significant difference in mean farmer care score between dogs that stayed at home and those that did not (U = 1467, z = -1.38, p = 0.17, n = 146). A similar result was found for the care of dogs that chase wildlife in all age categories (U = 1624, z = -0.79, p = 0.43, n = 146).

As farmer care score is affected by farm type (see section 3.3.5.), the data were separated according to farm type to further investigate these behavioural problems with respect to the care score. These analyses revealed that, on subsistence farms, the LGDs reported to stay home rather than accompany the flock (n = 6) were provided significantly less care than those dogs that did not stay at home (n = 29) (U = 38, z = -2.20, p = 0.028, Fig. 2.10.a). Conversely, it appeared that LGDs that chased wildlife (n = 4) were provided better care than those that did not (n = 31) (Fig. 2.10.a). However, this result was not significant due to the small sample size of dogs that chased wildlife on subsistence farms (U = 32, z = -1.62, p = 0.11). None of the dogs on subsistence farms displayed both staying home and chasing wildlife behaviours.

On commercial farms, LGDs that stayed at home (n = 24) were given no less care than those that did not (n = 87) (U = 944, z = -0.77, p = 0.44, Fig. 2.10.a). A similar result was found for the care provided for LGDs that chased wildlife (n = 27) than those that did not (n = 84) (U = 1096, z = -0.28, p = 0.78, Fig. 2.10.b). Eleven of these LGDs displayed both chasing wildlife and staying at home behaviour.

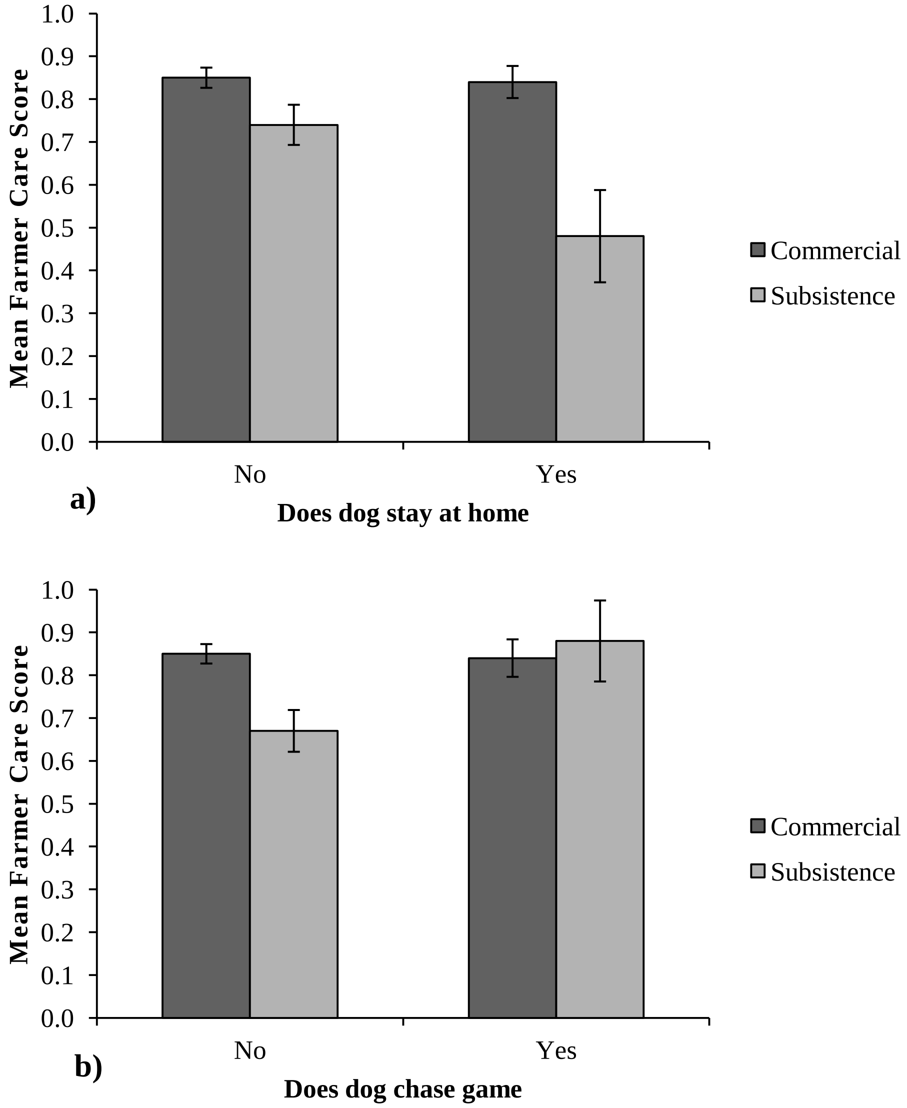

Fig. 2.10. Comparisons between the mean farmer care score (+/- S.E.) for **a)** dogs that do or do not stay at home on commercial (n = 24 and n = 87, respectively) and subsistence (n = 6 and n = 29, respectively) farms and **b)** dogs that do or do not chase wildlife on commercial (n = 27 and n = 84, respectively) and subsistence (n = 4 and n = 31, respectively) farms.

2.4. Discussion

2.4.1. Economic costs and benefits and subsequent farmer satisfaction with LGDs

The percentage of LGDs reducing and/or eliminating livestock losses reported here is similar to that reported in the CCF programme previously (Marker *et al.* 2005a) and higher than LGD success rates reported elsewhere (Green *et al.* 1984; Coppinger *et al.* 1988). These results support the current reputation of LGDs as a useful tool for both commercial and subsistence farmers to reduce livestock losses (Rigg 2001; Shivik 2006). This is further witnessed by the increasing number of farming communities adopting LGDs that had previously not used them in the USA (Andelt & Hopper 2000) and South Africa (Stannard 2006).

Farmer satisfaction with their LGDs reported here was somewhat higher than reported by Marker *et al.* (2005a). It appears that the CCF programme has matured since the previous study by Marker *et al.* (2005a). The training guidelines provided by CCF have been refined over time, which has led to an overall increase in good LGD behaviours (attentiveness, trustworthiness and protectiveness), which were positively correlated with farmer satisfaction in this study.

Interestingly, farmer satisfaction was more strongly correlated with LGD attentiveness and trustworthiness than with protectiveness. Furthermore, the attentiveness and trustworthiness of LGDs were relatively closely correlated and only attentiveness was correlated with LGD protectiveness. These relationships are in line with the Coppinger *et al.*'s (1983) suggestion that LGD attentiveness is the key factor for LGDs reducing livestock losses, as a dog that is always with the livestock will disturb predators trying to hunt them. Additionally, they found that attentive and trustworthy behaviours combine to produce good working LGDs. Thus, it appears that the farmers in this study that witnessed attentive and trustworthy LGD behaviour were satisfied with their LGDs, as they suspected that their LGDs protected the livestock.

Farmer satisfaction did not have a straightforward relationship with livestock losses in this study, especially for those LGDs that did not reduce livestock losses. On closer inspection, the highly satisfied farmers either blamed the herder for the livestock losses or had used LGDs before and did not expect the dog to reduce losses any further. Among the farmers that were less than satisfied with their LGDs, the poor performance of these dogs was connected to their physical condition – one was injured and the other two malnourished. These results are similar to the report by Green *et al.* (1994), who considered that the reasons for LGDs not reducing livestock losses were not the fault of the LGD for half of the reported cases in their survey.

The percentage of farmers that considered their dogs to be economically beneficial in this study falls between the results obtained previously (69.8% reported by Marker *et al.* (2005a), and 84.4% by Green *et al.* (1984)). However, the cost-benefit analysis appears to underestimate the value of LGDs reported by the farmers. The reason for this was similar to the reason for the apparent mismatch between farmer satisfaction and LGD performance provided above. Additionally, farmers that report low average livestock losses before and since obtaining LGDs may still see the dog as beneficial as it prevents any high loss events from occurring, despite the irregularity of these events (Rigg 2001). Lastly, some of the farmers in this study reported no losses before obtaining the LGDs evaluated, either because they had used LGDs previously or because they bought the livestock at the same time as the LGD. These farmers considered their LGDs to be a valuable preventative measure, as livestock losses were expected to occur in the absence of LGDs.

The economic cost-benefit analysis presented in this study considers only the fundamental costs and benefits of LGDs. This analysis excludes the costs of time spent training the dog and any costs of livestock that may be lost by the LGD killing or injuring them during the training phases (Green *et al.* 1984; Smith *et al.* 2000). Similarly, it excludes the potential extra benefits of LGDs decreasing the labour required, in cases where a herder is no longer necessary, and the intangible benefits such as greater peace of mind for the farmer (Green *et al.* 1984; Smith *et al.* 2000). Additionally, LGDs may reduce fear of predation among the livestock, which influences their behaviour and habitat selection (Shrader *et al.* 2008). Reducing livestock fear can lead to increased growth and reproduction (Howery & DeLiberto 2004).

The monetary estimates provided in this study are specific to the LGDs in the CCF programme, which provides discounts on the costs of obtaining and maintaining a LGD. Where LGDs are bred for commercial gain, farmers make a significant initial investment to acquire a LGD, which can range from US$240 to US$1000 in the USA (Smith *et al.* 2000). In South Africa, the average price of a purebred Anatolian is R3500.00; however, some conservation projects supply the dogs to farmers at no charge (pers. comm. Cilliers 2011, 11 May 2011). LGDs that are acquired at dog breeders' prices would therefore need to save more livestock than projected in this study. Lastly, the use of purebred LGDs by subsistence farmers is only made possible through the discount provided by CCF; these farmers would otherwise be excluded from using purebred LGDs to protect their livestock.

2.4.2. The influences of farm type, care provided and LGD age on LGD protectiveness

Despite the discounts provided by CCF, the subsistence farmers in this study were unable to provide the same level of care as provided by the commercial farmers. The farmer care score in this study comprises the quality of food provided (i.e. money spent) and the regularity of the owners' involvement with the dog (i.e. time spent). The amount of time spent with the dog is likely to vary among both commercial and subsistence farmers, as not all of the farmers in both groups live permanently at their farms. This is particularly true for the emerging commercial (part of the commercial farm type) and resettled farmers (part of the subsistence farm type): 53.3% of these farmers were found to rely on employment off the farm in Schumann's (2009) survey. Thus, the differences in farmer care score between commercial and subsistence farmers is likely due to the cost of supplying high quality dog food to their LGDs.

