Cape Peninsula University of Technology

BARKING UP THE WRONG TREE: CHARACTERIZING FARMERS, FARMS, AND A BEHAVIOURAL FRAMEWORK REGARDING LIVESTOCK GUARDIAN DOG USE IN SOUTH AFRICA

by

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Thesis submitted in fulfilment of the requirements for the degree

Master of Conservation Sciences

in the Faculty of Applied Sciences

at the Cape Peninsula University of Technology

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Cape Town

December 2021

DECLARATION

I, Craig Bruce Glatthaar, declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Craig Glatthaar

11 December 2021

Signed	**Date**

ABSTRACT

The relevance of livestock guardian dogs (LGDs) as a potentially non-lethal method of encouraging predator and livestock coexistence is seen as a responsible conservation tool. Decision making by landholders with regards to wildlife coexistence and depredation mitigation is difficult to measure and driven by numerous elements relating to the farmers, the farm environment, various social constructs as well as the landholders' own attitudes, social pressures, perceived behavioural control and behavioural intent that leads to action. Understanding these landholders and the psychosocial dimensions of what influences LGD use is an important knowledge gap to fill if these LGDs are to better serve both livestock farmers and wildlife interests. In a quantitative survey study amongst 113 livestock farmers in South Africa, I explored and characterized the factors associated with LGD use. I consider human-wildlife coexistence, historical and current use of LGDs before exploring the knowledge gaps in LGD research pertaining to farmers and the factors associated with LGD use. Using Boosted Regression Trees (BRTs) – I explored and characterized several factors that are associated with LGD use. Users of LGDs were more likely to have a higher diversity of livestock species, have a reduced proportion of their total income derived from animals and use a greater number of non-lethal mitigation methods compared with LGD non-users. Sociodemographic and psychosocial constructs relating to wildlife value orientations, tolerance to predators, tangible and intangible cost and benefits of predators, empathy for predators, like or dislike of predators and number of positive experiences with predators were all less significant as determinants of LGD use than the more practical implications relating to predator type, number of farming enterprises, mitigation methods, and the frequency and extent of specific predator problems. Notably, a LGD support organization that places LGDs with farmers showed the greatest relative influence on LGD use. The third part of the study builds upon these findings utilizing the foundational constructs of the Theory of Planned Behaviour (TPB) and Wildlife Tolerance Model (WTM). Results showed that the three constructs of attitude, subjective norms, and perceived behavioural control (PBC) explained 49 % of the variance in behavioural intent to use or continue using an LGD. The role of the LGD support organisation, farmers' considerations of the perceived affordability, ease of use and effectiveness of LGDs and farmers' mutualistic orientations were all strong predictors of LGD use. I conclude that farm and farmer characteristics should be an integral element in LGD support organizations objectives of achieving farmer-predator coexistence using LGDs. The TPB model, incorporating elements of the WTM, can be used as a framework in guiding predictability of intent to use or continue using LGDs. Using this model will aid in understanding LGD use as a depredation mitigation method and this in turn will help improve adoption of LGD programs as a carnivore coexistence strategy.

ACKNOWLEDGEMENTS

I would like to express my utmost gratitude to the following people and organizations:

- Karin Wernström Glatthaar, my wife, my rock, my greatest fan, who's endless encouragement carried me through the course of these three years.
- Prof Sjirk Geerts, for always encouraging and always challenging me, who's great patience and enthusiasm has instilled a sense of curiosity for the natural world I will carry with me for the rest of my days.
- Dr Katherine Whitehouse-Tedd, for not only inspiring this study, guiding me through countless challenges and sharing her seemingly bottomless knowledge, but also for showing me where humility and grace can so beautifully intersect with science.
- Dr Ruth Kansky, who's astounding ability to make the most complex elements of social and natural science seem completely fathomable for a mere mortal like myself. Thank-you for all the encouragement and for keeping me going, when the going got tough.
- The authors are grateful to Cheetah Outreach Trust and Predation Management South Africa for their permission to use this dataset and for their assistance in accessing their farmer databases.
- Annie Beckhelling, who's endless energy and passion for conservation continues to inspire so many.
- Deon Cilliers and Cyril Stannard, the soldiers on the frontline of conservation. I will never forget the great time I spent in the field with such committed and knowledgeable conservationists.
- Dr Martin Kidd, for his guidance in the world of scary statistics.
- Ms Anneli Hardy for her guidance and suggestions regarding the various statistical applications, as well as her gentle encouragement – see you on Zoom again!
- All the landowners for their engagement and eagerness in contributing to this study.
- Wilderness Safaris and their commitment to supporting conservation and my studies.
- Dr Megan Parker, Dr Ngaio Richards, Dr Laurie Marker, and Dr Daniel Kinka for their inspiration and love for working dogs in conservation.
- The esteemed South African author David Bristow and brilliant copy editor Josephine Bestic, for proofreading the thesis.
- Nicoline “heel mooi” Jongens, my dear friend and greatest supporter.
- For the “A team” – many braais missed, many surf sessions slipped over the last three years. Thank-you for your patience.

DEDICATION

To my parents, who at a young age instilled a great passion for the natural world within me, and who encouraged me on this research journey but sadly passed away before seeing this work's completion…I hope heaven publishes this one for you both to read.

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GLOSSARY

Acronyms/Abbreviations

CCB	Cheetah Conservation Botswana
CCF	Cheetah Conservation Fund
COT	Cheetah Outreach Trust
EWT	Endangered Wildlife Trust
HWC	Human-wildlife coexistence
HWI	Human-wildlife interaction
LGD/s	Livestock Guardian Dog/s
LGD-MM	Livestock Guardian Dog Mitigation Method
PBC	Perceived Behavioural Control.
TPB	Theory of Planned Behaviour
WTM	Wildlife Tolerance Model
WVO/s	Wildlife Value Orientation/s

CHAPTER ONE: GENERAL INTRODUCTION

"*While staying at this estancia, I was amused with what I saw and heard of the shepherd-dogs of the country. When riding, it is a common thing to meet a large flock of sheep guarded by one or two dogs, at the distance of some miles from any house or man. I often wondered how so firm a friendship had been established."*
(Charles Darwin, *The Voyage of the Beagle*, New York: P.F. Collier and Son,1909, p. 163)

1.1 Conflicts over wildlife impact in agricultural landscapes

The relationship between predator and prey is well known but remains a complex and dynamic relationship (Mills and Biggs 1993; Brown et al., 1999; Radloff and Du Toit, 2004; Ripple et al., 2014; Clements et al., 2014; Clements et al., 2016). Predator and prey population dynamics are maintained both in terms of a bottom-up control, where prey resource limits predator numbers, and a top-down control, where predator numbers limit prey numbers (Hörnfeldt, 1978; Beschta and Ripple, 2006; Wallach et al., 2010). Additional factors, such as parasites and disease can further influence population dynamics. The introduction of prey species, such as livestock, into this complex predator and prey system has received wide attention (Moore, 1995; Thorn et al., 2012; Minnie et al., 2015). In Europe and North America, wolves (*Canis lupus*), bears (*Ursus arctos*), wolverines (*Gulo gulo*) and coyotes (*Canis latrans*) prey upon sheep (Landa et al., 1999; Treves and Karanth 2003; Prugh et al., 2009; Rigg et al., 2011). In Asia, tigers (*Panthera tigris*) and leopards (*Panthera pardus*) prey upon various livestock (Bagchi et al., 2003; Treves and Karanth, 2003). In Africa, there is a host of complex depredation dynamics where several predator species, such as lions (*Panthera leo*), leopard, cheetah (*Acinonyx jubatus*), brown hyaena (*Hyaena brunnea*) and baboons (*Papio ursinus*), prey upon livestock (Patterson et al., 2004; Skinner and Chimimba, 2005; van Niekerk, 2010; Thorn et al., 2013). The depredation impact of mesopredators such as black-backed jackal (*Lupulella mesomelas)* and caracal (*Caracal caracal)* is also significant in an African context (van Niekerk, 2010; Thorn et al., 2012; Badenhorst, 2014). Addressing the challenges around achieving predator and livestock coexistence is of great economic, social and conservation concern. The economic consequences of livestock depredation include loss of income, loss of food producing animals, damage to agricultural production and food security for livestock farmers dependent on farming as a direct food source (Barua et al., 2013). These consequences also include the cost of managing and mitigating depredation due to the loss of livestock (Moreira-Arce et al., 2018). Depredation is a major challenge to both subsistence and commercial livestock farmers worldwide (Graham et al., 2005; Woodroffe et al., 2007; Torres et al., 2018).

Predators have an economic impact when preying on livestock (Reynolds, 1996; Treves and Karanth, 2003; Moreira-Arce et al., 2018).

Together with economic costs the social costs for livestock farmers can involve stress due to the loss of livestock (Moreira-Arce et al., 2018) and the anxiety around the management of livestock depredation. For both commercial and subsistence farmers in South Africa, the management, and decisions around mitigating livestock loss due to predators is a complex one, especially when looked at in the context of coexistence strategies between livestock and predators. In some cases, livestock farmers' response to depredation is to attempt to lethally eliminate the predator threat. However, this lethal elimination of predators by livestock farmers is considered a major threat to predator survival (Treves and Karanth, 2003; Inskip and Zimmermann, 2009; Boshoff et al., 2016).

In terms of conservation for predators, the threat of habitat loss as well injury or loss of life due to retaliatory actions from farmers, is equally real (Kerley et al., 2017). Lethal control of predators does not however always occur in relation to perceived costs or damage to humans. In the absence of perceived costs to human’s, indiscriminate lethal elimination of predators occurs (Marker et al., 2003). In a South African context, the costs of livestock loss due to predation is incurred by the farmers alongside a desire or expectation to conserve the remaining biodiversity (McManus et al., 2015; Kerley et al., 2017). Human-wildlife coexistence in a livestock and predator context, is therefore of conservation concern and the evaluation or development of potential solutions to livestock depredation offer important areas of research.

1.2 Livestock depredation methodology and mitigation methods

Predator numbers and distribution have been reduced, largely because of the increasing human presence in unprotected wilderness areas (Treves and Naughton-Treves, 2005). However, cheetah, leopard and smaller predators like caracal and black-backed jackal persist in many farming areas in South Africa. These smaller predators have filled the void left by larger predators which were previously removed (Lloyd, 2007). This mesopredator release has resulted in these predators now becoming apex predators in some food chains and at the same time these mesopredators are now the major cause of livestock losses in southern Africa (Marker et al., 2003; Lloyd, 2007; Balme et al., 2009; Hunter and Barrett, 2011; Thorn et al., 2012; Drouilly and O’Riain, 2019; Nattrass et al., 2019). The National Environmental Management: Biodiversity Act 2004, ensures the legal protection of several South African carnivore species, including brown hyaenas, cheetahs, leopards, and African wild dogs (*Lycaon pictus*). The Act does however allow specific methods of lethal control for non-protected wildlife and even leopard and cheetah may be legally killed in defence of livestock. Caracal and black-backed jackal are killed in large numbers across South Africa, as they are not protected under the Biodiversity Act (Skinner & Chimimba, 2005; Bergman et al., 2013; Kerley et al., 2019). For small populations of endangered predators, like cheetah for example, it is important to consider their conservation in South Africa (Marnewick et al., 2007; Durant et al., 2017).

In these unprotected areas, several mitigation methods are available to farmers to reduce livestock depredation, ranging from lethal to non-lethal controls (Treves et al., 2003; McManus et al., 2015; Treves et al., 2016). In a HWC context, lethal controls involve the killing of predators and non-lethal controls involve altering the predator's behaviour without killing the predator (McManus et al., 2015). Some lethal management methods involve hunting, trapping, and poisoning (Reynolds and Tapper, 1996; Treves et al., 2003; Treves and Naughton-Treves, 2005; McManus et al., 2015; Treves et al., 2016; van Eeden et al., 2018). Trapping can involve both lethal and live-trapping and one might argue that live-trapping may be ineffective and lethal, since translocated animals do not always survive the trapping methods or the translocations (Sijtsma et al., 2012; Clements et al., 2014). In more recent times, lethal methods have become less acceptable and public opinion has generally been against the use of lethal methods (Slagle et al., 2017; Liordos et al., 2017). Non-lethal methods have been considered (Treves et al., 2003; Treves et al., 2016) and involve fencing, human patrols, aversive agents, repellents, scare devices and antifertility agents (Shivik et al., 2003; McManus et al., 2015).

Lethal control methods to reduce livestock depredation can have a dramatically negative effect on the conservation efforts to protect predator biodiversity (Graham et al., 2005; Baker et al., 2008; Inskip and Zimmermann, 2009; Treves et al., 2016; van Eeden et al., 2018; Nattrass et al., 2019) and in turn can result in cascading impacts on ecological communities (Berger, 2006; Wallach et al., 2010; Nattrass et al., 2019). McManus et al. (2015) compared the costs and benefits of lethal vs non-lethal mitigation and management controls on livestock farms in South Africa. During the first year of instituting both lethal and non-lethal mitigation methods, non-lethal control costs were very similar to lethal management strategies. However, in the second year of control, the non-lethal costs were much lower than in previous years and depredation costs decreased further as the program continued. Their results showed that non-lethal methods of control could reduce depredation and would be economically advantageous compared to lethal methods of predator control. One such a perceived non-lethal method is livestock guardian dogs (LGDs).