Contrary to expectations, the protectiveness of LGDs was not related to the care provided by the farmer. Consequently, no significant difference in LGD protectiveness was found between the two farm types for any of the analyses. A significant negative relationship between farmer care and LGD age was found by Marker *et al.* (2005a) for all farm types. In the current study, a negative relationship between farmer care and LGD age was found only on subsistence farms.

The relationship between farmer care and LGD age on subsistence farms may be due to several factors. As there are no previous studies regarding the care of purebred LGDs by subsistence farmers over time, the following observations are from the author's experience of running the CCF LGD programme. The initial cost of N$700 can be viewed as quite substantial by some of these farmers, which causes them to consider their current financial ability when acquiring a LGD. The farmers receiving dogs from CCF then attend a training session, during which they are made aware of their responsibility to provide quality dog food and that malnourished dogs can be confiscated with no refund (see Chapter 1). The farmers may therefore provide adequate care for newly-acquired LGDs as the money invested in the dog would be squandered if the dog was confiscated. However, over time the initial investment is recovered by the LGD saving livestock and the maintenance costs may be seen as too expensive, especially if other factors (e.g. losing external employment) lead to financial insecurity. The farmers may also observe that the LGD continues to be protective despite the declining food quality and therefore consider the provision of quality food to be an unnecessary expense.

This study revealed no distinct maximum lifespan for LGDs in the CCF dog programme; LGDs from six months to ten years of age were reported to be protective by their owners. Thus, provided that LGDs do not suffer premature deaths, which are common in the CCF programme (Marker *et al.* 2005b), farmers can benefit from the use of LGDs for an extended period.

The young age at which LGDs reportedly became effective in this study is contrary to previous suggestions that LGDs must mature and/or gain experience with predators before becoming effective (Green *et al.* 1994; Rigg 2001). However, Green *et al.* (1994) pointed out that LGDs operating in areas where the predators are not too numerous or persistent and aggressive can reduce predation from a young age. Furthermore, Coppinger *et al.* (1983) suggest that one of the main ways that LGDs of all ages protect the livestock is simply by distracting the predator.

Several of the oldest LGDs in this study were given perfect protectiveness scores by the farmers that used them. These were clearly highly experienced dogs and most of them (10 out of 15) had eliminated livestock losses entirely in the year of evaluation. It must be taken into account that dogs displaying unwanted behaviour are generally transferred out of working conditions or suffer premature deaths (Green & Woodruff 1990; Marker *et al.* 2005b). Thus, dogs in the oldest age category are likely to be above average in terms of their behaviour, which would inflate the protectiveness score of LGDs in this category.

2.4.3. Development of LGD behaviour and common behavioural problems

The behavioural development of LGDs with age appears to be complex, with the findings of this study showing no direct correlations between the behaviour of young and adult dogs. This result is similar to that found for puppy aptitude testing in the LGD programme previously (Marker *et al.* 2005a).

The lack of trustworthiness among juvenile dogs is due to the frequency of rough play behaviour, which tends to disappear as they mature, particularly if the dogs are corrected (Dawydiak & Sims 2004). This was supported by the results for biting livestock – 6-12 month old dogs bit livestock more frequently than older dogs. Similarly, Green *et al.* (1984) reported that 10% of LGDs killed or injured livestock when they were young, but most dogs discontinued this behaviour as they matured. In the CCF programme, farmers are advised to correct play behaviour and thus prevent the development of predatory behaviour towards the livestock (Schumann 2003). The reduction of reported LGD behaviour problems in the CCF programme since 1999 supports the postulate that untrustworthy behaviour can be minimised with correct training.

In contrast to trustworthiness, attentiveness is developed in LGDs from a young age, provided that the dog is kept with the livestock at all times (Black & Green 1985; Green & Woodruff 1990). For young dogs, attentiveness will reflect the way they are handled – the dog remains with the flock all the time if it is kept with them by a herder and/or restrained to the livestock enclosure (Dawydiak & Sims 2004). The high attentiveness of young dogs reported here is likely due to these early training methods, which resulted in highly attentive adult dogs.

Protectiveness scores for juvenile and adult dogs are difficult to measure, as protective behaviours (e.g. barking at and chasing predators) are not always witnessed by the farmer

(Dawydiak & Sims 2004). Juvenile LGD protectiveness was estimated by inquiring whether the puppies barked at strange sounds, people or things, as barking is seen as the early phase of protective behaviour (Lorenz & Coppinger 1986). The adult protectiveness scores include the farmers' opinions of their LGDs protective behaviour (excellent, good, fair or poor) and the level of stock lost since receiving the LGD. The consistency in the LGD scores as juveniles and adults indicates that the same underlying LGD behaviour was measured by both scores.

The finding that staying home and chasing wildlife was more prevalent in the 39-63 month category was unexpected, as there are no previous examples in the literature of LGDs developing these negative behaviours at this age. In an attempt to explain the occurrence of these behaviours, the effects of the herder and farmer care were examined.

The expected effects of herder presence and/or changing herders on LGD trustworthiness could not be conclusively established in this study due to small sample sizes. A high quality herder would be expected to prevent both staying at home and chasing wildlife behaviours (Schumann 2003). The opposite may be true for a low quality herder that does not work well with the dog and/or encourages wildlife-chasing behaviour (Schumann 2003). Investigating herder quality in relation to the development of these behaviour problems would therefore be an avenue for future research.

On subsistence farms, LGDs that stayed at home were provided significantly less care than those that did not. This, in conjunction with the increased prevalence of this behaviour at 39-63 months, corroborates with the trend of declining farmer care on subsistence farms with LGD age. Thus, it can be concluded that LGDs that start staying at home later in life on subsistence farms lack the energy required to accompany the flock due to dietary deficiencies. The results for chasing wildlife with respect to farmer care were not conclusive, as chasing wildlife was rare among LGDs on subsistence farms. Furthermore, LGDs that are provided poor quality food would lack the energy to chase wildlife, it is therefore not surprising that none of the dogs on subsistence farms displayed both staying at home and chasing wildlife behaviours.

In contrast to the subsistence farms, it appears that commercial farmer care has no effect on either staying home or chasing wildlife behaviours. This was expected, as farmer care among commercial farms was relatively consistent for the LGDs in this study. Thus, the emergence of behavioural problems on commercial farms is likely to be linked to factors that were not examined in this study.

2.4.4. Conclusions and recommendations

The perceived success of any method used to mitigate farmer-predator conflict depends heavily on the opinions of the farmers that incorporate the method into their farming practices (Shivik 2006). The high level of farmer satisfaction found in this study, at levels beyond the objective cost-benefit analysis, indicates that the use of LGDs is acceptable, practical and applicable for Namibian farmers. Thus, LGDs pass the test set by Breitenmoser *et al.* (2005) and satisfy Shivik’s (2006) farmer psychological assuagement criterion.

The majority of the LGDs in this study were cost-effective (Mitchell *et al.* 2004) and economically efficient in terms of the low cost required to obtain and maintain them (Shivik 2006). As LGD training methods have been refined in the CCF programme, the complexity (Shivik 2006) of raising and training a LGD has been reduced and the prevalence of LGD behavioural problems has declined. Lastly, with a potential effective lifespan of over nine years, LGDs in the CCF programme that do not die prematurely satisfy the requirement of long-term use set by Mitchell *et al.* (2004).

Although LGDs in Namibia satisfy all of the above evaluation criteria, there is still scope for further research, particularly with respect to the development of LGD behavioural problems. The recommendations to reduce these behavioural problems may differ for commercial and subsistence farmers, as they use LGDs under different conditions. In particular, the CCF dog programme should focus on providing more low-maintenance dogs for subsistence farmers to make the care of LGDs more affordable.

The use of LGDs is becoming commonplace among commercial farmers in Europe, the USA and South Africa (Rigg 2001; Stannard 2006) and literature on raising and training purebred LGDs abound (Lorenz & Coppinger 1986; Green & Woodruff 1990; Dawydiak & Sims 2004; van Bommel 2010). However, raising and training non-purebred LGDs by subsistence communities is not as thoroughly documented (but see Black & Green 1985). Nevertheless, there is still potential for expanding the use of non-purebred LGDs in communal areas (24% of the farmers in Laikipia district, Kenya used LGDs, Woodroffe *et al.* 2007; 21% of the farmers in Ghanzi district, Botswana used LGDs, Selebatso *et al.* 2008). In these communities, the training methods can be improved to increase LGD attentiveness to the livestock, rather than being attentive only to the herders (Woodroffe *et al.* 2007) or acting solely as alarms near bomas at night (Ogada *et al.* 2003). The lessons learned from the CCF dog programme should therefore be used to educate subsistence farmers on the correct care and training required to produce effective livestock guarding dogs.

3. The Effectiveness of Livestock Guarding Dogs for Conservation

3.1. Introduction

3.1.1. Carnivore conservation and LGDs as a farmer-predator conflict mitigation measure

The lethal control of carnivores to protect domesticated animals from predation is a significant threat to the long term conservation of carnivore species worldwide (Treves & Karanth 2003; Graham *et al.* 2005; Woodroffe *et al.* 2005; Inskip & Zimmermann 2009). Where predators range outside protected areas, they come into conflict with livestock owners, who may kill predators in response to the perceived and real threats posed to their livestock (see Chapter 1). Additionally, the use of unselective lethal methods (e.g. poison) to control relatively abundant predators on farmlands (e.g. black-backed jackal and caracal *Caracal caracal*) can have broad negative ecological impacts (Snow 2006; Avenant & du Plessis 2008). Consequently, the mitigation of human-predator conflict with the specific goal of reducing predator killing outside protected areas is an essential component of carnivore and biodiversity conservation (Sillero-Zubiri & Laurenson 2001; Marker *et al.* 2003b; Jackson & Wangchuk 2004; Kissui 2008).

In response to the need for effective, non-lethal conflict mitigation measures, traditionally-used preventative methods that involve guarding livestock from predators have received increasing research attention (Ogada *et al.* 2003; Breitenmoser *et al.* 2005; Woodroffe *et al.* 2007). Particularly, the use of specialized livestock guarding dog (LGD) breeds have been promoted as a widely applicable and socially acceptable non-lethal method of reducing human-carnivore conflict (Landry 2001; Rigg 2004; Marker *et al.* 2005a; Gehring *et al.* 2006; Gehring *et al.* 2010a; Urbigkit & Urbigkit 2010). Despite this promotion, LGDs have not been evaluated in terms of their contribution to predator conservation and their potential impact on non-target species. In this chapter, I present such an evaluation of LGDs placed on Namibian livestock farms as part of a predator conservation initiative.

3.1.2. Evaluating LGDs in terms of farmer predator control

Conflict mitigation measures aimed at reducing livestock losses have been promoted under the assumption that farmers kill predators as a direct response to livestock losses experienced (Landry 2001; Jackson & Wangchuk 2004; Marker *et al.* 2005a; Woodroffe *et al.* 2007). That this assumption is rarely tested is surprising, considering the many examples of mismatched farmer attitudes and behaviour compared to livestock losses suffered (Marker *et al.* 2003b; Treves & Karanth 2003; Madden 2004; Breitenmoser *et al.* 2005; Sillero-Zubiri *et al.* 2007; Selebatso *et al.* 2008; Inskip & Zimmermann 2009). If farmer attitudes towards predators influence their predator control strategies more than livestock losses, then the introduction of livestock protection measures such as LGDs may have little effect on farmer predator control.

Human tolerance and perceptions of carnivores are influenced by their cultural and socio-economic backgrounds (see Chapter 1). In broad terms, subsistence and commercial farmers may vary both with respect to their level of tolerance for predators and the resources available for predator control (Romañach *et al.* 2007; Selebatso *et al.* 2008). As carnivores occur on subsistence and commercial farmlands throughout Africa, evaluations of conflict mitigation methods to reduce predator killing should be conducted on both farm types (Romañach *et al.* 2007; Selebatso *et al.* 2008). As LGDs in the CCF programme are used on both farm types, I used this opportunity to examine how and if predator killing relative to the use of LGDs differed between commercial and subsistence farms.

3.1.3. The potential for LGDs as intraguild predators on target carnivore species

One aspect of predator conservation using LGDs that has not been addressed in published scientific literature is the possibility that LGDs kill predators whilst guarding the livestock.

Although LGDs are widely considered to be a non-lethal predator control method (Mitchell *et al.* 2004; Shivik 2004; Breitenmoser *et al.* 2005; Gehring *et al.* 2006), domestic dogs have been recorded as intraguild predators of small- to medium-sized carnivores (Vanak & Gompper 2009). As LGDs are bonded with livestock and are therefore protective of these livestock, it is likely that these relatively large dogs (male and female Anatolian Shepherds can weigh 50 kg, Dawydiak & Sims 2004) kill medium-sized carnivores that threaten the small stock. The alternate hypotheses that LGDs function as a non-lethal *versus* lethal control method were examined in this study.

Four carnivore species – leopard *Panthera pardus*, cheetah, caracal and black-backed jackal – were chosen as the target species in this study, as they are commonly reported to cause small stock losses in southern Africa (Marker *et al.* 2003b for cheetah; Avenant & du Plessis 2008 for jackal and caracal; Balme *et al.* 2009 for leopard). The target carnivore species were then separated into two groups according to their body size and predatory roles, with jackal and caracal grouped together as mesopredators and cheetah and leopard grouped as apex predators.

Due to the comparative body sizes of meso- and apex predators to the LGDs, I expected that LGDs would be more likely to function as intraguild predators on the relatively small mesopredators, than on the larger apex predators (Palomares & Caro 1999; Donadio & Buskirk 2006). LGDs were furthermore expected to kill the main livestock-killing predator species more frequently than the other predator species. Thus, LGDs would satisfy the predator selectivity criterion provided by Mitchell *et al.* (2004) for lethal control methods.

I adapted Shivik's (2004; 2006) measure of biological efficiency to evaluate LGDs with respect to the different target carnivore categories. Although the economic cost and level of management intensity provided by Shivik (2004; 2006) remains the same, the conservation benefit of LGDs may vary for each of the target carnivore species. Conservation benefit was measured by the number of individual predators from each species that were killed on farms before and since LGD introduction. The numbers of predators killed by LGDs were combined with the number of predators killed by the farmer to calculate the total number of predators killed on farms since LGD introduction. Larger carnivores that require larger tracts of habitat and larger prey species (Carbone & Gittleman 2002) are at greater extinction risk than smaller carnivores (Cardillo *et al.* 2004). Thus, the overall effect of LGDs would be deemed biologically efficient if they provided greater protection (i.e. fewer numbers killed) for the apex predators than for the mesopredators in this study area.

3.1.4. Assessing the environmental impacts of LGDs through the killing of non-target species

The environmental impact of predator control methods refers to their negative effects on non-target species in the ecosystem (Mitchell *et al.* 2004). In the same way that LGDs could function as intraguild predators on the target predator species, they are capable of killing smaller carnivore species that rarely or never cause livestock losses (Butler *et al.* 2004; Vanak & Gompper 2009; Young *et al.* 2011). Despite the likelihood of these encounters, there are no records of LGDs killing small, non-target carnivores in the published literature. As these smaller carnivores have important ecological functions in maintaining small mammal and insect populations (Blaum *et al.* 2009), LGDs that kill these species could have negative impacts on farm ecosystems.

A commonly reported but poorly studied characteristic of LGDs is their tendency to chase wildlife (Hansen & Bakken 1999; Marker *et al.* 2005a; Vercauteren *et al.* 2008; Gingold *et al.* 2009). Despite these records of wildlife-chasing behaviour, no studies indicate how many LGDs kill the wildlife they chase. In situations where wildlife may transmit diseases to livestock, the tendency of LGDs to chase wildlife away from livestock is viewed in a positive light (Vercauteren *et al.* 2008; Gehring *et al.* 2010b). In Namibia, however, wildlife – particularly large wildlife species – are considered a valuable resource by farmers (Richardson 1998; Naidoo *et al.* 2010). The potential for LGDs to chase and kill wildlife is therefore a negative aspect of the use of LGDs in Namibia. In this chapter, the environmental impact of LGDs (as per Mitchell *et al.* (2004)), is documented.

As the killing of non-target species by LGDs is of concern to both farmers and conservationists, possible reasons for and circumstances surrounding non-target killing by LGDs were examined. LGDs were expected to kill non-target species either as a function of livestock protection or as a function of inattentive or untrustworthy behaviour; the latter is linked to wildlife-chasing, which is considered to be negative LGD behaviour (Marker *et al.* 2005a and see Chapter 2). I further hypothesized that if LGDs killed non-target carnivores to protect the livestock they would not eat the carcasses of the animals they killed. Conversely, if LGDs hunt wildlife as a function of wildlife-chasing behaviour or due to hunger, they would be expected to eat the carcasses of the animals killed.

3.1.5. Objectives and hypotheses

The following objectives (numbered) and hypotheses (lettered) emerged from the review provided above.

1) To test the assumption that farmer predator control is related to livestock losses and hence evaluate the effectiveness of LGDs for reducing the numbers of predators killed by farmers.
    a. Farmers will target predator species that are more frequently reported to cause livestock losses than species that are rarely reported to cause losses.

b. Predator control strategies would differ between commercial and subsistence farmers, both before and since LGD introduction.

c. Livestock losses reported by farmers will be associated with their predator control strategies, both before and since LGD introduction.

d. If predator killing by farmers is linked to attitudes towards predators irrespective of the presence of LGDs, the number of predators killed by farmers before and since the introduction of LGDs would be correlated.

e. Among those farmers that kill known numbers of predators before and/or since LGD introduction, they will kill fewer predators per farm per year since than prior to LGD introduction.

2) To test whether LGDs function as a non-lethal or lethal method of predator control through intraguild predation and evaluate LGDs in terms of predator selectivity (Mitchell *et al.* 2004) and biological efficiency (Shivik 2006).

   a. If LGDs function as a non-lethal form of predator control, LGDs would not be reported to kill any predator species by farmers; alternatively, if some farmers report that LGDs kill predators, then the LGDs would be a form of lethal control.

   b. If LGDs are reported to kill predators, they would kill mesopredators more frequently than apex predators due to their differences in relative size to the LGDs (Donadio & Buskirk 2006).

   c. If LGDs kill predators out of protection for livestock, they would kill more predators of those species that are more frequently reported to cause livestock losses than species that rarely cause livestock losses.

   d. Overall, LGDs are expected to reduce the number of predators killed on farms, yet their effect is expected to be biologically efficient: threatened apex predators will benefit from the introduction of LGDs more than locally abundant mesopredators.

3) To determine the impact of LGDs on non-target carnivore and other wildlife species and the behavioural reasons for LGDs killing these species.
    a. A minority of LGDs will be reported as killing non-target species.
    b. LGDs that kill non-target carnivore species will be reported as protecting their livestock and they will not eat the carcasses of these animals.
    c. LGDs that kill wildlife prey species will be reported as displaying hunting behaviour and they will eat the carcasses of these animals.

3.2. Materials and Methods

3.2.1. Data collection and manipulation

The evaluation questionnaires developed in the CCF dog programme (Marker *et al.* 2005a) were modified for this study to include questions on predator control by the farmer and wildlife killing by the LGDs. As the questionnaires developed for the 1999 and 2004 studies (see Chapter 2) did not include questions on these topics, the data collected for this chapter are restricted to the dogs evaluated using the 2009 questionnaire only (see Appendix).

In order to compare levels of predator killing and livestock loss before and since the LGD introduction, the respondents were asked to recall these events in the year before they received LGDs and in the last year since LGD introduction (called 'the survey year' hereafter). These data therefore relied upon the respondents being present on the farm before the LGD; this was not always the case when the respondent was an employee on the farm. Among the older dogs in the survey, the accuracy of the data relied on the respondents' memory of these events before the LGD came to the farm. Thus, some respondents could not answer the questions and some were not able to give figures of livestock lost or predators killed, but were only able to say if there were losses and if predators were killed on the farm. Although these uncertain responses reduced the sample sizes required for statistical testing, I considered that having fewer, more accurate responses was more important than trying to get uncertain respondents to produce figures.