1.3 Livestock guardian dogs as a historical depredation mitigation method

In a rather ironic turn of events, it was a predator, the dog *Canis lupus familiaris*, that became our earliest domesticated partner and one that has been at our side ever since (Derr, 2011; Galibert et al., 2011). The unproven theory on canine domestication is that humans domesticated canines about 14, 000 - 15,000 years ago and that humans did not necessarily master wolves to give rise to what we know today as companionable dogs (Coppinger and Coppinger, 2001; Galibert et al., 2011). There is a growing theory that our relationship with our canine companions was rather built on mutual benefit and respect (Coppinger and Coppinger, 2001). Dogs have been used over centuries in guarding applications for humans and over time these guarding roles have become more specialized, such as protecting livestock. In our early relationship with canids, humans took advantage and through selective breeding, chose the desired traits that led to the domestication of wolves and the creation of dogs (Derr, 2011). According to Derr (2011), "We chose them, to be sure, but they chose us too, and our shared characteristics may well account for our seemingly unshakable mutual intimacy". The relationship thus crafted with our canine companions was not only through the initial influence by our own hand and was probably one based on a mutual respect thanks to the varied talents and advantages both species offered one another (Derr, 2011). This relationship between humans and dogs has now resulted in potential conservation applications.

Livestock guardian dog (LGD) is a term used to define specialized breeds of dogs that have been selectively bred to protect livestock and at the same time reduce predator mortalities by offering a more responsible form of predator control (Bigi et al., 2018). The modern-day diversity of LGD breeds was likely initiated via the exchanges between nomadic herders as they moved between pastures; various dog forms interbred and were subsequently selected for the best protection traits (Coppinger and Coppinger, 2001). Various breeds are more popular in certain regions than others. For example, currently in the USA, the Great Pyrenean Mountain Dog is the most popular breed, with other breeds such as the Akbash, Anatolian Shepherd, Maremma and Komondor also being popular (Green and Woodruff, 1980; Green et al., 1984; Kinka and Young, 2019). In South Africa Anatolian Shepherds are one of the more popular LGD breeds. Interestingly, a recent paper by Horgan et al. (2021) considered that indigenous Tswana dogs are more practical livestock guardians in an arid African savanna compared with their expatriate cousins. Despite all of this, Green and Woodruff (1988) as well as Kinka and Young (2019), noted that the variety of dog breed used did not affect the effectiveness of livestock protection.

Due to a very low prey drive, LGDs have had an evolutionary, protective connection working with shepherds, and their physical characteristics ensure they blend in with the herd (Jones, 2005; Dohner, 2007; Gehring et al., 2010). The LGDs tend to exhibit longer bonding periods than many other breeds to ensure they bond with their livestock (Green and Woodruff, 1988; Allen et al., 2017; Whitehouse-Tedd et al., 2019). When predators are confronted by a large dog who reacts to them in a variety of ways – from defensive to play behaviour – this disorientates and confuses the predator, disrupting its prey drive (Kinka and Young, 2018). These dogs might well be the "ultimate disruptive-stimulus tool" (Shivik, 2006). Coppinger (1988) considered that LGDs went through a series of social interactions such as marking with their scent, showing aggression, and dominating postures to disrupt predatory behaviour from wolves. Even though the LGD behaviour disrupts the predator's hunting pattern, this does not necessarily result in engagement (Kinka and Young, 2018). Barking and defensive posturing drives predators away before confrontation becomes necessary (Green and Woodruff, 1983).

All these elements, from the evolutionary history and bond between human and dog, to the breeds that fulfil a protective role, and finally the behavioural and physical characteristics of LGDs, combine to what we currently know is a responsible tool in the complex landscape of human and predator coexistence.

1.4 Current use of livestock guardian dogs

Changes in agricultural systems, two world wars and the almost near extermination of predators like brown bears (*Ursus acrtos*) and wolves had resulted in a major decline in the use of LGDs (Gehring et al., 2010). Over the last number of decades many populations of these predatory species have recovered (Ribeiro and Petrucci-Fonseca, 2004). With ever expanding livestock practices and the recovery of predators in Europe, livestock depredation is on the increase again (Enserink and Vogel, 2006; Ripple et al., 2014; Khorozyan and Waltert, 2019). The re-introduction of one of the world's ancient crafts of LGD use was seen as a tool towards achieving a degree of coexistence between wolves and sheep farmers in Europe (Rigg, 2001). From Europe and the USA, LGDs have only relatively recently spread to other regions of the world such as Canada, Africa, parts of South America, and Australia (Coppinger and Coppinger, 2001). This was in response to the return and conservation of large predators to many of their former ranges (Landry, 1999; Rigg, 2001; Gehring et al., 2010; Scasta et al., 2017). Europe and USA offer similar environments where LGD use in livestock protection occurs (Coppinger and Coppinger, 2001; Gehring et al., 2010). The use of LGDs is now also practised with increasing frequency in Africa. Some of the earliest work with LGDs in Africa was conducted by the Cheetah Conservation Fund (CCF) in Namibia in with the aim of reducing cheetah predation on livestock (Marker et al., 1996; Marker, 2000; Marker et al., 2003; Marker et al., 2005; Marker et al., 2020). Marker's focus on conservation research with cheetah populations in Namibia lead to her discovery of human-wildlife conflict between livestock farmers and cheetah. This was the catalyst to the founding of CCF and the establishment in 1994 of one of the first research grounded LGD programs in Africa. The long-term monitoring and research at CCF resulted in the publication of a number of findings relating to LGD effectiveness, LGD behavioural problems, ecological impacts of LGD use and LGD performance under varied conditions. In terms of managed LGD programs in Africa, we now see LGD use not only in Namibia but also in Botswana and South Africa. An ancient tool to reduce livestock depredation is thus finding a conservation application globally.

Historically the focus of LGD research was on their role in decreasing livestock depredation. More recently however, their role as a conservation tool and the impact on wildlife and potential landscape of fear that they create, has received more attention (Allen et al., 2017; Eklund et al., 2017; Allen et al., 2019; Spencer et al., 2020; Whitehouse-Tedd et al., 2020). The protective traits in LGDs are due to selective breeding, but training and conditioning is critical to the successful utilization of their instinctive behaviours (Coppinger and Coppinger, 1980; Coppinger and Coppinger, 2001; Dohner, 2007). It is imperative that the correct rearing of LGDs is considered to ensure the correct development of instinctual behaviours as well as the more obvious safety for people in the presence of protective and actively working LGDs (Marion et al., 2018). These LGDs are an effective tool for reducing livestock loss (Marker et al., 2005; Scasta et al., 2017; Khorozyan and Waltert, 2019; Marker et al., 2020) but consideration must be given to the fact that they cannot only be a non-lethal control in depredation mitigation but might in some cases kill the predator (Whitehouse-Tedd et al., 2020). The CCF program reported the most frequent behavioural problems as chasing wildlife and not accompanying the livestock, which reduces the effectiveness of the LGD (Marker et al., 2005; Urbigkit and Urbigkit, 2010; Potgieter et al., 2016; Whitehouse-Tedd et al., 2019). However, Whitehouse-Tedd et al. (2019) showed in a recent study that 44% of behavioural challenges with LGDs were successfully corrected following corrective training by the project managers. If there is engagement with a predator it can have a negative effect in that the LGD might act as a lethal control, killing the predator or the LGD may be maimed or killed which is also counterproductive and a welfare concern for the LGD as well as the wildlife (Potgieter et al., 2016; Whitehouse-Tedd et al. 2020). This is counterproductive to responsible livestock protection and the use of LGDs as a potential non-lethal form of predator control is in question (Potgieter et al., 2016). Whitehouse-Tedd et al. (2019) concluded that despite interactions with predators, these interactions were uncommon, defensive in nature, short in duration and predominantly non-lethal, that LGDs do still offer great conservation benefit in being used as a responsible mitigation method to reduce livestock depredation.

The effectiveness of various control methods may vary depending on the type of predators involved in livestock predation (Moreira-Arce et al., 2018). Today the management of interactions between predators and livestock has changed thanks to social and psychological shifts in the populace, where lethal predator control is now considered unacceptable in many places (Reiter et al., 1999; Slagle et al., 2017; Pooley et al., 2017). In a study in South Africa regarding farmers perceptions of predators, their culpability for livestock losses, and the protective measures used, it was concluded that farmers showed preference for the removal of predators from livestock farming areas, but that there was some support for non-lethal control methods (Whitehouse-Tedd et al., 2021).

Human-wildlife coexistence is therefore a complex scenario and is comprised of varying degrees of ecological as well as socio-economic processes (Treves et al., 2004). Ogada (2003) and Woodroffe and Frank (2005), have shown that a high number of predator mortalities are as a direct result of retaliatory actions by farmers due to livestock depredation. These retaliatory killings are a serious challenge to conservation policies for predator protection (Treves and Karanth, 2003; Van Bommel et al., 2007). Inherent fear of wildlife can be a key element in hostility towards wildlife that drive these retaliatory killings of predators (Prokop et al., 2009). Tangible or material benefits and costs are important determinants of behaviour and tolerance towards wildlife and the quantification of these variables is key in assessing wildlife impact in an anthropogenic context (Kansky et al., 2016; Thondhlana et al., 2020). The identification of possible solutions to human-wildlife coexistence strategies can be hindered if elements such as fear towards wildlife, trust in management agencies, perceptions of control in wildlife conflict situations, or intrinsic beliefs in wildlife value are not considered (Bruskotter and Wilson, 2013). Reaching consensus on the preferred conservation strategies to enable human-wildlife coexistence is complex and compromised when one party asserts its interest over, and at the expense, of another (Dickman, 2010; Young et al., 2010). The ability for stakeholders to collaborate on initiatives, goals and actions regarding conservation related topics can be hindered by clashing and alternative views (Manfredo et al., 2017). Apart from people’s own perceptions and attitudes, social factors play a critical role in understanding human-wildlife coexistence but are rarely considered (Prokop et al., 2009; Dickman, 2010; Bottrill et al, 2014; Bennett, 2016; Nyhus, 2016).

Decision making by stakeholders with regards to wildlife conflict and depredation mitigation is complex and driven by numerous elements relating to sociodemographic, wildlife value orientation, tolerance, and external risk factors (Dickman, 2010). Decision making fundamentally refers to the process of reaching conclusions and / or making choices. There are at least five dimensions that affect how individuals make decisions. The first decision making construct refers to that decision making is often associated with uncertainty (Trepel et al., 2005; Shiv et al., 2005). The second construct is that options in decision making will have an assigned value which is derived from either the punishment or reward based on the outcome of the decision (Mellers et al., 2001; Ursu and Carter, 2005). Thirdly, decision making is a process that happens over time, where past outcomes and actions influence the future assessment of options to the decision-maker (Yarkoni et al., 2005). The fourth dimension is that decision making involves an engagement between individuals or groups of individuals, whereby values are not only considered by the decision maker but also the values others place on the action (Haselhuhn and Mellers, 2005). The fifth dimension is that decision making is highly dependent on the context of the situation (Huckfeldt et al., 2005; Shiv et al., 2005; Ursu and Carter, 2005).

Many studies regarding human-wildlife coexistence focus on the wildlife dimensions but it is being increasingly recognised and acknowledged that a focus on a human dimension of HWC is equally critical (Redpath et al., 2013; Manfredo, 2015; Kansky et al., 2016). Human-wildlife coexistence is a series of interactions between ecosystems, biodiversity and people and can be framed as occurring within social ecological systems (Folk et al., 2004). These interactions can be termed human-wildlife interactions (HWI) and comprise of individuals and groups where an event involving contact between humans and nondomestic species has occurred (Whitehouse-Tedd et al., 2020). As attitude (and the resultant tolerance and behavioural responses towards wildlife) is considered a critical theme to understanding HWI (Dickman, 2010; Decker et al., 2012; Kansky et al., 2014), conservation related research in the field of HWI typically involves measuring stakeholder's attitudes towards wildlife in a HWC context (Decker et al., 2012; Whitehouse-Tedd et al, 2020). The decision making and psychological aspect within HWC is therefore complex, requiring a multidisciplinary approach incorporating the human dimensions of HWC (Game et al., 2014; Kansky et al., 2016). These human dimensions in LGD use, as a form of HWC, are at the centre of this study.

1.5 Decision making in human-wildlife coexistence and LGD use

Negative perceptions of predators and common social characteristics drive emotional responses to wildlife, in this case predators (Treves et al., 2004; Kretser et al., 2008).

Human-wildlife coexistence strategies are complex and landholder's views on wildlife value need to be acknowledged to build effective HWC strategies where people's economic and social circumstances might be impacted due to predators (Hulme and Murphree, 2001; Moreira-Arce et al., 2018). Wildlife values tend to be developed from a young age according to the cognitive hierarchy and it is these values that comprise the beliefs, behaviours, and attitudes of individuals (Fulton et al.,1996). Studies have shown that experiences with nature during childhood is more important that socio-demographic factors in terms of developing positive attitudes towards wildlife (Hosaka et al., 2017; Mnisi et al. 2021). Studies such as that of Treves et al. (2016) and Kansky et al. (2016), have demonstrated the importance in understanding stakeholders to develop effective human-wildlife coexistence strategies using frameworks such as the wildlife tolerance model (Kansky et al., 2016). In a livestock farming context, these beliefs, behaviours, and attitudes are in turn influenced by a series of socio-economic factors and costs associated with livestock depredation (Oli et al., 1994; Fulton et al., 1996; Hutton and Leader-Williams, 2003; Kaczensky et al., 2004; Lindsey et al., 2005; Moreira-Arce et al., 2018). Understanding psychological elements such as farmers' perceptions regarding wildlife value and farmer's beliefs, behaviours, and attitudes towards livestock depredation, and specifically LGD use in reducing livestock depredation, are the crux of this study. If these LGDs are to be advocated as effective conservation tools that serve both livestock farmers and wildlife interests, then these psychological aspects that influence LGD use are important to understand to aid human-wildlife coexistence programs.