In the few cases where respondents were uncertain of the number of predators killed by the farmer and/or the numbers of predators or non-target species killed by the LGD, their responses were excluded from analyses requiring exact numbers. Thus, the mean numbers of jackal, Chacma baboon *Papio ursinus* and small game killed by the LGD are conservative estimates, as five, three and two respondents respectively were unsure of the numbers killed by the LGDs. Similarly, the mean numbers of jackal (five uncertain of numbers before and three since the LGD) and caracal (two before and one since the LGD) killed by farmers are conservative estimates. These respondents were, however, certain that these predators were killed; their responses were therefore retained for analyses where only the frequencies of these incidents were required.

In the survey, only cases where farmers killed one or more of the four target carnivore species (jackal, caracal, cheetah and leopard) were recorded. In the cases where farmers killed more than one species of predator on their farms, these were counted separately for each of the four target predator species, but were counted as individual farms employing lethal control of predators. For analyses of predator control on different farm types, the farms were separated into commercial and subsistence categories in the same manner as detailed in Chapter 2.

The prevalence of LGDs eating the carcasses of the animals killed was determined from respondents that reported LGDs killing target and/or non-target species. Furthermore, these respondents were asked whether they thought the LGDs were displaying protective or hunting behaviour. This question was simplified during interviews with respondents that did not understand the question clearly – the interviewer asked whether the LGD only killed animals that came near the flock/herd (protective) or killed animals that were far from the livestock (hunting). The LGDs that killed several different species were counted separately for analyses of the different species or categories of species, but counted as individual LGDs that killed target and/or non-target species.

3.2.2. Data selection

Where one LGD was evaluated more than once in the 2009-2010 survey, only the first evaluation was selected for analysis. If, however, the second evaluation was completed with a more certain respondent, the responses from the second evaluation were used.

In the analyses for farmer predator control, only the evaluation for the first LGD received from CCF was selected for those farmers with multiple dogs. The rationale for this was that predator control is expected to be influenced by the presence of the first LGD received; the influence of subsequent LGDs on farmer predator control would be confounded by the presence of the first LGD. Similarly, for the analyses on LGDs killing target and non-target species, if two LGDs from CCF worked together during the survey period the second LGD was excluded from these analyses to exclude the influence of the first dog’s behaviour on the second.

Not all farmers in the survey killed predators before and since the LGD introduction and not all LGDs killed predators. The analyses for the mean numbers of predators killed by farmers only and the overall numbers of predators killed by farmers and/or LGDs were therefore conducted on relevant subsets of the data. The numbers of farmers killing target predator species and the numbers of LGDs reported to kill target carnivore species relative to the total number surveyed is reported. Similarly, the mean numbers of non-target carnivore and game animals killed by LGDs were calculated using a subset of LGDs that were reported to kill non-target species.

Baboons and domestic dogs were infrequently and never reported to kill livestock in the current study, respectively. These species are therefore not among the target carnivore species with respect to farmer predator control. Nonetheless, both species have been verified as killers of small livestock in other studies (Butler 2000; Holmern *et al.* 2007; Bergman *et al.* 2009). Thus, where LGDs were recorded to kill baboons or dogs I considered them to be target carnivores for discussion purposes.

Non-target carnivores were categorised as those species that have not been reported in the published literature as verified killers of small livestock. Furthermore, the game species recorded as being killed by the LGDs were categorized as either small or large game. For the antelope species, springbok *Antidorcas marsupialis* and larger antelope were considered large game (adult weight > 30 kg, Skinner & Chimimba 2005); common duiker *Sylvicapra grimmia* and smaller antelope were considered small game (adult weight < 25 kg, Skinner & Chimimba 2005). Warthogs *Phacochoerus africanus* were included as small game, as they are a less valuable species for hunting. Mammals smaller than four kilograms were not included in this analysis (including hares, rock hyraxes *Procavia capensis* and rodents, Skinner & Chimimba 2005) as these species have no commercial value as game animals.

3.2.3. Statistical analyses

A Chi-square test for independence with Yates' continuity correction was used to test whether predator control by farmers was associated with livestock losses, both before and since LGD introduction. The data collected on numbers of predators killed by the farmers and LGDs were positively skewed and not normally distributed (Kolmogorov-Smirnov and Shapiro-Wilk tests, $p < 0.001$). Thus, non-parametric tests were used – the Wilcoxon Signed-Rank test for data using repeated measures, Mann-Whitney *U* tests for comparisons between independent categories and Spearman's Rank Order Correlation for correlation tests. All statistical procedures were conducted using SPSS 12.0.1 and only the results where $p < 0.05$ were considered significant.

3.3. Results

3.3.1 The use of LGDs to mitigate conflict and reduce lethal predator control on Namibian farms

Prior to receiving LGDs, the jackal was the most frequently reported species to cause livestock losses, followed by cheetah, caracal, leopard and baboon in order of decreasing frequency (Table 3.1). This order was repeated subsequent to LGD introduction, although fewer farmers reported losses since the LGD introduction to all predator species; only baboons caused no livestock losses in the survey year since the LGDs (Table 3.1). Farmer predator control of the target carnivores before the LGDs followed a similar pattern to the reported damage-causing predator species (Table 3.2). Jackals were killed by 19 farmers (28%), cheetahs and caracals were killed by four farmers (6%) each and one farmer (2%) killed one leopard in the year before the LGD (Table 3.2).

Table 3.1. The number (%) of farmers reporting predator species to cause livestock losses in the year before and in the survey year since receiving LGDs.

Cause of livestock loss	Jackal	Cheetah	Caracal	Leopard	Baboon	No loss
Before LGD (n = 57)	42 (74)	15 (26)	14 (25)	5 (9)	3 (5)	8 (14)
Since LGD (n = 71)	21 (30)	8 (11)	5 (7)	3 (4)	0 (0)	46 (65)

Contrary to expectations, reported livestock losses were not associated with predator elimination by farmers, either before ($\chi^2 = 0.87$, df = 1, p = 0.35, n = 63) or since ($\chi^2 = 0.00$, df = 1, p = 1.00, n =79) LGD introduction. The low frequency of farmers that reported no livestock losses during the year before the LGD, yet eliminated predators in that year (one farmer) violated the minimum cell frequency requirement of the Chi-square test. Nonetheless, a closer inspection of the data revealed that the lack of association between livestock loss and predator elimination was due to higher-than-expected farmer tolerance for livestock losses. Among farmers that reported livestock losses in the year before receiving LGDs, the majority (70%, n = 63) stated that they did not eliminate predators during the same year. Similarly, 79% (n = 79) of the farmers reporting losses in the survey year since LGD introduction did not eliminate predators in this year.

Before receiving LGDs, the percentage of commercial farmers killing predators (32%) was similar to the percentage of subsistence farmers killing predators (30%), (χ^2 = 0.00, df = 1, p = 1.00, Table 3.2). Five commercial farmers that previously killed predators did not kill predators in the survey year since LGD introductions; all six subsistence farms that killed predators previously did not kill predators in the survey year. However, the percentage of commercial (11%) and subsistence (30%) farmers that stopped killing predators since LGD introduction were not significantly different (χ^2 = 3.51, df = 1, p = 0.06, n = 65).

Three commercial farmers had not killed predators before the LGDs, yet killed predators in the survey year; these were more closely examined to determine the reasons for predator control. The two farmers that started killing jackals in the survey year had used LGDs for several years prior to the survey year and – according to these farmers – this was the first year that either of them lethally controlled predators. Both farmers stated that selective jackal control had become necessary (they shot one and five jackals, respectively, which were found close to the livestock) due to an apparent dramatic increase in the jackal population in their area (the farmers are neighbours). Similarly, one commercial farmer that received the LGD at the same time as the livestock (the questions regarding predator control before the LGD were therefore not applicable) killed one caracal in the survey year. The caracal was shot at night whilst in the kraal; this farmer stated that he had not killed any predators prior to the survey year since obtaining a LGD.

Table 3.2. The number (%) of responding commercial and subsistence farmers killing the four target predators in the year before the LGD and in the survey year since LGD introduction.

Farmers responding	Jackal	Cheetah	Caracal	Leopard	All predators
Before LGD, all farmers (n = 67)	19 (28)	4 (6)	4 (6)	1 (2)	21 (31)
Since LGD, all farmers (n = 70)	12 (17)	0 (0)	3 (4)	0 (0)	13 (19)
Before LGD, commercial (n = 47)	13 (28)	3 (6)	4 (8)	0 (0)	15 (32)
Since LGD, commercial (n = 50)	12 (24)	0 (0)	3 (6)	0 (0)	13 (26)
Before LGD, subsistence (n = 20)	6 (30)	1 (5)	0 (0)	1 (5)	6 (30)
Since LGD, subsistence (n = 20)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

The numbers of predators killed per farm per year before LGD introduction were positively correlated with the numbers of predators killed in the survey year since LGD introduction on the same farms ($\rho = 0.30$, $p = 0.01$, $n = 70$). Nonetheless, among those farmers that killed known numbers of jackals ($n = 16$), they killed fewer jackals in the survey year since (4.5 ± 2.30 per farm per year) than before (6.5 ± 2.16 per farm per year) LGD introduction ($z = 2.05$, $p = 0.04$). Three farmers killed 2.2 ± 0.44 caracals each in the year before the LGD and 1.0 ± 1.00 caracal each in the year since the LGD introduction, but this difference was not significant ($z = -1.34$, $p = 0.18$). Four farmers killed 4.0 ± 2.38 cheetahs each in the year before the LGDs; no cheetahs were killed by farmers in the survey year. A single leopard was killed by a farmer in the year before the LGD and no leopards were killed in the survey year.

3.3.2. LGDs as intraguild predators of target carnivores and implications for their use in predator control

LGDs were most frequently reported to kill jackals (37 LGDs reported, 45% of total), followed by baboons (nine LGDs reported, 11% of total), caracals (three LGDs reported, 4% of total), domestic dogs (two LGDs reported, 2% of total) and cheetah (one LGD reported, 1% of total). No leopards were killed by LGDs in the CCF programme during the survey year.

Subsets of farmers that killed predators and/or reported their LGDs to kill predators were chosen to analyse the overall effects of LGD introduction on target predator killing. Overall, more jackals were killed per farm in the survey year by the farmers and the LGDs combined (5.6 ± 1.15), than were killed by the same farmers in the year before they received LGDs (2.9 ± 1.09) (z = -3.15, p = 0.002, n = 36, Fig. 3.1.a). Similarly, farmers and LGDs combined killed 2.0 ± 0.82 caracals per farm in the survey year, whereas the same farmers killed 1.1 ± 0.52 caracals in the year before the introduction of LGDs; however, this result was not significant (z = -0.67, p = 0.50, n = 6, Fig. 3.1.b).

A converse trend was found for cheetahs: farmers killed 3.2 ± 2.01 cheetahs per farm in the year before LGD introduction, whereas no farmers killed cheetahs and one LGD killed one cheetah in the survey year (0.2 ± 0.20 cheetahs killed per farm). However, this trend was not significant due to the small sample size (z = -1.51, p = 0.13, n = 5, Fig. 3.1.c). Leopard killings could not be compared before and since LGD introduction, as only one farmer killed one leopard in the year before the LGD and no farmers killed leopard since LGD introduction, nor did the LGDs kill any leopards in the survey year.

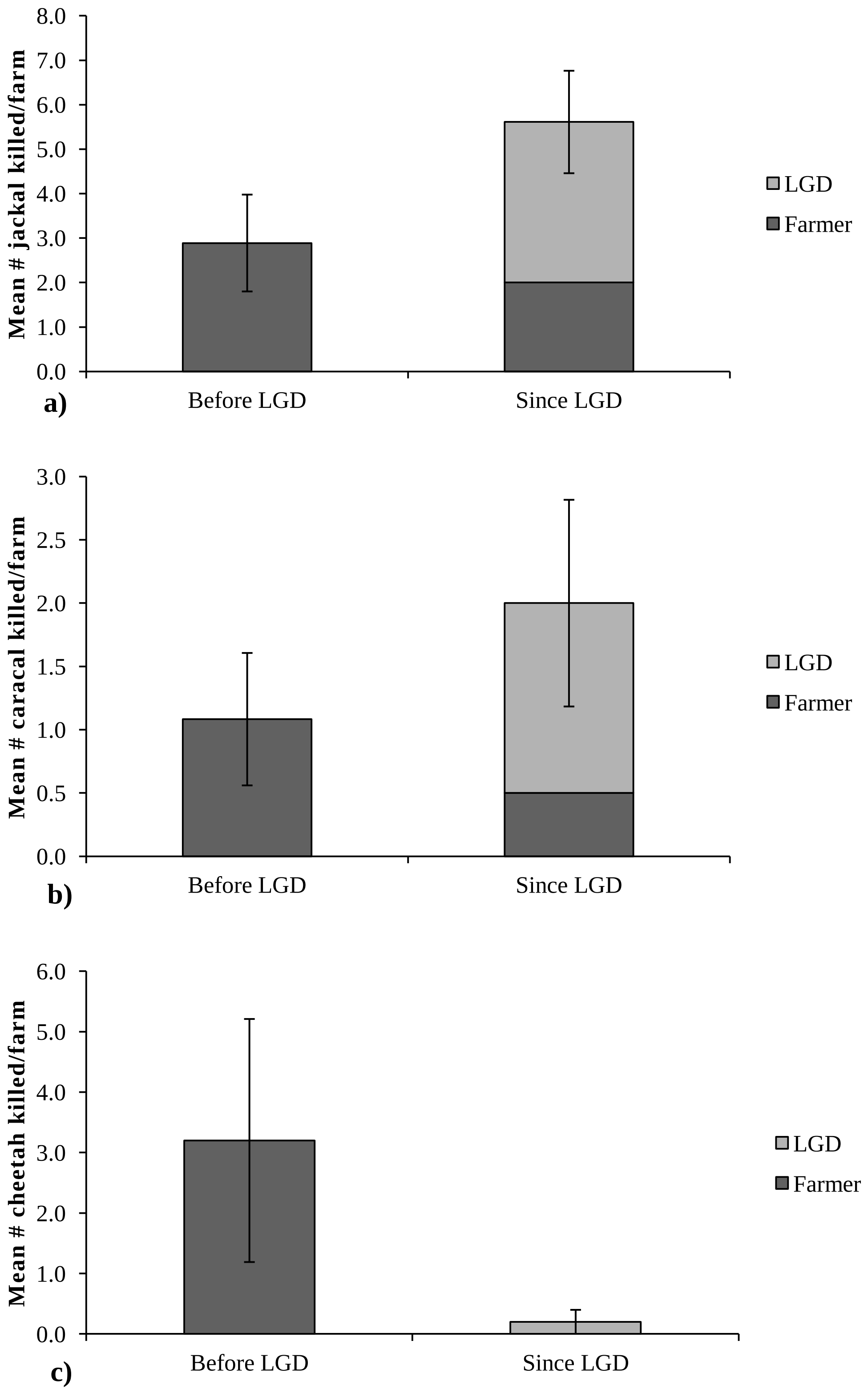

Fig. 3.1. A comparison of the mean number (± S.E.) of **(a)** black-backed jackal (n = 36), **(b)** caracal (n = 6) and **(c)** cheetah (n = 5) killed on farms per year before (farmer kills only) and in the survey year since the LGD (farmer and LGD kills combined).

The six dogs that killed a known number of baboons killed an average of 1.3 ± 0.21 baboons per LGD in the survey year. The two LGDs that killed domestic dogs killed three and two dogs in the survey year, respectively.

3.3.3. The prevalence and reasons for LGDs killing non-target carnivore and game species

Sixteen LGDs (19%, n = 83) were reported to kill non-target species. Two of these LGDs killed non-target carnivore species – one of them killed one bat-eared fox *Otocyon megalotis* and the other an unknown number (‘many’ according to the respondent) of African wildcat *Felis silvestris*. Both LGDs also killed target carnivores (baboon killed by one, jackal and caracal by the other); these LGDs did not eat the carcasses of either the target or non-target carnivores they killed. The farmers owning these LGDs stated that the LGDs killed both target and non-target carnivores out of protection for the livestock. However, one of these LGDs also killed small game species and this was reported as hunting behaviour by the respondent.

Fifteen LGDs (18.1%) were reported to kill small and/or large game species, eight of which did not eat the carcasses of the game they killed. Eight LGDs (10%) killed small game, six of which killed 1.5 ± 0.22 animals each (two respondents were uncertain of numbers killed); three of these LGDs ate the carcasses. Furthermore, eight LGDs (10%) killed 1.8 ± 0.49 large game animals each and four of these LGDs ate the carcasses. Only the calves of the large game species (eland *Tragelaphus oryx*, kudu *Tragelaphus strepsiceros* and oryx *Oryx gazella*) were killed by the LGDs. One LGD killed both small and large game animals, but did not eat the carcasses of the game it killed.

The reasons for LGDs killing game species were unclear, as 13 of the 15 LGDs reported to kill non-target prey species also killed target predator species. Despite the LGDs killing game species, eight of the farmers owning these LGDs stated that the dogs were protecting the livestock and not hunting game. However, five respondents suggested that their LGDs acted out of protection for the livestock when killing predators, but they displayed hunting behaviour when killing game species. Two respondents were unsure as to whether the LGDs were protecting the livestock or hunting game.

3.4. Discussion

3.4.1. LGDs as a mitigation strategy in terms of predator control in response to livestock losses

This study was limited to small stock losses only, the relative order of damage-causing predator species presented here is therefore not a complete picture of predator problems on farmlands overall. Studies conducted in Namibia (Marker *et al.* 2003b; Stein *et al.* 2010) and Botswana (Selebatso *et al.* 2008) indicated that cheetah and leopard are considered a greater problem as predators of game and cattle, which are more valuable than small stock. However, cheetahs are often killed by Namibian farmers as a threat to small stock (Marker *et al.* 2003a). Similar to this study, the small stock farmers in South Africa consider jackal and caracal as the main damage-causing predators (Avenant & du Plessis 2008). As reported by farmers in the current study, baboons have been found to prey on small stock in Zimbabwe (Butler 2000) and Tanzania (Holmern *et al.* 2007).

As expected, farmers targeted the main cause of livestock losses, i.e. jackal, more than the other predator species, with a similar pattern followed for the other target species in this study (Tables 3.1 and 3.2). The high level of tolerance among farmers for damage-causing predators found here is not necessarily representative of overall farmer tolerance in Namibia, which was reported to be lower in previous studies (Marker *et al.* 2003b). The farmers in the LGD programme represent a subset of farmers in the country that request assistance from conservation organisations such as

CCF to provide them with non-lethal solutions to livestock losses. Thus, the results from the 'predator-friendly' farmers in this study must be applied with caution to the broader livestock farming community. The positive correlation that was found between predators killed before and since the LGDs indicated that farmer characteristics not directly measured in the current study (e.g. farmer attitudes) influence their predator control strategies. As only commercial farmers killed predators since the LGD, this conclusion applies only to commercial farmers in this study.

In broad terms, the presence of LGDs reduced the frequency of all predators causing livestock losses and the frequency of farmers killing target predators species. Additionally, the proportions of predator-killing farmers were similar among both commercial and subsistence farmers (Table 3.2). Although all of the subsistence farmers ceased killing predators since the LGDs, there was no detectable difference between changes in predator control on commercial relative to subsistence farms. In contrast, other African studies that included both types of farmers reported that commercial farmers expressed more positive attitudes towards, and higher tolerance for, predators than subsistence farmers (Romañach *et al.* 2007; Selebatso *et al.* 2008). These studies did not compare differences in predator killing by the two types of farmers, although Kissui (2008) reported high levels of retaliatory killing of large carnivores by subsistence farmers in Kenya.

The presence of LGDs provided greatest conservation benefit for cheetah, with little effect on leopard conservation; none of the farmers reported killing these species in the survey year. Less benefit was provided by LGDs for caracal and jackal on commercial farms – these species were still killed, but at a lower rate than before the LGD. Jackal and caracal are relatively abundant in the study area and farmers subsequently use lethal control of these species in combination with their LGDs. Using lethal and non-lethal preventative measures in combination, particularly for relatively abundant damage-causing species, has been recommended in predation management literature (Mitchell *et al.* 2004; Sillero-Zubiri & Switzer 2004; Breitenmoser *et al.* 2005).