1.6 Livestock guardian dogs and knowledge gaps

The effectiveness of LGDs in reducing livestock depredation is the subject of much research, however, the implications of various aspects of LGD control needs to be investigated further (Gehring et al., 2010; Leijenaar et al., 2015; Kinka and Young, 2018; Whitehouse-Tedd et al., 2019; Marker, 2020; Spencer et al., 2020). There has been little research applied to the factors influencing LGD use in South Africa. A number of these factors relate to complex psychological dimensions in human-wildlife coexistence dynamics. Understanding these landholders and the human dimensions of what influences LGD use and designing a framework to consider the influences on LGD use is a glaring gap in current LGD research. This is an important gap to fill to build upon effective human-wildlife coexistence strategies with regards to LGD programs in South Africa.

1.7 Research aims and objectives

Even though LGDs have shown to be an effective form of reducing livestock predation (Coppinger, 1988; Green and Woodruff, 1988; Marker et al., 2005; Rust et al., 2013; Potgieter et al., 2015; Eklund et al., 2017; Whitehouse-Tedd et al., 2019; Marker et al., 2020;

Spencer et al., 2020), not all landholders use LGDs. This study aims to understand the factors that determine or influence LGD use and to design a framework to understand the drivers behind LGD use by landholders in South Africa. Most of South Africa's land area is considered rangeland; livestock farming accounts for almost 50% of the agricultural sector and employs almost 250 000 people (Meissner et al., 2013). In South Africa, a scientific assessment on livestock predation concluded that estimated livestock losses due to predation equated to about 0.5% of the Agriculture, Forestry and Fishing sector's GDP and 0.01% of national GDP (Kerley et al., 2019). As an important industry in South Africa, and with such a diverse livestock farming sector, across multiple environments with varying degrees of livestock depredation from various predators, South Africa is an ideal country to address some of these questions.

Apart from the factors determining LGD use and a framework for understanding the drivers of LGD use, I will also explore and compare the attributes of farmers that use LGDs and those that do not. The psychological aspects of farmers' attributes are important to understand if LGDs are to be advocated as effective conservation tools that serve both livestock farmer/rancher and wildlife interests. The ability to conserve predators and derive the ecological benefits associated with these species will ultimately depend upon factors driving landholder's decisions to use, or not use LGDs.

I will consider factors that potentially influence LGD use. These include sociodemographic factors, farming and predator factors, external organizations, as well as a host of social constructs that might influence LGD use. By considering multiple factors I aim to establish which factors are most influential in LGD use and how. Leading on from the factors that influence LGD use, I will use the Theory of Planned Behaviour (TPB) model to characterize attitudes, social norms, and perceived control of behaviour of farmers towards LGD use (Ajzen 1985; Manfredo, 2008). By incorporating elements of the Wildlife Tolerance Model (WTM) (Kansky et al., 2016), I aim to build a framework that considers the predictors that influence LGD use.

1.8 Thesis Outline

Chapter 1: General Introduction

This chapter provides a general introduction on human-wildlife coexistence in agricultural landscapes, looking specifically at livestock landscapes and the mitigation methodology in reducing livestock depredation. This leads us into detail on livestock guardian dogs historically and currently as a depredation mitigation method. The knowledge gaps and research aim, and objectives conclude the chapter.

Chapter 2: Characterizing farmer and farm related factors associated with livestock guardian dog use

Studies on livestock guardian dog use have mostly focused on the effectiveness of LGDs. In this chapter I explore the plethora of variables and constructs that might influence LGD use. The complexity of these variables – ranging from sociodemographic factors and farmer characteristics such as age, farm size, income variables, number of farming enterprises, farming enterprise type and lethal and non-lethal mitigation methods – is explained and their importance on LGD use determined. I also consider the farmer's environment which consists of predator type, cost, exposure, and problem of predators as well as awareness of various farming support organizations. Finally, in a series of social constructs adapted from the WTM, I consider elements such as tolerance, cost vs benefit, empathy to predators, farmers' wildlife value orientations and farmers' opinions on farming support organizations as factors determining LGD use.

Chapter 3: Applying the Theory of Planned Behaviour to livestock guardian dog use

The TPB is a widely used behavioural model that assumes behaviour is planned and that any action a person takes is governed by three belief systems, these being attitudinal beliefs (attitudes towards a specific action or belief), normative beliefs (beliefs governed by the expectations of others) and control beliefs (beliefs about external factors that may either enable or obstruct the intended behaviour). If human behaviour towards LGD use is governed by attitude towards LGD use, social norm pressures regarding LGD use and perceived control over one's own volitional control to use or not use LGDs (and influencing factors, i.e., their ability to perform the behaviour), then by using the TPB I can build a model to explore which factors have a significant influence on LGD use. I incorporated the WTM into this model with the aim of building a more robust predictive model in determining what drives LGD use.

Chapter 4: If LGD organizations are critical pathways to the adoption and success of LGD programs, then understanding the implications of both practical and psychosocial constructs relating to LGD use will be critical to program success for these LGD organizations. This combined with the utilization of the TPB model, including elements of the WTM, will provide a framework for understanding the factors influencing behavioural intent to use LGDs. Chapter two and chapter three form the foundation for chapter four's summary on the applications that ultimately should lead to a greater understanding when characterizing farmers, farms and the behavioural framework regarding LGD use in South Africa.

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CHAPTER 2: CHARACTERIZING FARMER AND FARM RELATED FACTORS ASSOCIATED WITH LIVESTOCK GUARDIAN DOG USE

Abstract

Achieving human-wildlife coexistence (HWC) between livestock farmers and predators sharing a mosaic of agricultural and natural areas, is a growing challenge. One method to achieve this, and often advocated by conservation organizations, is the use of livestock guardian dogs (LGDs). While considerable work has been undertaken to explore the effectiveness of LGDs in preventing livestock loss by deterring predators, the human dimension of LGD use is largely unknown. Here I aim to categorize the various social dimensions associated with LGD use. In a quantitative survey study among 113 livestock farmers and using the Wildlife Tolerance Model (WTM) as a theoretical framework, I build an understanding of the farming stakeholders and the psychometric and farm characteristics relating to LGD use in South Africa. My findings suggest a series of associations relating to the farmer's demographics, farm environment, predators and psychosocial constructs that can be associated with LGD use. Support organizations that place LGDs had the greatest relative influence on LGD use. Farmers using LGDs were more likely to have a higher diversity of livestock species, have a reduced proportion of their total income derived from animals and use a greater number of non-lethal mitigation methods compared with LGD non-users. My research shows that understanding predator type, number of farming enterprises, mitigation methods, and the exposure and extent of specific predator problems are potentially more useful characteristics for LGD support organizations to consider than farmer's psychosocial constructs, where notably, LGD use was not associated with farmer's wildlife orientations, empathy, or tolerance towards predators. For LGD support organizations to achieve greater success in the coexistence value of working LGDs, understanding the characteristics of farms and farmers is an integral pathway to increase LGD success in South Africa.

2.1 Introduction

Competition for resources increasingly brings humans and wildlife into conflict with one another. This human-wildlife coexistence (HWC) can incur significant costs to people's livelihoods and is recognized as a global priority (Torres et al., 2018). In an agricultural context, HWC involves persecution of predators by livestock managers as prevention or retaliation against livestock depredation (Torres et al., 2018). In a global context, the cost of livestock depredation is deemed significant for many farmers. This cost can be non-monetary in nature and include the fear or stress of living with predators (Torres et al., 2018). At the same time there is the desire to conserve the remaining biodiversity (McManus et al., 2015; Kerley et al., 2017).

In agricultural livestock landscapes, conflict arising over the depredation of livestock around the world affects >75% of the world's Felidae (Inskip and Zimmerman, 2009) and other predators such as wolves and jackals (Berger and Conner, 2008; Thorn et al., 2012). The removal of apex or larger predators has opened ecological niches for smaller predators, known as mesopredator release (Soulé et al., 1988; Ritchie, 2006; Ritchie and Johnson, 2009; Ripple et al., 2014, Boshoff, Landman and Kerley, 2016). In a South African farming context, most predators on farms are mesopredators (van Niekerk, 2010; Badenhorst, 2014; Kerley et al., 2017). Black-backed jackal (*Canis mesomelas)* and caracal (*Caracal caracal)* have previously been reported to account for more than 65% and 30% of livestock losses in South Africa respectively (van Niekerk, 2010), and are generally considered the most persistent predators of South African livestock (van Niekerk, 2010; Badenhorst, 2014; Kerley et al., 2017).

With predator numbers declining globally (Ripple et al., 2014) and where direct human causes are driving this decline (Myers et al., 2007), human tolerance is an essential part in the conservation of predators (Packer et al., 2009; Bruskotter and Wilson, 2013; Treves and Bruskotter, 2014). Research to understand the extent of tolerance and its effect on predators is increasing and is becoming an important part of building conservation-based models (Kansky and Knight, 2014; Kansky et al., 2014). One aspect of tolerance in farming landscapes is the willingness of farmers to implement mitigation methods to reduce livestock depredation (McManus et al., 2015; Kansky et al., 2016). Several mitigation methods are available to farmers to reduce livestock depredation, ranging from lethal (example, poison) to partially non-lethal (example, LGDs) to purely non-lethal controls (example, flashing cat's eyes) (Treves et al., 2003; McManus et al., 2015; Treves et al., 2016). In recent times, lethal methods have become less acceptable since public opinion has generally been against the use of lethal methods (Slagle et al., 2017; Liordos et al., 2017). Non-lethal methods involve fencing, human patrols, aversive agents, repellents, scare devices and antifertility agents (Shivik et al., 2004; McManus et al., 2015; Treves et al., 2014). Another perceived non-lethal mitigation method is the use of livestock guardian dogs (LGDs).

There are numerous examples world-wide of the effectiveness of livestock guardian dogs (LGDs) in reducing livestock losses by protecting livestock from predation (Rust et al., 2013; Kinka and Young, 2018; Spencer et al., 2020; Whitehouse-Tedd et al., 2020). In South Africa, LGDs have also shown to be an effective means of reducing livestock depredation

(Rust et al., 2013; Leijenaar et al., 2015; Whitehouse-Tedd et al., 2019; Whitehouse-Tedd et al., 2020). This is important as livestock predation has a significant impact on the agricultural sector's GDP (Kerley et al., 2019) with almost 50% of the agricultural sector being livestock farming (Meissner et al., 2013). Together with this, South Africa has complex predatory ecosystems that require conserving (Bergman et al., 2013; McManus et al., 2015; Kerley et al., 2017) This, together with already well-established LGD programs, makes South Africa an excellent study area regarding the use of LGDs as a depredation mitigation method.

With an increase in livestock predation due to the conservation of predators and predators returning to their former ranges, LGDs are increasingly being used as a tool to manage depredation Surprisingly, little research has been done to understand the social and psychological factors associated with their use (Landry, 1999; Ribeiro and Petrucci-Fonseca, 2004). Since human-wildlife coexistence strategies may have economic, social and health related implications for people (Decker et al., 2012), conservationists propose that the social, physical, and psychological aspects of people need to be considered in designing conservation and coexistence strategies (Minteer and Miller, 2011). With human dimensions being central to solutions for complex conservation conflicts over wildlife, specifically in this case conflict over livestock-predator interactions, understanding the psychosocial elements of LGD use is potentially crucial to success.

One such interdisciplinary theory in understanding these psychosocial elements for the application of HWC research and management is the Wildlife Tolerance Model (WTM) (Kansky et al., 2016). This theoretical framework aims to discern key variables and drivers of tolerance in human-wildlife conflict and coexistence contexts (Kansky et al., 2016). The WTM consists of two elements; an outer model with six variables and an inner model with 11 variables (Kansky et al., 2016). Using the WTM as a framework, this study aims to investigate several factors that may be involved in influencing LGD use. To achieve this aim, I categorized the factors relating to LGD use into three components being (a) descriptors of the farmers themselves, (b) relevant aspects of the farmer's environments, and (c) depredation-related social constructs. The complex mosaic of sociodemographic variables, mitigation methods, predators, and various psychological constructs in conjunction with different support organizations influencing LGD use, has rarely been considered and forms the basis of this study.

To characterize farms and LGD use I measured the influence of a series of sociodemographic and mitigation method variables on LGD use. The use of LGDs as a depredation mitigation method occurs on a range of varied farm types including freehold, emerging, and resettled lands (Marker et al., 2020). Farm types relating to size represent a range of management strategies relating to LGD use (Marker et al., 2020) and I therefore hypothesized that farm size influences LGD use. I also explored the sociodemographic variables relating to age and years spent living on the farm to see if these had an influence on LGD use. The economics of lethal versus non-lethal mitigation methods is important to consider in HWC management (McManus et al., 2015), since associated costs might influence the choice of mitigation method (Kerley et al., 2017). I therefore hypothesized that income derived from animal farming is associated with LGD use. In terms of livestock type, LGDs have been used to protect a range of livestock species and are considered particularly effective for smaller herds of goats and sheep (van Eeden et al., 2018; Smith et al., 2020). The use of LGDs in protecting large stock (cattle) and poultry (chickens and geese) is less common (Van Bommel et al., 2012). I therefore hypothesized that the type of farming enterprises (livestock species) is associated with LGD use. Diversification of farming enterprises reduces economic risk (Meissner et al., 2013). However, more diversified farming enterprises could influence a larger variety of predators and more diverse mitigation methods being required (Kerley et al., 2017). Considering this, I hypothesized that the number of farming enterprises is associated with LGD use. The use of LGDs is but one of many mitigation methods for farmers to consider (Fleming et al., 2014). There is limited scientific evidence regarding the interactive effects of using a range of non-lethal mitigation methods together (Avenant et al., 2009; McManus et al., 2015) and we also need to consider the affordability, ease of use and effectiveness of these non-lethal mitigation methods. These interactive effects might well be associated with LGD use as a mitigation method. I aimed not to understand these interactive effects between mitigation methods on LGD use but hypothesized that the number of non-lethal mitigation methods used is associated with LGD use.

Varied predator types in South Africa present a range of challenges and mitigation method options for the farmer (Avenant et al., 2009; Eklund et al., 2017). The choice of mitigation methods and variety in predator species targeting livestock in South Africa is a complex subject and understanding predator type, exposure and extent of the predator problem are some of the first steps in designing effective mitigation method management strategies (Kerley et al., 2017). I therefore hypothesized that the number of predator types (species) present, the extent of the predator problem and the frequency of certain predators seen on the farm is associated with LGD use.

Apart from reducing livestock depredation, LGDs can provide additional benefit by improving farmer attitudes towards predators (Rigg et al., 2001, Rust et al., 2013, Horgan, 2015).

However, whether LGD users are characterized by pre-existing positive attitudes towards predators or whether using a LGD improved their attitudes towards predators remains largely unknown. To test this, I hypothesized that farmers who recognized benefits (tangible and intangible) from predators on their farms, would be more likely to use LGDs compared with farmers who did not recognize any benefit value of having predators on their farms. Wildlife value orientations (WVO) are widely used to categorize and assess human-wildlife interactions and to predict human behaviour towards wildlife and towards mitigation methods (Manfredo et al., 2009; Teel et al., 2010). Connected to these values is empathy. The idea of focusing on emotional drivers, like empathy, as opposed to environmental friendliness (sustainability practices from an economic, not emotional perspective), might well be the future of more sustainable practices in environmental conservation (Sobel, 1996; Guergachi et al., 2010). Empathy for wildlife not only increases support for wildlife conservation directly but can elevate the moral consideration for nature (Ghasemi and Kyle, 2021). I considered farmer's value orientation and empathy towards wildlife and hypothesized that farmers not using LGDs would display more utilitarian orientations towards wildlife and reduced empathy towards predators, whereas farmer's using LGDs would display stronger mutualistic orientations towards wildlife and more empathetic tendencies towards predators. This is because high scores in mutualism and low scores in utilitarian orientations are more likely to be associated with coexistence strategies involving wildlife (Manfredo et al., 2009; Herrmann et al., 2013; Cerri et al., 2017) and that LGDs appear to enable coexistence (Spencer et al., 2020). One construct of empathy is compassion, and it has been shown that compassion is a relevant factor in increasing citizens engagement in wildlife conservation (Greving and Kimmerle, 2021). If empathy helps motivate pro-environmental and conservation orientated behaviour (Shelton and Rogers, 1981; De Berenguer, 2007), I considered that farmers with greater empathy towards predators were more likely to be using LGDs (Smith et al., 2020; Spencer et al., 2020). One of the determinants of predator survival in non-protected areas in South Africa, apart from HWC, is the concept of tolerance towards predators and livestock loss (Kerley et al., 2017). Increased tolerance of wildlife is seen as one of the critical elements in the building of a human-wildlife coexistence culture (Dubois et al., 2017). As LGDs are considered to enable coexistence (Spencer et al., 2020), I hypothesized, considering a series of tolerance constructs, that tolerance towards predators and tolerance to depredation would be associated with LGD use. Apart from internal psychometric variables that might be associated with LGD use, it is equally important to consider the role external factors, such as organizations involved in supporting farmers, play and their association with LGD use. There is no single organization responsible for the myriad of mitigation methods available to reduce livestock depredation in South Africa (Nattrass and Conradie, 2015; Kerley et al., 2017). These organizations range from agricultural associations to local municipalities and private or charitable conservation organizations focusing on LGD placement and support. I hypothesized that the trust, general performance, degree of communication, knowledge and skills of support organizations would influence LGD use.

2.2 Methods

2.2.1 Study area

South Africa has little land area that is arable and 91% of the land is classified as arid or semi-arid. Over 69% of South Africa's land area is under rangeland (WWF, undated; DAFF, 2017). Livestock (defined as domesticated animals and wildlife or game, that are managed for human benefit or commercial purposes) are mostly free ranging on these farms which renders them vulnerable to depredation (Kerley et al., 2017). Livestock carrying capacity in South Africa increases from west to east as the rainfall increases. In the drier western and central areas, sheep tend to dominate, while cattle are more frequent in the eastern rangelands where it is considerably wetter. Game farming is more prolific in the eastern and northern regions with some game farming being done in the drier western parts of the country (DAFF, 2017).

2.2.2 Participant selection and recruitment

Both commercial and subsistence farms from eight of the nine provinces – no participants from Gauteng as no livestock farmers were included in this province – in South Africa, were included as participants (Fig. 2.1). Participants were selected based primarily on predator related interaction as opposed to geography or sociodemographic variables. Participants were informed that the survey was to be utilized in understanding the use of mitigation methods in a HWC context. In the case of LGD users, participants were informed that this was a LGD mitigation method focused study. Two stakeholder groups were compared in the survey sample, those livestock farmers using LGDs and those not using LGDs (Fig. 2.1). Farmers not using LGDs as a mitigation method were then investigated as to the other lethal and/or non-lethal mitigation methods they were using. Farmers with LGD's were recruited via the Cheetah Outreach Trust (COT) and through referral means. For farmers not using LGDs I engaged with Predation Management South Africa (PMSA). This organization aims to provide guidelines and advice to producers to manage livestock predation, thus implying, these farmers had predators present, would possibly utilize mitigation methods to reduce predation, and would form a critical control group together with the LGD users recruited through COT.

2.2.3 Survey design and data collection

A pilot survey was conducted with 22 respondents (n = 8 for LGD users; n = 14 for LGD non-users) from 05 November 2019 – 20 December 2019 to confirm clarity of the questions and measure completion times. The pilot survey allowed for assessment of the data collection instrument (Nyatanga, 2005) and simplified enough to keep the survey to one language, being English. The WTM proposes an outer model and an inner model. The outer model determines perceptions of costs relative to benefits of living with a species, based on the extent to which a person experiences a species. This then also determines tolerance. Further perceptions of costs and benefits are predicted by the inner model's eleven variables. I adapted the six outer model variables and eleven inner model variables to suit the parameters relating to human-wildlife coexistence in the context of LGD use. Due to restrictions and challenges posed by COVID with in-person questionnaires, I designed an online questionnaire using the software alchemer (https://www.alchemer.com/). Alchemer allows for advanced coding enabling target question-based display logic and the validation of questions based on certain selection criteria. All 113 completed responses were answered on the online platform. Ethics was granted under the Cape Peninsula University of Technology (201016974/01/2020) and Nottingham Trent University (#ARE192039). All participants gave signed consent for the use of their anonymized data. Questionnaires were administered by email from 7 May 2020 – 22 March 2021. Attempts to reduce non-response bias included the anonymization of data and follow-up communication with non-responders. Given the questionnaire comprised >100 items, responses were further incentivized by including a sponsored safari prize.

The survey comprised 128 items (Appendix A) and the questionnaire was divided into the following nine sections: (1) A series of sociodemographic factors that included years lived on the farm, age, income from farming, income from animal farming, total household income, farm size, number of farming enterprises, number of mutton sheep, wool sheep, cattle, goats, chickens, geese, and game. (2) The type and number of farming enterprises and size of the livestock herd and/or flocks. Livestock enterprises were defined as one or more of the following selections: mutton sheep, wool sheep, cattle, goats, chickens, geese, game and other. (3) The livestock depredation mitigation methods – hereafter referred to as mitigation methods – were divided into six lethal (poison, baited wildlife cage traps, shooting from a vehicle, night hunting, leg hold or gin traps and hunting wildlife with a dog pack) and 12 non-lethal mitigation methods (wildlife proof mesh boundary fencing, protective livestock collars, electrified fencing, human patrols, flashing cat's eyes tied to livestock, call the local conservation authorities, synchronized breeding, radio collars, anti-fertility agents, night pens

/ bomas, aversive agents and LGDs). I classified LGDs as non-lethal mitigation methods on the basis that they are intended to deter, not kill, but I acknowledged that lethal interactions between wildlife and LGDs do occur (Potgieter et al., 2016, Whitehouse-Tedd et al. 2020). I considered each mitigation method's perceived affordability, ease of use and effectiveness score. (4) The predator type and factors relating to predators were considered in terms of the extent of the problem and exposure to predators. I also considered social variables relating to predators such as like vs dislike and number of positive and negative experiences with predators. (5) I considered both the tangible and intangible costs of predators. These were adapted from the WTM (Kansky et al., 2016). For tangible costs, I considered livestock loss in number and monetary (ZAR) value. For intangible costs, I considered the challenge of living with predators. I also considered tangible and intangible benefits. Benefits were considered in four different spatial dimensions being beneficial to oneself, the community, humankind, and nature. Tangible benefits were the perceived monetary benefit as well as the actual monetary benefit. Intangible benefits could be aesthetic value, appreciation value, existence value, cultural or symbolic value. (6) Using further elements of the WTM (Kansky et al., 2016) I structured a part of the survey to elucidate the six different construct items relating to tolerance. (7) I used the WVO (Teel et al., 2010) to establish value orientations for both LGD users and LGD non-users via a series of Likert scale items. The Teel and Manfredo framework and methodology was used to categorize both LGD users and non-users by their WVO type (Teel and Manfredo, 2009, Teel et al., 2010). These four orientations are mutualist, utilitarian, pluralist and distanced. (8) Using the perspective-taking aspect of empathy, I designed six statements to build a profile of empathy for each farmer. (9) I considered the awareness amongst farmers of seven organizations related to depredation management. Of these organizations, two are focused on LGD placement and management, these being Cheetah Outreach Trust (COT) and Endangered Wildlife Trust (EWT) and the other five organizations (local farmer's associations, National Wool Growers Association (NWGA), Agri SA, local municipality and Department of Environmental Affairs and Development Planning), are general farming support organizations which include some depredation management and mitigation. I then considered farmers' opinions relating to the trust, general performance, degree of communication and level of knowledge and skills for these seven farming support organizations. I structured a series of hypotheses based on these variables and constructs relating to LGD use (Table 2.1).

2.3 Analysis

To ensure categorization of variables and robust sample sizes I collapsed variables into various data categories (Appendix A). I used nonparametric testing considering the relatively small sample size and initially used CART analysis to explore the data. To then test for interactive effects between variables and constructs prior to Boosted Regression Tree (BRT) modelling, I used the Kendall rank correlation coefficient test. Based on these, I included all categorical and continuous variables in the BRT modelling. To analyse the associative relationships between variables and their association with the response variable, LGD use, I used BRTs. Boosted regression trees are a model built on decision tree algorithms and boosting methods (Elith et al., 2008). I built three models based on “who are the farmers?”, “farmer’s environment” and “social constructs”.

Variable selection for the three BRT models was done by dropping unimportant variables, as the model ignores predictor variables that are not informative when fitting the trees in a form of simplification analysis (Elith et al., 2008). This prevented redundant predictors to increase the variance. Due to the small sample size, I was unable to run both a training and testing set, so I ran one continuous set of modelling (Elith et al., 2008). I noted that the interactive effects between predictor variables were low on all accounts and, hence, did not report further on interactive effects. I aimed to fit the BRT model for each section with an optimal number of trees (nt) for prediction (Elith et al., 2008). I ran multiple tests with varied learning rates (lr), bag fraction rates (bfr) and tree complexities (tc). I tested various lr, bfr and tc rates for each section to fit the optimal model and then achieved variable selection by simplifying the model by excluding poorly informative predictor variables. Using cross-validation (CV) I was able to build a large tree and then reduce the tree complexity by collapsing the weakest links. My aim was to find the combination of parameters (lr, tc and nt) that achieved the minimum predictive error, and which was considered optimal for the sample size of 113 observations. All analyses were done in R (version 3.6.2, 2019-12-12) using the GBM package for BRT.