The nature of the data collected in this study allows only a snapshot of the farmers' predator control strategies, rather than a complete picture of how LGDs affect long-term predator control. This was illustrated by the three farmers that reported killing more predators since the LGDs – all of these farmers generally did not control predators, with the exception being the few selectively killed during the survey year. These examples further illustrate that other factors not directly linked to the presence of LGDs (e.g. predator abundance) may play a role in determining farmer predator control strategies.

3.4.2. Selectivity and biological efficiency of LGDs – combined effects of predator killing by farmers and LGDs on target predator species

The reports of LGDs killing predator species in this study support the hypothesis that LGDs function as a lethal method of predator control, particularly for mesopredators. The net result of LGD introduction for mesopredators was increased killing (though this was only significant for jackals), whereas non-significant trends indicated that LGDs reduced the numbers of apex predators killed. LGDs can therefore be considered a biologically efficient means of predator control (as adapted from Shivik 2006), which provide a greater conservation benefit for apex predators than mesopredators on farmlands in Namibia. The killing of mesopredators reported here is in contrast to previous suggestions that LGD encounters with predators are mainly ritualized and rarely lead to fights (Coppinger *et al.* 1988). However, a recent review indicated that LGD-wolf encounters can be fatal for both animals (Urbigkit & Urbigkit 2010).

In line with reports of livestock losses and farmer predator control, LGDs most frequently killed jackals. The greater numbers of LGDs killing meso- rather than apex predators (only one LGD killed a cheetah and no LGDs killed leopard) support the hypothesis that large LGDs function as intraguild predators on medium-sized carnivores (Donadio & Buskirk 2006). However, the relatively high prevalence of LGDs killing baboons was unexpected, as Donadio & Buskirk (2006) expect that intraguild killing is linked to the degree of risk that the intraguild prey poses to its intraguild predator. As LGDs are occasionally killed by baboons (CCF unpublished data), there is a significant risk for LGDs as intraguild predators of baboons. However, intraguild predation by LGDs is an exceptional example of this phenomenon, as LGDs act in protection of their livestock (Urbigkit & Urbigkit 2010).

Increasing the individual selectivity of most damage control techniques is hampered by subsequent increases in the cost and complexity of the techniques, thus rendering them inefficient for locally abundant damage-causing species (Mitchell *et al.* 2004; Treves & Naughton-Treves 2005). In coyote predation management, call-and-shoot in combination with denning and toxic livestock protection collars are thought to be among the most selective damage control tools available (Mitchell *et al.* 2004; Sillero-Zubiri & Switzer 2004). However, the selectivity of call-and-shoot and denning is based on the expert use of calling devices and theories that breeding individuals are more likely to cause livestock losses than non-breeding individuals, respectively (Mitchell *et al.* 2004; Sillero-Zubiri & Switzer 2004). The use of toxic livestock protection collars are likely to be more selective for damage-causing individuals, but is limited by legislation regarding the use of poison and social acceptance (Mitchell *et al.* 2004).

LGDs that are attentive to the livestock are most likely to encounter individual predators that approach the flock closely than those predator individuals that avoid domestic livestock. As this potential for individual-selectivity relies on natural LGD behaviour, they have an advantage over other control methods (e.g. trapping, De Wet 2006) in that no special training is required to increase their selectivity. The use of LGDs is also more socially acceptable than any method requiring toxins, as they are considered by the public as a non-lethal, 'environmentally friendly' method of predator management (Fox & Bekoff 2011). The findings presented in this study portray LGDs as a selective method of lethally controlling mesopredators, with the potential for providing a conservation benefit for apex predators.

3.4.3. The ecological impact of LGDs with respect to non-target carnivore and game species

The non-target effects of LGDs on small carnivores in this study were minimal, as only two of the LGDs were reported to kill non-target carnivore species – bat-eared fox and African wildcat. In terms of intraguild predation, Donadio & Buskirk (2006) suggest that large relative size differences between predators and prey would reduce the level of intraguild predation. Additionally, if LGDs kill in response to threats posed to livestock, then the low prevalence of LGDs killing non-target carnivores is explained by the lack of threat that these species pose to livestock.

Compared to the effects of LGDs on non-target carnivore species, the prevalence of LGDs killing game species was relatively high in the current study. The prevalence of LGDs killing game reported here was similar to the prevalence of LGDs chasing wildlife (19%) in Chapter 2. In contrast, Hansen and Bakken (1999) reported that 91% of the LGDs they observed had a tendency to chase reindeer. However, previous studies have only reported LGDs chasing, but not killing game species (Hansen & Bakken 1999; Vercauteren *et al.* 2008; Gehring *et al.* 2010b).

Although relatively few game animals were killed per LGD, harassment by dogs can cause ungulate behavioural changes that lead to reduced reproductive success (Gingold *et al.* 2009). However, the study by Gingold *et al.* (2009) was conducted in relatively small, game-proof fenced pastures (100-240 ha). They reported that the game in the largest of these enclosures avoided LGDs more successfully than game in smaller enclosures. In contrast, LGDs in the CCF programme operate on relatively small sections of extensive livestock farms, and the small stock graze within walking distance of their overnight enclosures (Marker *et al.* 2005a). Furthermore, only game camps on Namibian farms are game-proof fenced and land used for livestock farming is cattle fenced, through which game species can move freely (Marker-Kraus *et al.* 1996).

As commercial and subsistence Namibian farmers utilize game in addition to livestock (Richardson 1998; Naidoo *et al.* 2010), they would benefit from training guidelines that address the reasons for LGD game-killing behaviour. However, the reasons for LGDs killing game were unclear in this study, as not all of these LGDs displayed untrustworthy hunting behaviour and/or ate the carcasses of the animals they caught. Nonetheless, the training materials provided by CCF suggest that wildlife-chasing behaviour can be reduced by reprimanding young LGDs for barking at wildlife (Schumann 2003). This recommendation stems from the assumption that LGDs chase wildlife out of protection for the livestock, as barking in young LGDs is thought to be a display of protective behaviour (Lorenz & Coppinger 1986).

3.4.4. Conclusions

This is the first time that the use of LGDs has been specifically evaluated as a conflict mitigation strategy, in terms of predator control and environmental impact. From this evaluation, LGDs in Namibia have the potential to benefit apex predators by reducing the indiscriminate lethal control of these species, whilst concurrently acting as a lethal method of mesopredator control.

Furthermore, although LGDs are introduced predators with the potential to cause severe environmental disturbance, the LGDs in this study had a minimal impact on non-target carnivores and game species. Nonetheless, the behavioural drivers of LGDs that kill game species remain unclear and warrant further research.

Although LGDs have been successful in controlling livestock predation and reducing subsequent predator killing by farmers in Namibia, they should not be considered as a ‘silver bullet’ for conflict mitigation in other countries. In particular, the raising and training of LGDs must be adapted to local livestock husbandry practices, or *vice versa*. In the parts of Namibia where the CCF dog programme primarily operates, herding animals during the day and keeping them in kraals at night is common practice (see Chapter 1). Under this system, LGD training and monitoring is easily conducted and corrective training of LGD behavioural problems can be applied.

4. General Discussion

This study answered the key research questions and met the primary research goals set forth in Chapter 1. This is the first simultaneous evaluation of LGDs from the perspectives of livestock farmers and predator conservationists. In Chapter 2, the livestock production aspect of LGDs was assessed by fulfilling the following objectives: 1) to determine the perceived farmer satisfaction and cost-effectiveness of LGDs, 2) to examine the factors that potentially influence LGD performance, and 3) to investigate the development of LGD behavioural problems. In Chapter 3, the conservation aspect of LGDs was assessed by fulfilling the following objectives: 1) to test whether the introduction of LGDs led to the expected reduction of predator killing by farmers, 2) to test the assumption that LGDs act as a non-lethal form of predator control, and 3) to determine the impact of LGDs on non-target species. Nonetheless, the findings of this study should be interpreted in light of the following limitations of the study design and data collected.

4.1. Study Limitations

This study was not conducted under controlled experimental conditions. The following potentially confounding factors could therefore not be controlled and must be taken into account for the interpretation of the findings presented here.

Due to the nature of the LGD programme, the surveyed farmers were not chosen by the researchers, but *vice versa*. Thus, these farmers do not represent a homogenous group, nor are they fully representative of all farmers in Namibia. In particular, livestock management, stocking rates and the initial level of livestock predation varied among the farmers; all of these factors have been found to influence farmer-predator conflict (Blaum *et al.* 2009; Stein *et al.* 2010). Furthermore, these farmers represent a subset of farmers that are willing to work with predator conservation organisations; they are therefore likely to have positive attitudes towards predator conservation than other farmers. Several studies have shown that farmer attitudes towards predators influence their predator control strategies and their support for predator conservation in general (Oli *et al.* 1994; Marker & Dickman 2004; Zimmermann *et al.* 2005; Romañach *et al.* 2007; Kissui 2008; Selebatso *et al.* 2008).

The lack of baseline data on predator and prey populations on the farms before and since LGD introduction limited the conclusions that could be drawn from this study. These data would have provided insights into the actual impact of LGDs on the populations of both target and non-target species. The extensive nature of the LGD programme in Namibia (see map provided in Chapter 1) precluded the collection of such data, which would have required intensive studies on every farm where LGDs were evaluated.

The data collected since the beginning of the CCF dog programme presented in Chapter 2 allowed for some changes over time to be detected. However, the changes made to the evaluation questionnaires over time reduced the consistency of the data and the resolution for some of the results presented. These problems were eliminated for some of the results presented in Chapter 2 and in all of the Chapter 3 results, as these data were collected using the 2009 questionnaire only.

The number of livestock saved by the LGDs was costed in Chapter 2 according to the current market prices of goats and sheep, however, subsistence farmers have limited access to commercial markets (Mendelsohn 2006). Consequently, studies focusing exclusively on subsistence farmers use the percentage of livestock holdings lost, rather than money lost, to predators in order to calculate the costs of predation (e.g. Butler 2000; Madhusudan 2003; Holmern *et al.* 2007). The economic cost-benefit analysis provided here is nonetheless useful for comparison with other study areas where farming costs and benefits can be economically valued.

Finally, the questions referring to the period before LGD introduction relied on the respondents' recollection of events that occurred several years previously (especially for older dogs). More accurate data would have been provided if the respondents were interviewed prior to LGD introduction. In future, farmers should be interviewed before LGDs are placed using questionnaires that are comparable to the LGD evaluation questionnaires.

Notwithstanding these limitations, this study provides useful insights into the use of LGDs for livestock production and conservation. These findings have the following implications for the management of LGDs used for mitigating farmer-predator conflict in Namibia and globally.

4.2. Implications for the use of Livestock Guarding Dogs

4.2.1. LGDs and livestock husbandry

The farmers in the CCF dog programme enclose their livestock at night in kraals and, as reported by Marker *et al.* (2005a), the majority employed livestock herders. These management practices have the following implications for the interpretation of the findings presented in this study with respect to the applicability of LGDs elsewhere.

The use of kraals and herders are known to reduce livestock losses in conjunction with the use of dogs in Africa (Ogada *et al.* 2003; Woodroffe *et al.* 2007). Thus, the finding that the majority of LGDs eliminated livestock losses entirely should not be expected under conditions where no other livestock protection measures are used. However, studies from the USA and Europe have shown that LGDs reduce the level of livestock losses under varying husbandry systems, including extensive systems where livestock are neither kraaled nor accompanied by herders (Andelt 1992; Smith *et al.* 2000; Gehring *et al.* 2010a).

In addition to aiding the effectiveness of the LGDs, herding and kraaling practices are likely to reduce the prevalence of LGD behavioural problems, particularly wildlife-chasing behaviour. Hansen & Smith (1999) reported that LGDs operating in an extensive system with no handlers displayed untrustworthy behaviour by chasing sheep and wildlife. However, the LGDs used in their study were not raised under ideal conditions for working dogs – the main problems were the late age at which the dogs were put with livestock (12-16 weeks of age) and over-handling by people when the dogs were young. Similarly, the unsupervised LGDs evaluated by Gingold *et al.* (2009) were reported to harass wildlife.

The lack of supervision and subsequent wide-ranging behaviour of LGDs in these studies places them in the rural, free-ranging dog category defined by Vanak & Gompper (2009); they found that dogs within this category killed more wildlife than rural dogs with limited ranges. Due to the herding and kraaling practices on Namibian farms, LGDs evaluated in this study fall into this latter category (see Chapter 3). Furthermore, the correct training of LGDs from a young age to ensure correct bonding with the livestock in the CCF programme (see Chapter 1) was likely to have contributed to the relatively low prevalence of LGD wildlife-chasing behaviour reported here. Thus, LGD ranges should be limited and attention should be given to correct LGD training and supervision in order to reduce their impact on wildlife populations.

4.2.2. The cost-effectiveness of LGDs

The LGDs evaluated here are part of a programme intended to assist farmers through discounting the purchase and dog food prices for farmers receiving LGDs. Thus, the cost-benefit analysis conducted in this study underestimates the costs for farmers that acquire LGDs from independent breeders. The use of LGDs may therefore only be cost-effective for unassisted farmers where the benefits provided by the LGDs are greater than those reported in this study. Nonetheless, commercial farmers in the USA that bought LGDs from independent breeders reported that their LGDs were cost-effective (Andelt 2004).

This study revealed that the use of purebred LGDs by marginally profitable subsistence farmers may not be sustainable in the long term, even with external support. Several groups of subsistence farmers in Africa use local dogs to accompany livestock or act as watchdogs near kraals (Ogada *et al.* 2003; Woodroffe *et al.* 2007) and local dogs have been successfully trained by subsistence farmers in the USA to reduce livestock losses (Black & Green 1985). Thus, programmes to assist subsistence farmers should focus on further reducing the costs of maintaining LGDs in the long term. This could be achieved by using local dogs and/or cross-breeding purebred LGDs with local dogs to reduce their size and subsequent maintenance (i.e. food) requirements. The training methods used for purebred LGDs can be used to help subsistence farmers maximize the effectiveness of local dogs used to guard livestock.

4.2.3. LGDs as intraguild predators – implications for predator conservation

One aspect of the use of large breed LGDs that was revealed in this study, which has been given scant attention in published literature, is their predation on medium-sized carnivores. Although lethal LGD-carnivore encounters have been recorded previously, instances of LGDs killing other carnivores are considered rare (Urbigkit & Urbigkit 2010). However, Urbigkit & Urbigkit's (2010) review covers studies in areas where LGDs defend their livestock against similar- or larger-sized predators, e.g. bears (*Ursus arctos* and *U. americanus*) and wolves. The only study where LGD encounters with medium-sized predators were directly observed was conducted by McGrew & Blakesley (1982). They placed inexperienced LGDs that were not bonded with livestock in enclosures with sheep and known sheep-killing coyotes. In the cases where the LGDs responded aggressively during these tests, they only chased the coyotes and no lethal encounters were witnessed. Nonetheless, from their experience with several LGD breeds, Green & Woodruff (1990) noted that Anatolian Shepherds had a tendency to kill coyotes.

The presence of herders, who observed the LGD-predator encounters reported here, provided data that may otherwise go unrecorded where LGDs are not supervised. Thus, lethal encounters between LGDs and mesopredators are likely to be more prevalent than indicated by studies conducted on unsupervised LGDs.

It appears that the LGDs in the CCF programme assisted 'predator-friendly' farmers to continue tolerating apex predators (limited in this study to cheetah and leopard) by reducing livestock losses. The persistence of apex predators outside national parks is a priority among conservationists worldwide (Woodroffe & Ginsberg 1998). This is particularly important for wide-ranging and competitively subordinate carnivore species such as cheetah (Marker-Kraus *et al.* 1996) and African wild dog *Lycaon pictus* (Swarner 2004). However, given that cheetah and wild dog are vulnerable to intraguild killing by larger carnivores (Creel & Creel 1996 for wild dog; Durant 2000 for cheetah), large LGDs should be used with caution to defend livestock against such species. In particular, Palomares & Caro (1999) found that groups of intraguild predators tend to kill larger intraguild prey species. The use of large LGDs in groups could therefore lead to increased incidents of LGDs killing larger carnivores, particularly solitary individuals (e.g. female cheetahs).

In contrast to the findings for apex predators, it appears that LGDs increased the level of lethal control of mesopredators, particularly jackals. In southern Africa, jackal and caracal (Avenant & du Plessis 2008) pose a threat to small livestock and are thus heavily persecuted (Stadler 2006). As these mesopredators are resilient to human persecution (De Wet 2006), the main conservation concern regarding farmer predator control efforts is the killing of non-target species and subsequent environmental impact (Snow 2006; Avenant & du Plessis 2008). Furthermore, literature on the control of another widespread mesopredator, the coyote, suggests that lethal control methods are most effective when specific damage-causing individuals are targeted (Jaeger 2004; Mitchell *et al.* 2004). The findings in the current study support the hypothesis that LGDs function as a species-specific and, potentially, individually-selective form of mesopredator control.

A closer examination of the characteristics of the predators that were likely to encounter LGDs in this study is useful for recommendations regarding the potential impact of LGDs on predators in other regions. The most frequent victims of LGDs were jackal and baboon. Jackals are known to be active during the day (although mainly crepuscular, Loveridge & Macdonald 2003) and baboons are strictly diurnal (Skinner & Chimimba 2005); these species are therefore likely to encounter LGDs during the day. In contrast, caracal and leopard are nocturnal (Skinner & Chimimba 2005) and tend not to enter night-time livestock enclosures where dogs can be heard barking (Ogada *et al.* 2003; Woodroffe *et al.* 2007). Furthermore, black-backed jackals are known to display risk-taking behaviour by approaching larger carnivores on kills (Mills 1990) and dominate the larger side-striped jackal *Canis adustus* through aggression (Loveridge & Macdonald 2003). Thus, damage-causing jackals could be killed by the LGDs as they take the risk to access livestock as an easy source of food and/or challenge the larger canids. Conversely, cheetahs are known to actively avoid larger carnivores (Durant 2000) and would therefore be expected to avoid large LGDs, which was supported by the findings in this study. Assessments of local predator species in terms of activity periods and behaviour towards larger carnivores should therefore be conducted before introducing large LGDs to specific areas.

4.3. Directions for Future Research

4.3.1. Effectiveness and environmental impact of LGDs under different livestock husbandry conditions

Comparative studies on LGDs used under different livestock husbandry systems (i.e. intensive vs. extensive) in southern Africa would complement the research conducted on other continents (Coppinger *et al.* 1988; Green & Woodruff 1990; Hansen & Smith 1999). As with the current study, most other studies on the effectiveness of LGDs under varying conditions have not been experimentally conducted (see Gehring *et al.* 2010a for a review). Despite the paucity of hard evidence, Coppinger *et al.* (1988) suggested that LGDs would be least effective in guarding non-flocking sheep that are allowed to range freely over large areas. An experimental test with LGDs used with flocking vs. non-flocking sheep under intensive vs. extensive management would provide a broader assessment for the use of LGDs.

To assess the attentiveness of LGDs under husbandry systems where herders are not generally employed, LGDs and livestock could be collared with Global Positioning System (GPS) tracking collars to examine the relative distance between the LGDs and their flocks. However, this would be more applicable for use with flocking sheep, as non-flocking sheep tend to disperse over a large area – LGDs may remain close to uncollared sheep that are far from collared sheep within the same ‘flock’. In a similar manner, the LGDs’ tendency to chase wildlife could be inferred from GPS data, as the act of pursuing wildlife would show the LGD rapidly leaving the flock in pursuit of its quarry. However, this would not provide data on the species that LGDs pursue, or whether they kill the animals they chase.

Under extensive livestock management, the current recommendations are to use several LGDs to guard the livestock (Coppinger *et al.* 1988; van Bommel 2010). However, little attention has been given to the possible increased environmental impact where several LGDs are used with minimal human supervision. Gingold *et al.* (2009) found that groups of six to nine LGDs harassed adult gazelle and possibly killed gazelle fawns within fenced enclosures. Under extensive livestock management, LGDs would have the potential to range widely and would therefore be expected to have a greater impact on wildlife (Vanak & Gompper 2009). Thus, the ecological impacts of groups of LGDs used under extensive livestock management should be evaluated before recommending their widespread use under such conditions.