The predictor variables tested included 21 sociodemographic and mitigation method variables all relating to “who are the famers?” and their associations to LGD use (Appendix A). After running multiple tests with varied lt, bfr and tc, the final BRT model for these 21 variables was based on 3 trees with a learning rate (lr) of 0.002 and a bag fraction rate of 0.5. I considered 25 predictor variables to establish the “farmer’s environment” and their associations to LGD use (Appendix A). After running multiple tests with varied lt, bfr and tc, the final BRT model for these 25 variables was based on 3 trees with a learning rate (lr) of 0.002 and a bag fraction rate of 0.75. I considered three different groupings of 33 variables and constructs relating to the “social constructs” potential associations with LGD use. The first grouping related to opinions of predators (Appendix A). After running multiple tests with varied lt, bfr and tc, the final BRT model for these 33 variables was based on 3 trees with a learning rate (lr) of 0.002 and a bag fraction rate of 0.75.

I concluded the BRT analyses by combining all the variables and social constructs from "who are the farmers?", "farmer's environment" and "social constructs". I considered the first model with no simplification and all 79 predictor variables and constructs made up of: 21 sociodemographic and mitigation method variables all relating to "who are the famers?", 25 predictor variables for the "farmer's environment" and 33 variables and constructs relating to the "social constructs". Thereafter I considered a final BRT model with simplification by dropping 37 variables that showed no or very low relative influence on LGD use.

To test for reliability, Cronbach's alpha ($\alpha > 0.70$) was used. To test the categorical variables for goodness of fit, homogeneity, and independence, and considering the non-random associations between categorical variables, I used a Fisher's exact test for counts below 5 (Table 2.2). This suited my small sample size ($n = 113$). To test differences between continuous variables T-Tests for normally distributed and Mann-Whitney U Test for non-normal data were used. I used Stata Statistical Software, (Release 17. College Station, TX: StataCorp LLC).

2.4 Results

In total 273 farmers were surveyed, of whom 113 participants (44 LGD users and 69 LGD non-users) completed all sections. As the survey was a detailed and lengthy survey, the primary reason for incomplete surveys was related to cognitive fatigue. Survey fatigue is a common challenge in the collection of date (Whelan, 2008), and for this reason question type and complexity was considered and the number of open-ended questions reduced to ensure a more user-friendly survey experience. I excluded one construct being belief in animal mind with a poor Cronbach's alpha value ($\alpha = 0.49$).

2.4.1 Who are the farmers? The sociodemographic factors relating to the farmers

Considering gender, 81% of all farmers surveyed were male with 19% female. According to a study conducting by the Sustainability Initiative of South Africa and the Western Cape Department of Agriculture in 2020, farmer ownership varied between 78% - 80% across all provinces for males and 20% - 22% across all provinces for females (Loubser, 2020). 83% of the farmers surveyed were the farm owner with 17% being the farm manager. Home language Afrikaans speakers were the dominant language group at 50%, with English home language speakers numbering 42%. Most farmers were commercial farmers (89%) (Fig. 2.2) with only 11% being subsistence farmers. Most respondents (70%) had a tertiary education. Neither farm size (mean 2706 ha for LGD non-users and 2862 ha for LGD users), years spent living on the farm (average 23 years) or farmer age could predict LGD use ($P > 0.05$; Table 2.2).

Most farmers surveyed were animal farmers (71% solely animal farming and 29% mixed farming). The percentage of total household income derived from animal farming (farming of livestock such as sheep, cattle, goats, poultry, and game) was significantly higher for LGD non-users (80%) than for LGD users (73%) ($P = 0.012$; Table 2.2). Income generated from mixed farming (i.e., both crop and animal farming), however, did not differ significantly between LGD users and LGD non-users ($P = 0.816$; Table 2.2). There was no significant difference between LGD users and LGD non-users in the number of mutton sheep ($P = 0.971$), wool sheep ($P = 0.094$), cattle ($P = 0.438$) or goats ($P = 0.937$) (Table 2.2) farmed. The mean number of farming enterprises used by LGD users was significantly higher than LGD non-users ($P < 0.01$; Table 2.2).

Although the sum of all mitigation methods used and the sum of all lethal mitigation methods used showed no significant difference regarding LGD use, I noted that the sum of all non-lethal mitigation methods used was significantly different in terms of LGD use, where LGD users used on average a higher number of different non-lethal mitigation methods than did LGD non-users (Table 2.2). There were no significant differences between opinions of LGD users and non-users in the perceived affordability, ease of use and effectiveness of lethal mitigation methods (Table 2.2, Fig. 2.3). Equally so there were no significant differences between opinions of LGD users and non-users in the perceived affordability, ease of use and effectiveness of non-lethal mitigation methods (Fig. 2.4). However, I noted that LGD non-users found both flashing cat's eyes tied to livestock and protective livestock collars to be more affordable, easier to use and more effective than did LGD users (Fig. 2.4). LGD users considered synchronized breeding more affordable and slightly more effective but harder to use than did LGD non-users (Fig. 2.4). I would expect a reasonable number of significant results by chance. Of all the non-lethal mitigation methods used by LGD users and LGD non-users, the most frequently used mitigation methods were all related to fencing type methods being night pens/bomas, wildlife proof mesh boundary fencing and electrified fencing (Fig. 2.5).

The number of farming enterprises accounted for the highest relative influence, (ri) at 21.92%, as a predictor variable on LGD use when accounting for all variables tested regarding "who are the farmers?" (Table 2.2; Fig. 2.6A). The total number of non-lethal mitigation methods accounted for the second highest relative influence, (ri) at 21.15%, as a predictor variable on LGD use when accounting for all variables tested regarding "who are the farmers?” (Table 2.2; Fig. 2.6B). Income from animal farming had the third highest relative influence (ri) at 7.32%, as a predictor variable on LGD use when accounting for all variables tested regarding “who are the farmers?” (Table 2.2; Fig. 2.6C). Effectiveness of all non-lethal mitigation methods showed the fourth highest relative influence, (ri) at 6.68%, as a predictor variable on LGD use when accounting for all variables tested regarding “who are the farmers?” (Table 2.2; Fig. 2.6D).

2.4.2 Farmer’s environment

The total number of predator types seen on the farm was significantly higher on farms with LGDs (P = 0.005; Table 2.2). On farms using LGDs and farms not using LGDs, jackals were the most frequently observed predator (Fig. 2.7). Among all predator species exposure to jackal was significantly higher for LGD users (P = 0.012; Table 2.2). Notably when considering the extent of perceived predator problem for all predators on the farms, leopard was the only predator showing statistically significant difference relative to LGD use, where leopards were rated significantly higher as a problem for LGD users compared with LGD non-users (P = 0.002; Table 2.2) The perceived intangible costs of living with predators (P = 0.129), tangible costs of number of livestock lost due to depredation for mutton sheep (P = 0.095), wool sheep (P = 0.968), cattle (P = 0.117), nor the total tangible costs in terms of monetary (ZAR) value of all livestock lost due to depredation (P = 0.163), showed any statistically significant difference between LGD users and LGD non-users (Table 2.2). The number of goats lost due to depredation was significantly higher for LGD users than LGD non-users (P = 0.027; Table 2.2). There were significant differences in LGD users and LGD non-users for awareness of both general support organizations and LGD focused support organizations (P < 0.01; Table 2.2). LGD non-users showed higher awareness of general farming support organizations than did LGD users, where-as LGD users showed higher awareness of LGD support organizations than did LGD non-users (Table 2.2).

After accounting for the average effects of all other variables in the “farmer’s environment” model, the extent of the problem for all predators combined accounted for the highest relative influence on LGD use (ri = 20.06; Table 2.2; Fig. 2.8A). Awareness of non-LGD focused organizations had the second highest relative influence on LGD use (ri = 18.81; Table 2.2; Fig. 2.8B). The total number of predator types (species) on the farm accounted for the third highest relative influence on LGD use when considering the farmer’s environment (ri = 17.06; Table 2.2; Fig. 2.8C). Exposure to jackal, caracal, leopard, and baboon showed the fourth highest relative influence associated with LGD use (ri = 13.60; Table 2.2; Fig. 2.8D).

2.4.3 Social constructs

Farmers' predator opinions

There was no significant association between like vs dislike of predators nor the number of positive and negative experiences with predators, with LGD use (Table 2.2). There was no significant difference between LGD users and non-users based on the perceived tangible monetary benefits of living with predators (*P* = 0.278), the actual tangible monetary benefits of living with predators (*P* = 0.161) nor the intangible non-monetary benefits of predators on the farm (*P* = 0.395; Table 2.2). I also found no significant differences in WVOs of mutualism and utilitarian orientations nor the construct of empathy for predators between LGD users and non-users (*P* = 0.278; Table 2.2).

Tolerance constructs

In the associations between tolerance constructs and LGD users and non-users, LGD users had a significantly higher willingness to lose mutton sheep (*P* = 0.043) or goats (*P* = 0.017), whilst the variables relating to willingness to lose wool sheep and cattle, did not differ significantly (Table 2.2). For all other tolerance measures such as the number of days a farmer would be willing for a predator to visit their farm/land (*P* = 0.765), number of days a farmer would be willing for a predator to visit their area/neighbourhood (*P* = 0.628), preference for killing a predator under a series of scenarios (*P* = 0.788) or tolerance towards predator populations increasing (*P* = 0.856), there was no difference between LGD users and non-users.

Organization opinions

Cheetah Outreach Trust (COT) are a LGD support organization (Fig. 2.9), and COT showed the greatest relative influence on LGD use when accounting for all variables tested regarding "social constructs" (ri = 39.44; Table 2.2; Fig. 2.10A). Both LGD users and non-users had similar opinions on mean trust, performance, communication, knowledge, and skills for all support organizations involved in farming practices (Table 2.2; Fig. 2.11). LGD users showed a higher degree of perceived trust, performance, communication, and knowledge towards LGD support organizations (COT and EWT combined) than towards the five general support organizations (Table 2.2; Fig. 2.11A). For LGD non-users the attitude towards LGD support organizations and general farming support were very similar (Fig. 2.11B). National Wool Growers Association showed a significant difference associated with LGD use and amongst LGD non-users scored, on average, the highest of all organizations in all four combined categories on trust, performance, communication and knowledge and skills across all organizations (Table 2.2).

2.4.4 Relative influence combined for "Who are the farmers?", "Farmer's environment" and "Social constructs"

The relative influence of COT showed the greatest influence on LGD use (ri = 20.82; Table 2.2) after accounting for the average effects of all variables and constructs in the model. Number of farming enterprises showed the second highest relative influence (ri = 13.32; Table 2.2) after accounting for the average effects of all variables and constructs in the model. Thereafter I saw that relative influence dropped off with 31 variables and constructs showing a relative influence of less than two in value.

2.5 Discussion

This study showed that awareness in South Africa, of both general farming support organizations as well as LGD placement and support organizations, was significantly associated with LGD use. Similarly, farming support organizations in South Africa have shown, in some instances, to be influential in terms of supporting HWC strategies (Kerley et al., 2017). Farmers' perceptions on trust, general performance, degree of communication and level of knowledge and skills of the LGD placement organization COT was significantly associated with LGD use. We need to consider though the inadvertent bias towards COT with the recruitment process for LGD users being done with COT. It is known that LGD support organizations support farmers in terms of placement, husbandry, and monitoring points to detect undesirable behaviours of LGDs (Marker et al., 2005; Potgieter et al., 2013; Whitehouse-Tedd et al., 2020; Horgan et al., 2021). Notably, more than 50% of farmer's not using LGDs in my study, were aware of the use of LGDs. If perceptions of LGD support organizations are strongly associated with LGD use and over half the farmer's surveyed were aware of, but did not use an LGD, this raises the question as to why these farmers were not using an LGD? It is important to acknowledge that in some instances LGDs are not the most effective method of reducing livestock depredation and LGD support organizations might influence LGD use where it is inappropriate (Whitehouse-Tedd et al., 2020). Another consideration with regards to LGD use and LGD support organizations, is the cost of this support. A recent study on the use of "landrace" Tswana LGDs in Botswana advocates for the more cost-effective use of these dog types as opposed to the purebred Anatolians used in Southern Africa (Horgan et al., 2021). The reliance of farmers on the external support offered by LGD support organizations poses several sustainability concerns for these conservation programs as evidenced during the study, where COVID regulations reduced the ability for LGD support organizations to visit with farmers as well as having an adverse impact on funding for the program.

The sustainability of inanimate mitigation methods might make these methods more attractive for farmers, but other considerations such as their affordability, ease of use and effectiveness also need to be considered. Farmers from my sample in South Africa used a variety of lethal and non-lethal mitigation methods in aiming to reduce livestock depredation. The three most frequently used non-lethal mitigation methods by LGD users and LGD non-users were all related to fencing type methods being night pens/bomas, wildlife proof mesh boundary fencing and electrified fencing. Among non-lethal mitigation methods, only aversive agents were considered more effective, affordable, and easier to use than LGDs. Poison was considered the most effective, affordable, and easy to use mitigation method of all lethal mitigation methods. Although LGDs were considered less affordable and harder to use than poison, LGDs were considered a more effective mitigation method. The number of non-lethal as opposed to lethal mitigation methods, was significantly associated with LGD use.

Unsurprisingly the number of predator types (species) and the extent of the predator problem across all predators seen on the farm were significantly associated with LGD use. Extent of predator problem for all predators showed the greatest relative influence on LGD use when considering all predator related variables. The extent of the leopard problem showed the most significant association with LGD use when compared to the extent of the problem for black-backed jackal, caracal, and baboon. Leopards are the most widespread large carnivore in South Africa and are frequently found outside protected areas (Swanepoel, 2008). Leopards appear to incorporate more livestock in their diet in areas like the Western Cape, where small livestock (sheep and goats) are the dominant farming enterprises (Norton and Henley, 1987; Mann, 2014; Jansen, 2016). This coupled with the perception, particularly in the Western Cape, that leopards are a major predator of livestock (Martins, 2011; Conradie, 2012) might have contributed to leopards showing the most significant association with LGD use when considering the extent of depredation problems across multiple predator types. Further research considering specifically the interactions between predator and LGDs would be valuable.

Apart from the perceived extent of the predator problem I also considered the exposure of predators on farms and this association with LGD use. Of all the predator species seen on farms surveyed in South Africa, black-backed jackal had the most significant association with LGD use. Black-backed jackal and caracal are the dominant predator species on farms relative to other predator species in South Africa (Thorn et al., 2012; Badenhorst, 2014). Black-backed jackals account for more than 65% of depredation related livestock losses in South Africa (van Niekerk, 2010). Black-backed jackals are noted to have a wide habitat tolerance and occur in all biomes (Nattrass and Conradie, 2015; Minnie et al., 2016). Previous research has shown that mitigation management, particularly lethal mitigation management, modifies the activity patterns of black-backed jackals in dispersing from high-density populations into vacant territories left due to lethal controls (Minnie et al., 2016). The adaptable nature of dogs and in this case, LGDs, supports the theory that such adaptable mitigation methods might be a better solution to combat the adaptability of the black-backed jackal in terms of reducing livestock depredation (Nattrass et al., 2020). More research is necessary regarding the responses of black-backed jackals to lethal and non-lethal mitigation methods as this provides valuable insights into understanding the role various mitigation methods, like LGDs, play in reducing livestock depredation.

There was little to no difference between LGD users and LGD non-users in terms of the reported number of mutton sheep, wool sheep and cattle lost annually to depredation events. The annual loss in number and percentage of goats was however significantly associated with LGD use. This supported the anecdotal evidence from COT, where several farms had diversification in their farming enterprises by farming several different livestock species. These farmers chose to place their Anatolian Shepherd dogs with goats as opposed to other farming enterprises (livestock species). The number of farming enterprises was significantly associated with LGD use and I considered that in conjunction with LGDs being used for one specific livestock species on a farm with diversified farming enterprises, that farm type might also be a factor associated with LGD use. In contrast to this, in Namibia livestock losses between farm types with LGDs showed no difference, although farmers on communal and emerging freehold farms reported better performance from their LGDs compared to farmers on resettled farmland (Marker et al., 2020). In South Africa LGDs can be considered a relatively cost-effective mitigation method when compared to more lethal mitigation methods (McManus et al., 2015). The relative costs per ewe of LGD use over one year, three years and five years is relatively low when compared to mitigation methods such as electric fencing, human shepherds, collar use or even hunting dogs (Kerley et al., 2017). Here I show that on average farmers using LGDs derived a lower amount of their household income from animal farming. This consideration might be related to more recreational, or hobbyist style farming and I acknowledge that further research in identifying novel factors relative to farm type in South Africa will be useful in understanding these associations with LGD use. If LGDs are more popular among a specific farm type, such as recreational or hobbyist farmers, with a diversified range of farming enterprises, then this will aid LGD support organizations in terms of targeting specific farms for LGD placement. The few subsistence farmers in my survey likely reduced my ability to detect differences in farm type association with LGD use. However, the strong association between LGD use and number of farming enterprises and reduced levels of income from animal farming, might be indicative of farm type and its influence on LGD use. The percentage of subsistence farms was too low to sample effectively (11%) and I suggest that further research on farm type would be useful to understand in its association with LGD use (Marker et al., 2020).

Unexpectedly, sociodemographic factors including age, the duration of time spent living on the farm and the size of the farm itself were unrelated to LGD use. This is unexpected as sociodemographic factors have been shown to play a role in LGD efficacy (Marker et al., 2020). There was little to no difference between LGD users and LGD non-users in perceived costs of living with predators. In general, LGD use was not related to value and ideological opinions on wildlife. The WTM psychosocial variables relating to wildlife value orientations, empathy towards predators, tangible and intangible costs of predators, tangible, and intangible benefits of predators, like or dislike of predators and number of positive experiences with predators did not show any significant association with LGD use. Similarly, tolerance to depredation in terms of the number and monetary value of livestock lost, as well as tolerance towards killing a predator, population size of predators and tolerance to spatial proximity of predators on the farm and in the area, did not significantly influence LGD use. This has important management implications for the LGD support organizations, such as COT, which showed the greatest relative influence on LGD use. I considered that the lack of statistical significance and relative influence with regards to the WTM adapted social constructs of WVOs, tolerance, empathy etc might be indicative of farmers with these orientations, not having partaken in the survey. In this study I surveyed LGD users post the placement of the LGDs. The associations relating to LGD use might be different prior LGD placement vs post LGD placement. The identification of significant associations with regards to LGD use might be consequences of LGD use in this case and it would be useful to conduct a longer study that takes into consideration these associations before and after an LGD is placed. Although I aimed to minimize non-response bias by regularly phoning and encouraging the collaborators to complete the survey, I did not collect any data on non-response bias. Models like the WVO are an integral part of detecting where conflict over wildlife arises and can aid in applying solutions to reduce human-wildlife conflict scenarios (White et al., 2005; Vaske, 2008). However, this study shows that for LGD support organizations, advocating for conservation and coexistence to influence farmer values, will be less effective than understanding the practical implications relating to predator type, number of farming enterprises, mitigation methods, and the frequency and extent of specific predator problems. Greater consideration for these practical implications associated with LGD use will likely serve as better tools in categorizing farmers for optimal LGD placement and depredation mitigation success. Although the intangible benefits of wildlife become exceedingly difficult to measure, we recognize that our relationship with nature is important to human wellbeing (Frumkin, 2001; St Leger, 2003). In this regard, for LGD support organizations to achieve greater success in the coexistence value of working LGDs, understanding the characteristics of farms and farmers is an integral pathway to LGD program success in South Africa.

I acknowledge that a mixed methods approach incorporating further qualitative methods should be considered in future research when surveying farmers. Shortcomings in BRT's predictive performance is influenced by sample size, and I acknowledge a larger sample size will improve the predictability of the model. The gains from increasing tc would be higher with larger data sets, as more data will provide more detailed information about the full range of effects from multiple variables on LGD use. Larger sample sizes would in future allow us to elect the highest tc. In this case with a smaller sample size (n = 113), for the model to achieve enough trees it required an exceedingly slow lr. Hence smaller sample sizes like the 113 observations are best modelled using simple trees (tc = 3 in this case) and slow lr to allow at least 1000 trees to be reached. Variable selection in BRT modelling is achieved because the model ignores non-informative predictors when fitting trees. Knowing the complexity of human decision making in the even more complex field of human-wildlife coexistence, we could consider increasing the number of variables in sample testing of a population. There is a balance between increasing the number of variables or observations in a tested population and the sample size. There might be an inverse relationship where, as variable numbers increase, so too would the number of completed surveys potentially decrease and so the optimal balance between variable numbers for robust BRTs and a large enough sample size need to be considered. Note that the sample size of LGD users in South Africa is limited so consideration should be given to increasing the sample size by including regions such as Namibia and Botswana where the use of LGDs is being practiced (Marker et al., 2020; Horgan et al., 2021). I also noted that partial dependence plotting for BRTs is not always a perfect representation of the effects of each variable on the response variable. This is particularly true if the predictor variables are strongly correlated or there are strong interactions within the data. More robustly pre-tested correlated observations would improve future BRT modelling in human-wildlife coexistence models by considering the interactive effects between all predictor variables. Apart from the BRT shortcomings I acknowledge that I was unable to determine if LGD use influences the use of other non-lethal mitigation methods or if the use of alternate non-lethal mitigation methods influence LGD use. Understanding these interactive effects between non-lethal mitigation methods is an area of research that requires further study and could have notable findings for organizations promoting the use of less lethal to non-lethal methods in reducing livestock depredation.

2.6 Conclusion

In this study I offer novel insight into the factors and characteristics that associate with LGD use among a subset of livestock farmers in South Africa. Notably the findings showed that psychosocial constructs relating to wildlife value orientations, empathy for predators, tolerance to predators, tangible and intangible cost and benefits of predators, like or dislike of predators and number of positive experiences were all less important as determinants of LGD use than were the more practical implications relating to predator type, number of farming enterprises, mitigation methods, and the frequency and extent of specific predator problems. The findings also showed that some sociodemographic factors like age, the duration of time spent living on the farm and the size of the farm itself were to LGD use. A crucial finding was that LGD support organizations, in this case COT, have a significant role to play when considering LGD's. The organization COT plays a critical role in terms of managing the breeding program for Anatolian Shepherd dogs, the assessment of suitable farm candidates for LGDs, the placement and bonding of the dogs with the livestock, as well as husbandry training and veterinary care and food costs for the dogs first year of placement. Understanding the characteristics that associate with LGD use will provide critical insight for LGD support organizations, aiding them in building more robust placement strategies and improving LGD program adoption. Although this study focused on LGD use in South Africa the results and principles of understanding the factors that associate with LGD use are broadly applicable and can be applied to Namibia (Marker et al., 2020) and Botswana (Horgan et al., 2021) and globally in North America (Urbigkit, 2010; Kinka and Young, 2018), Europe (Landry, 1999; Ribeiro et al., 2004) and Australia (Van Bommel and Johnson, 2012). Understanding the highly complex associative effect in a psychometric study relating to human-wildlife coexistence is a challenging field of research for the intersection of natural and social sciences. With this research I highlighted the critical role LGD support organizations play in LGD program success and by developing a better understanding of factors and characteristics associated with LGD use, this research will aid in improving LGD program sustainability, which will ultimately have a positive effect on conservation of carnivores where human-livestock conflict is present.

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2.8 List of figures

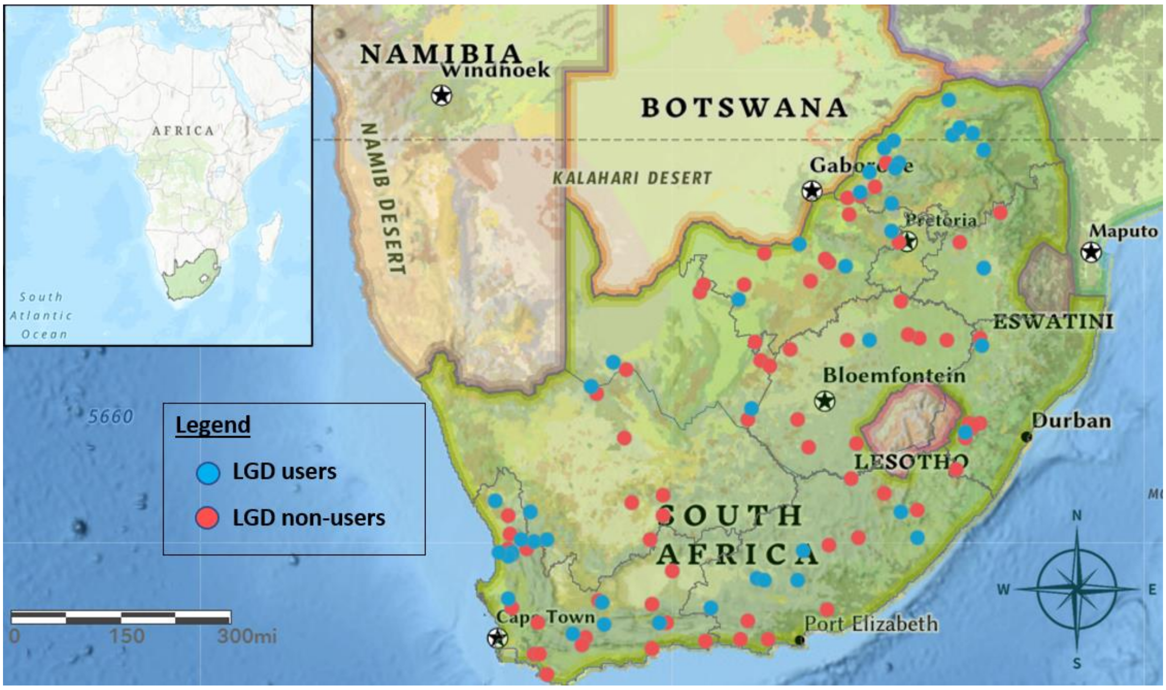

Figure 2.1: Survey participant farm localities in South Africa for both LGD users and LGD non-users (n = 113). Inset map - South Africa within Africa, with shaded relief and land-cover imagery with administrative boundaries and cities

Figure 2.2: Commercial farms utilizing LGDs but farming a variety of livestock in combination with agriculture. Seen here A) a farm outside Graafwater in the Western Cape, farming rooibos, goats, and sheep and B) an LGD bonding with her herd

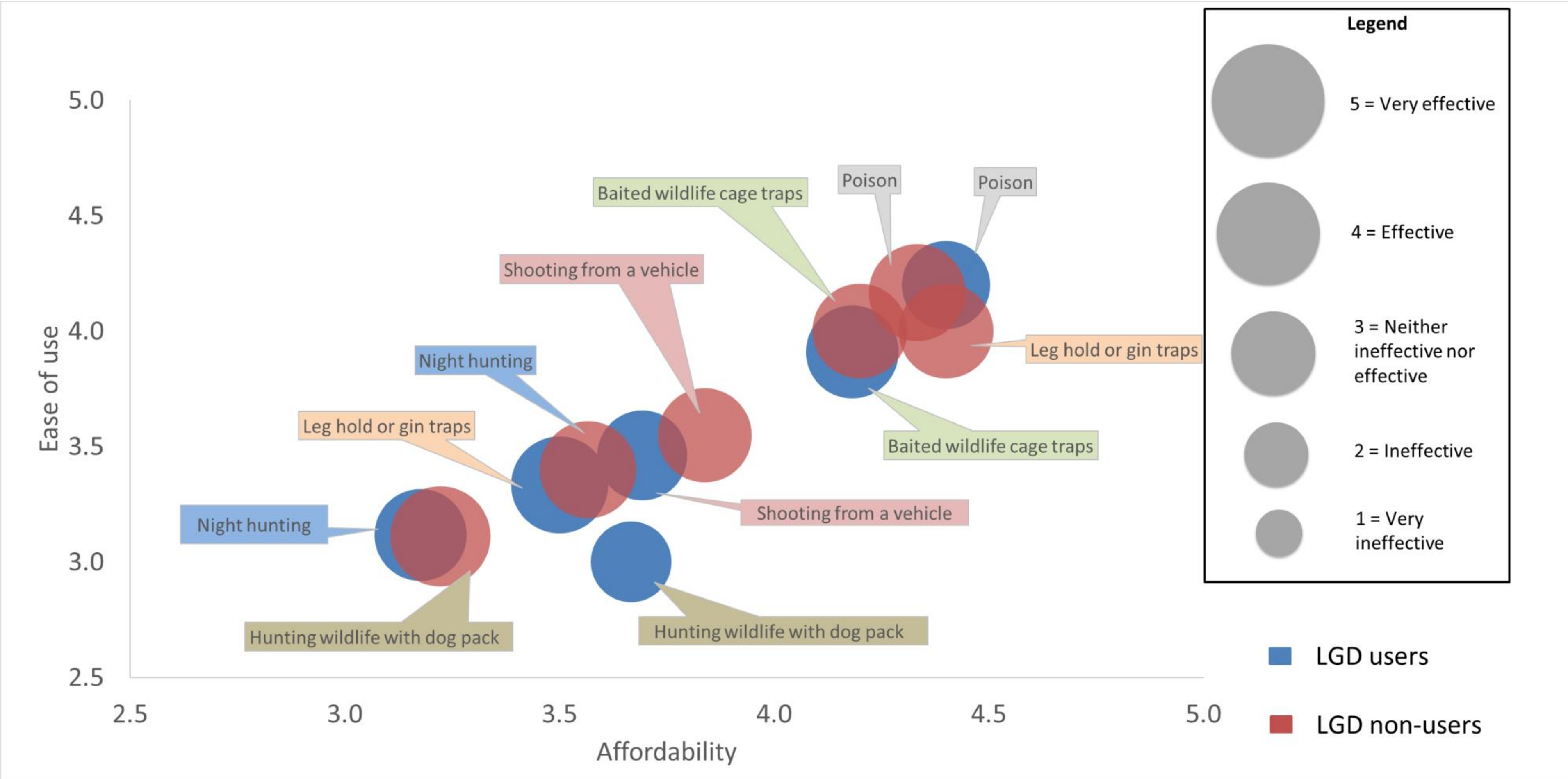

Figure 2.3: Farmer (n = 113) opinions on affordability, ease of use and effectiveness of varied lethal mitigation methods. Shaded bubble sizes denote perceived effectiveness of the mitigation method (1 = Very ineffective; 2 = Ineffective; 3 = Neither ineffective nor effective; 4 = Effective; 5 = Very effective)

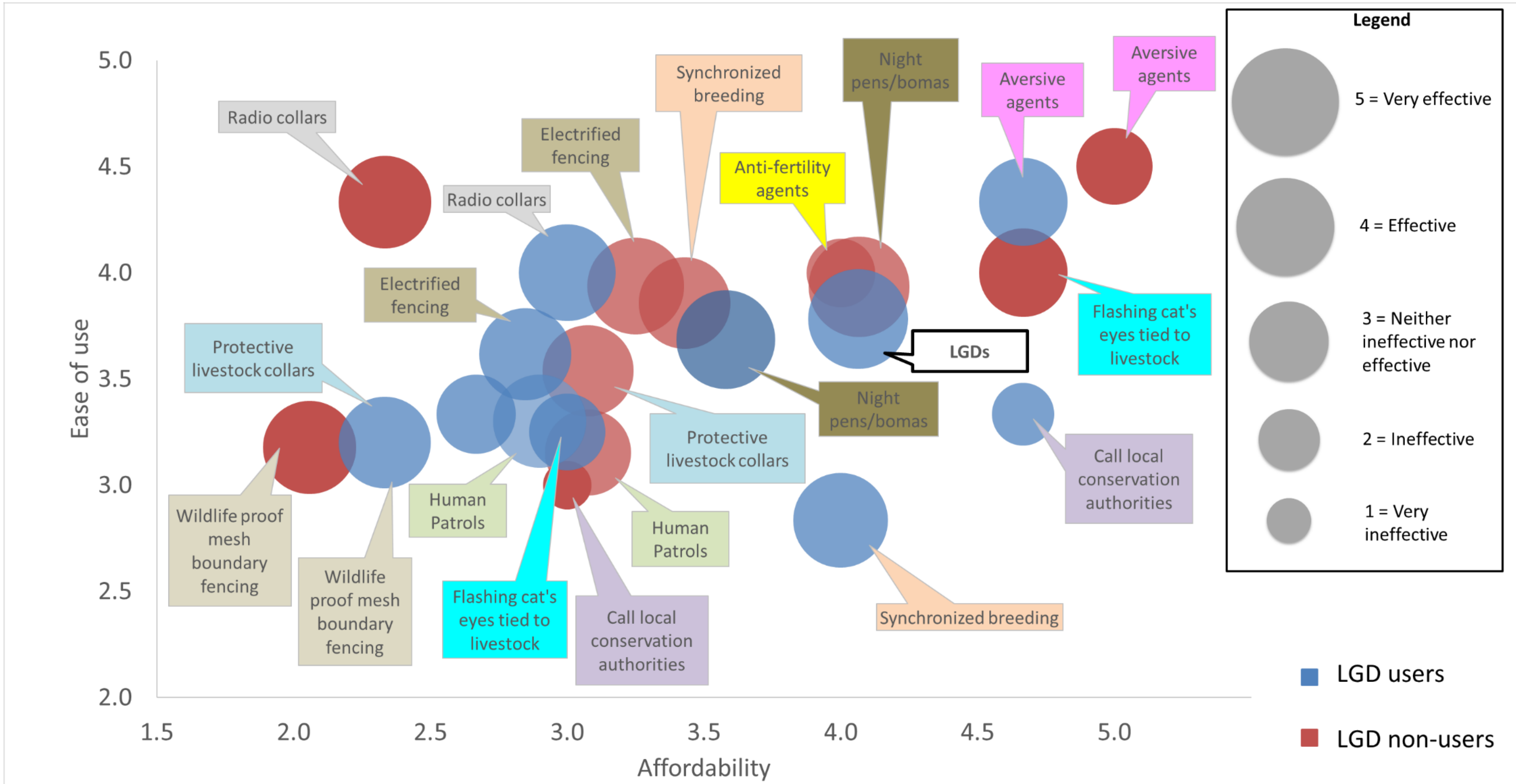

Figure 2.4: Farmer (n = 113) opinions on affordability, ease of use and effectiveness of varied non-lethal mitigation methods. Shaded bubble sizes denote perceived effectiveness of the mitigation method (1 = Very ineffective; 2 = Ineffective; 3 = Neither ineffective nor effective; 4 = Effective; 5 = Very effective)

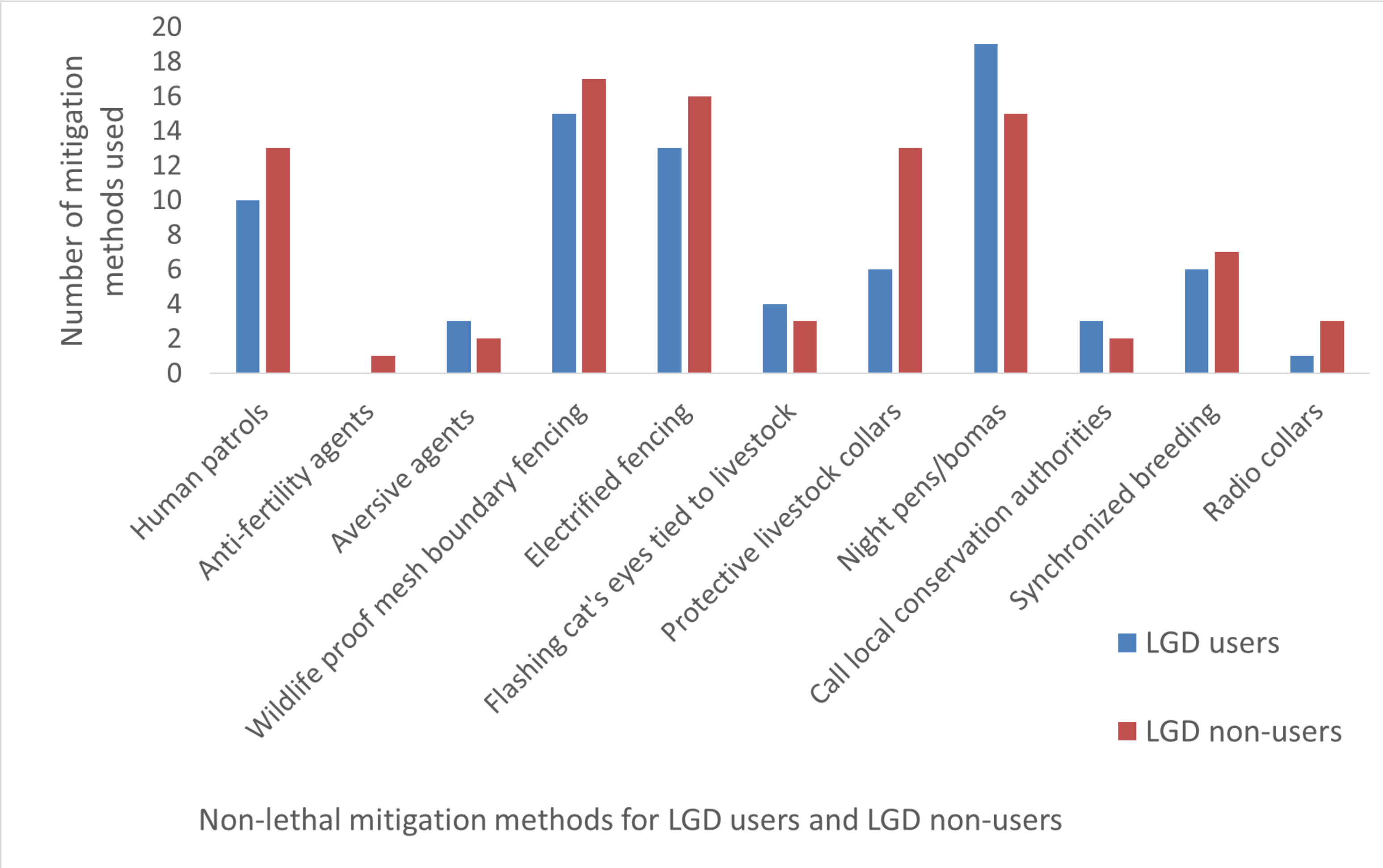

Figure 2.5: Type and number of non-lethal mitigation methods used by both LGD users and LGD non-users

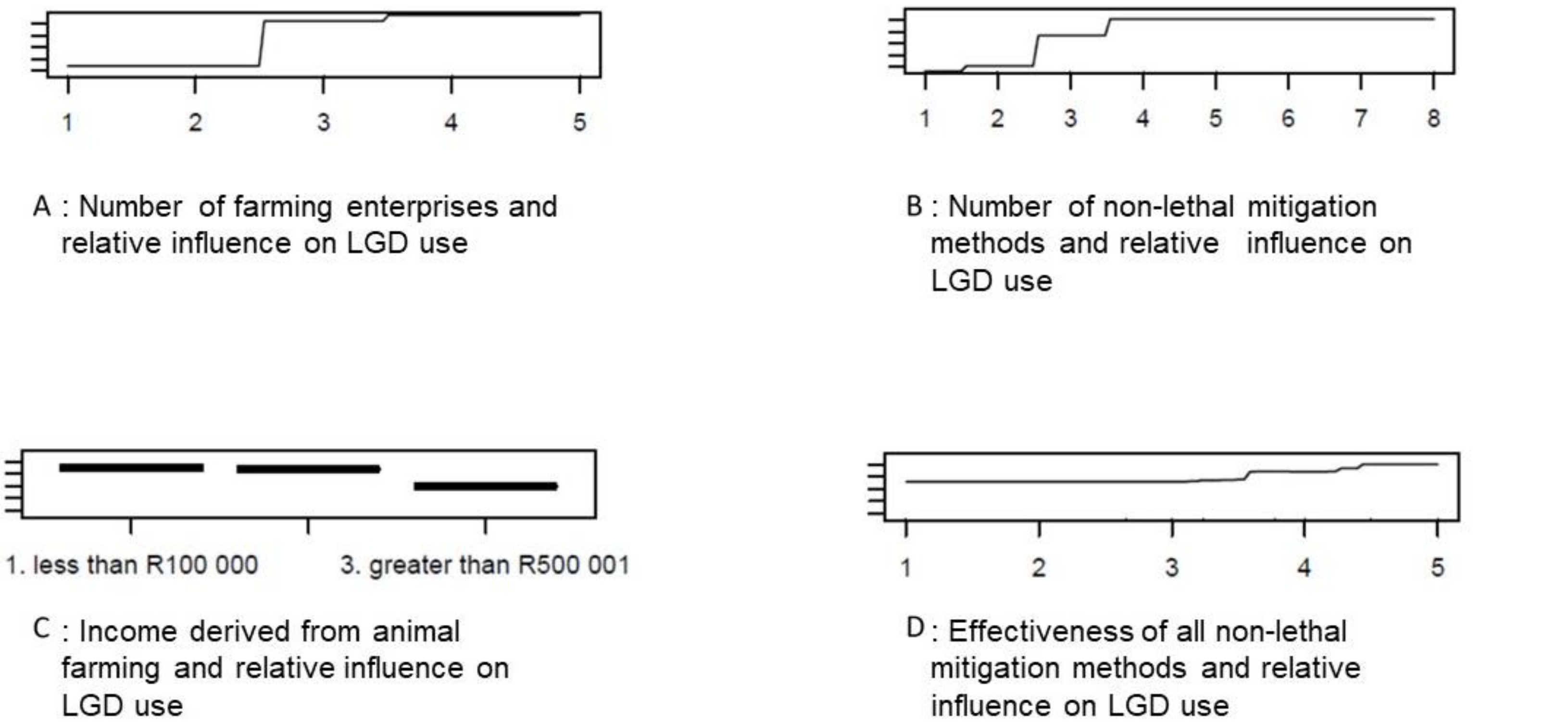

Figure 2.6: The percentage effect of the top four variables on LGD use after accounting for all other variables in the boosted regression tree for "who are the farmers?". A) Number of farming enterprises (livestock species) from 1 – 5, with relative influence of 21.92% on LGD use. B) Number of non-lethal mitigation methods from 1 – 9, with relative influence of 21.15% on LGD use C) Income derived from animal farming, where 1 = < R5000 - R100 000, 2 = R100 001 - R500 000, 3 = > R500 001 and relative influence of 7.32% on LGD use D) Effectiveness of all non-lethal mitigation methods, where 1 = Very ineffective, 2 = Ineffective, 3 = Neither ineffective nor effective, 4 = Effective and 5 = Very effective, and relative influence of 6.68% on LGD use

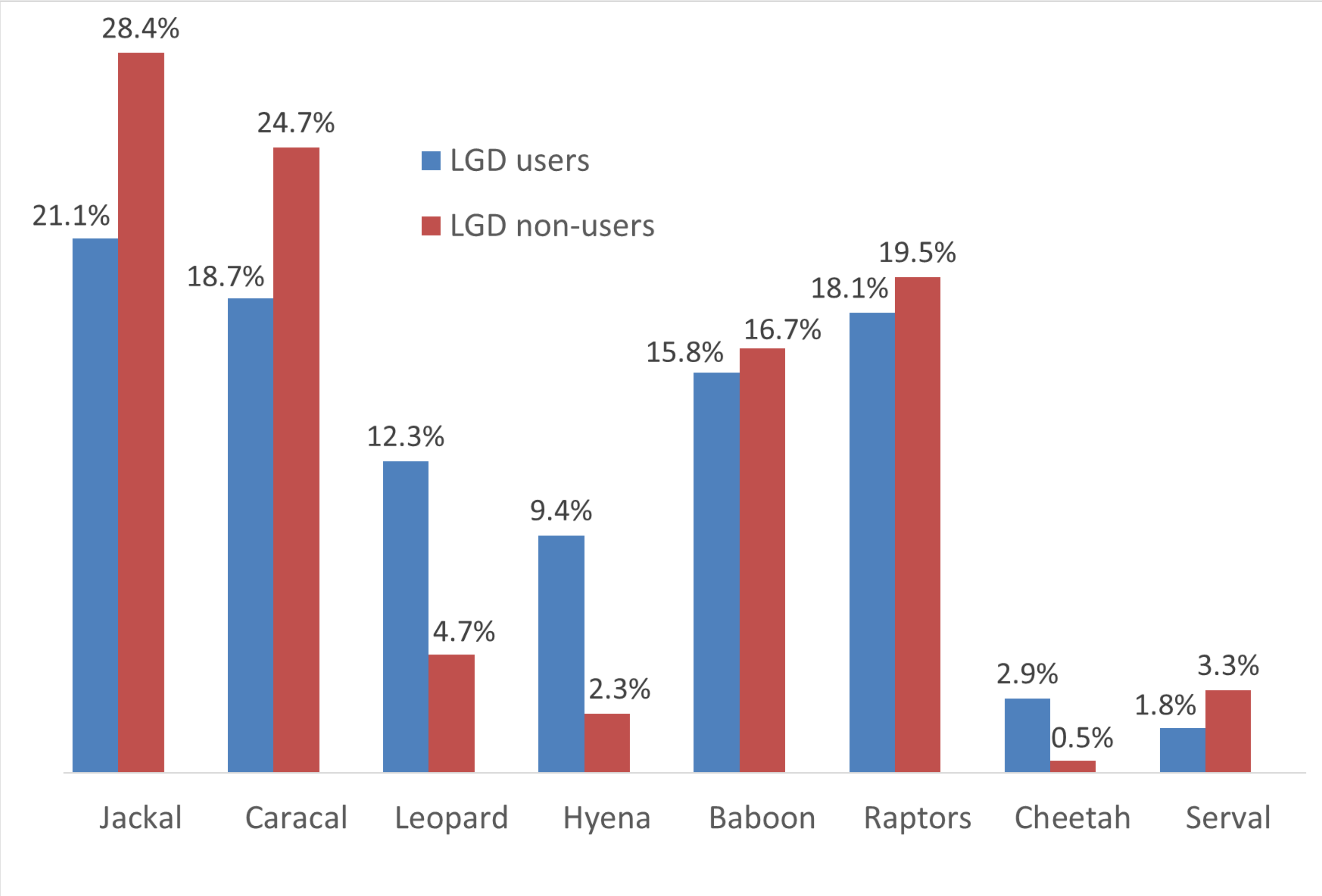

Figure 2.7: Percentage of predator type relative to all predators seen on farms by LGD users and LGD non-users

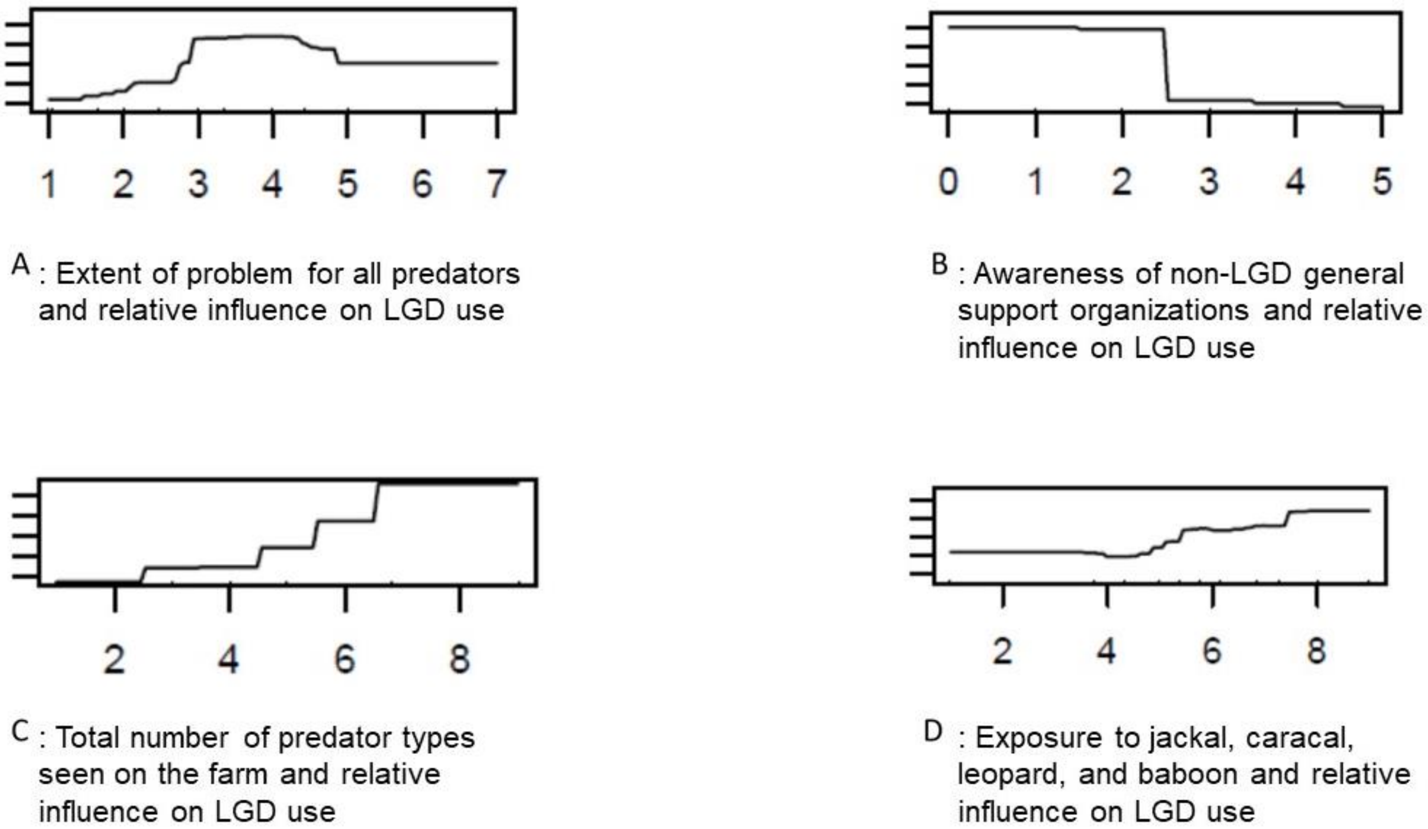

Figure 2.8: The percentage effect of the top four variables on LGD use after accounting for all other variables in the boosted regression tree for “farmer’s environment”. A) Extent of problem for all predators where, 1 = Not a problem at all, 2 = A slight problem, 3 = A slight problem but manageable, 4 = A medium problem that requires some intervention, 5 = A problem that requires major intervention, 6 = A problem that requires external assistance, 7 = A crises, with relative influence of 20.06% on LGD use. B) Awareness of non-LGD general support organizations where, 1 = Local farmers association, 2 = National Wool Growers Association (NWGA), 3 = Agri SA, 4 = Local municipality, 5 = Department of Environmental Affairs and Development Planning (DEADP), with relative influence of 18.81% on LGD use. C) Total number of predator types (species) seen on the farm, with relative influence of 17.06% on LGD use. D) Exposure to jackal, caracal, leopard, and baboon where, 1 = never, 2 = once a year, 3 = once every 3 months-once every 6 months, 4 = once every 2 months-once every 3 months, 5 = once a month-once every 2 months, 6 = 2 times a month-once a month, 7 = 1 times a week-2 times a month, 8 = 2-4 times a week, 9 = 5-7 days a week, with relative influence of 13.60% on LGD use

Figure 2.9: Livestock guardian dog support organization Cheetah Outreach Trust (COT), discussing husbandry practices with an LGD user near Klawer in the Western Cape

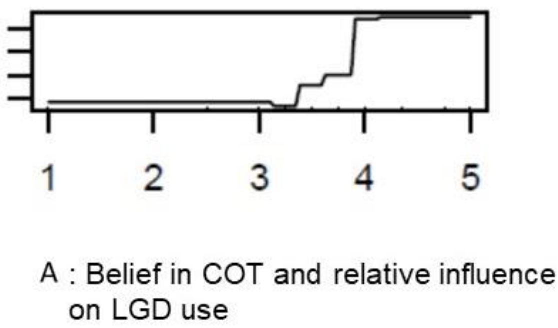

Figure 2.10: A) The percentage effect of the variable, farmer's belief in LGD support organization Cheetah Outreach Trust (COT), on LGD use. Total relative influence for belief in COT after accounting for all other variables in the boosted regression tree for "social constructs", is 39.44% influence on LGD use. The combined average score from 1- 5 is based on , 1 = Very low trust, very poor performance, very poor communication and, very poor knowledge and skills, 2 = Low trust, poor performance, poor communication and, poor knowledge and skills, 3 = Neither low nor high trust, neither poor nor good performance, neither poor nor good communication and, neither poor nor good knowledge and skills, 4 = High trust, good performance, good communication and, good knowledge and skills, 5 = Very high trust, very good performance, very good communication and, very good knowledge and skills