The likelihood of directly observing LGDs killing wildlife would be low under extensive management (due to minimal human contact with LGDs). Studies should therefore focus on monitoring the abundance, reproductive success and movements of wildlife species on farms with and without LGDs. Experimental sites with similar wildlife densities should be chosen and these experiments should ideally run for several years to account for temporal variations in wildlife movements and reproduction.

4.3.2. LGDs as intraguild predators on target carnivores

The pattern of intraguild predation by LGDs found here was combined with knowledge from studies on intraguild predation to make the following testable predictions for future research. The LGD body size and group size relative to the body size and group size of resident carnivores would be expected to predict the level of intraguild predation by LGDs on these species (Palomares & Caro 1999; Butler *et al.* 2004; Donadio & Buskirk 2006; Urbigkit & Urbigkit 2010). In conjunction with the predictions above, carnivores that pose the greatest threat to livestock in a given region are expected to be the most frequent victims of LGDs. Furthermore, predator species that display risk-aversive behaviour (e.g. cheetah, Durant 2000) would be less likely to be killed by LGDs than predators that display risk-taking behaviour (e.g. jackal, Mills

1990). Ideally, experiments would be designed to test the relative significance of each of these factors with respect to the frequency with which LGDs kill these predator species.

The finding that LGDs can function as significant intraguild predators of jackals provides several research opportunities. As victims of intraguild predation, jackal populations in the presence of LGDs may respond by spatially and/or temporally avoiding LGDs (Palomares & Caro 1999; Linnell & Strand 2000). Where LGDs are confined to livestock kraals at night, jackal movements relative to LGD locations would be predicted to show jackals temporally avoiding LGDs by moving further from LGDs during the day than at night (Arjo & Pletscher 1999). Where LGDs are allowed to roam freely at all times, one would expect that jackals would avoid LGDs spatially by making greater use of refuge areas that are infrequently used by LGDs (Durant 1998; Caro & Stoner 2003). LGD-jackal interactions can thus be interpreted in terms of the "ecology of fear" (Brown *et al.* 1999), where jackals would be expected to treat LGDs as a foraging cost for preying on livestock (Brown & Kotler 2004). Furthermore, monitoring jackal populations before and since LGD introduction can provide evidence for whether LGDs limit local jackal populations by killing them and/or reducing their access to livestock as a food resource (Linnell & Strand 2000).

The behavioural mechanisms of LGD avoidance employed by jackals could be explored by tracking individual LGDs concurrently with resident jackals using GPS collars and, where possible, directly observing LGD-jackal interactions. This type of study was conducted by Atwood & Gese (2010), who examined interactions between coyotes and re-introduced wolf packs. Coyote-wolf interactions would provide an interesting comparison to jackal-LGD interactions as both interactions are between medium-sized and large canids. However, LGDs do not provide scavenging opportunities for jackals (as is the case for wolves and coyotes), yet the livestock guarded by LGDs represent an attractive food source for jackals. Jackal avoidance of LGDs could be tested using neighbouring flocks of small stock with and without LGDs. One would predict jackals to preferentially prey upon unguarded flocks, after controlling for differences in natural prey abundance between sites (e.g. small mammals, Avenant & du Plessis 2008).

4.3.3. LGDs as a lethal method of predator control

With respect to human-wildlife conflict literature, the current study warrants further research on the use of LGDs as a lethal method of mesopredator control. The use of LGDs should be included in comparisons with other lethal methods such as livestock protection collars, call-and-shoot and trapping. The main criteria for comparison would be livestock loss reduction, cost-effectiveness, numbers of non-target species killed and individual selectivity.

Individual selectivity is the most challenging of these criteria to measure, as it requires the accurate determination of killed individuals as culprits of livestock depredation (Mitchell *et al.* 2004). Dietary studies of local jackal populations before and since the introduction of specific control methods using scat analysis is an indirect method to determine the presence of damage-causing individuals (as used by Sacks & Neale (2002) for coyotes). If the tested control method successfully eliminates livestock-killing individuals or deters them from preying on livestock, one would expect the proportion of jackal scats containing livestock remains to decline. For the evaluation of LGDs, direct observations of LGD-jackal interactions would provide more concrete evidence for the hypothesis that LGDs kill jackals that approach the livestock more frequently than jackals that avoid areas with livestock.

4.4. Summary

The evaluation of LGDs in this study was generally positive. However, LGD wildlife chasing and killing remains a concern, particularly where wildlife are considered economically valuable (e.g. in Namibia, Richardson 1998) or threatened (e.g. in Israel, Gingold *et al.* 2009). The underlying behavioural causes of this phenomenon remain elusive, which hinders the resolution of this problem through effective training. Furthermore, the sustainable use of large breed LGDs by subsistence farmers is limited by the financial abilities of these farmers to provide sufficient care for the dogs. In contrast, whilst commercial farmers provided sufficient care for LGDs, the introduction of LGDs had a limited effect on their jackal control strategies.

The findings presented here challenge the classification of LGDs as a purely non-lethal form of predator control. Rather, LGDs were found to kill mesopredators, particularly jackal, frequently and had a net effect of increasing the numbers of these carnivores killed on farms. Nonetheless, LGDs rarely and never killed cheetah and leopard, respectively, and could therefore be considered a non-lethal method to reduce livestock predation by these species.

The LGDs in the CCF programme were deemed useful by commercial and subsistence farmers, as they reduced livestock losses in a cost-effective manner for an extended period of time. With respect to conservation, the LGDs in this study were deemed a species-selective and biologically efficient form of predator control with a relatively minor impact on non-target species.

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Appendix

LSGD PROGRAMME

LSGD FOLLOW UP (over 6 months) Questionnaire SB #:____

Date: __ __ ____
Owners' name: ________________________________
Farm: _________________________ District: _________________ Farm nr: _____
Address: ____
Tel. (work, home, Cell):_______________________________
Name of dog: __________________________ Interviewed: ________________
Age: ____ Sex: male/female Transponder: ________________
Date of placement: ______________

1. How is your guarding dog working: Excellent ☐ Good ☐ Fair ☐ Poor ☐
2. Is it doing what you thought it would do? _________________________ Yes: ☐ No: ☐
3. Has there been economic benefit to having the dog? Yes: ☐ No: ☐

3.1 If yes, please describe: ____

4. Is the dog with the herd all the time? _____________________________ Yes: ☐ No: ☐
5. Where do your livestock sleep at night? _________________ In a kraal ☐ In a camp ☐
6. During the night, does your dog stay:

With the flock ☐ With the herder ☐ At the house ☐ Elsewhere ☐

6.1 If elsewhere, Where? ____

7. Does the dog appear to be part of the stock? ______________________ Yes: ☐ No: ☐
8. Is the dog submissive to members of the herd? _____________________ Yes: ☐No: ☐
9. Are the dog and stock bonded together? ___________________________ Yes: ☐No: ☐
10. Are there any other dogs with the herd? ___________________________ Yes: ☐No: ☐
11. Does the dog interact with other dogs? ___________________________ Yes: ☐No: ☐
12. How many losses did you have in the year before the dog? 0 ☐ 1-5 ☐ 6-10 ☐ >10 ☐ >40☐

12.1 What caused these losses: Jackal ☐ Cheetah ☐ Leopard ☐ Caracal ☐ Theft ☐

13. How many losses did you have in the last year since the dog? 0☐ 1-5☐ 6-10 ☐ >10 ☐ >40☐

13.1 What caused these losses: Jackal ☐ Cheetah ☐ Leopard ☐ Caracal ☐ Theft ☐

14. How would you rate your dog's protectiveness of your stock?

Excellent ☐ Good ☐ Fair ☐ Poor ☐

15. Has it effectively guarded against any predators? ____________________ Yes: ☐No: ☐
16. Has the dog killed any wild animals? _____________________________ Yes: ☐ No: ☐

16.1 If yes, what animals and how many? _______________________________________

16.2 Does the dog eat the carcasses? If yes, how much does it eat? ____________________

16.3 In your opinion, does the dog kill to: protect the stock ☐ hunt wildlife ☐ unsure ☐

17. Did you eliminate any predators on your farm in the year before the dog? Yes: ☐No: ☐

17.1 If yes, which predators and how many? ____________________________________

18. Have you eliminated any predators on the farm in the last year since the dog? Yes: ☐No: ☐

18.1 If yes, which predators and how many? ____________________________________

19. Does the dog have any behavioural problems? Such as:

Chasing game ☐ Biting livestock ☐ Staying home ☐ Attacking people ☐ Other ☐

19.1 What measures do you take to correct? __________________________________

20. Was corrective training of behaviour problems effective? ______________ Yes: ☐No: ☐

21. Were the problems reported to CCF? ______________________________ Yes: ☐No: ☐

21.1 If not, why didn't you report to CCF? ____

22. Do you have a herder? ____ Yes: ☐No: ☐

23. Was there a change of herder since the dog? ______________________ Yes: ☐No: ☐

23.1 If yes, what effect did this have on the dog? ______________ Good ☐ Bad ☐ None ☐

24. Do the herder and the owner share information on the dog and its progress? Yes: ☐No: ☐

25. How would you describe your dog's condition (health)?

Excellent ☐ Good ☐ Fair ☐ Poor ☐

25.1 If poor: what measures do you take? Please describe: ___________________________

26. Please describe what food you give to your dog: ____________________________________

26.1 How many times a day do you feed the dog? 1 2 3

27. How would you describe your involvement with the dog?

(If speaking to herder – ask how often owner comes to see dog)

Daily ☐ Once – several times a week ☐ Once – several times a month ☐ Only herder ☐

28. Has CCF given: Enough direction ☐ Not enough direction ☐ Too much direction ☐

28.1 Please explain not enough or too much: ______________________________________

29. Would you recommend the LSGD programme to other farmers? ________ Yes: ☐No: ☐

29.1 If not, why not? ____

30. Date of last vaccination: __ __ ____

Date of last rabies vaccination: __ __ ____

Date of last deworming: __ __ ____ Dewormer: _____________________

Anything else you would like to add? ____

Signature: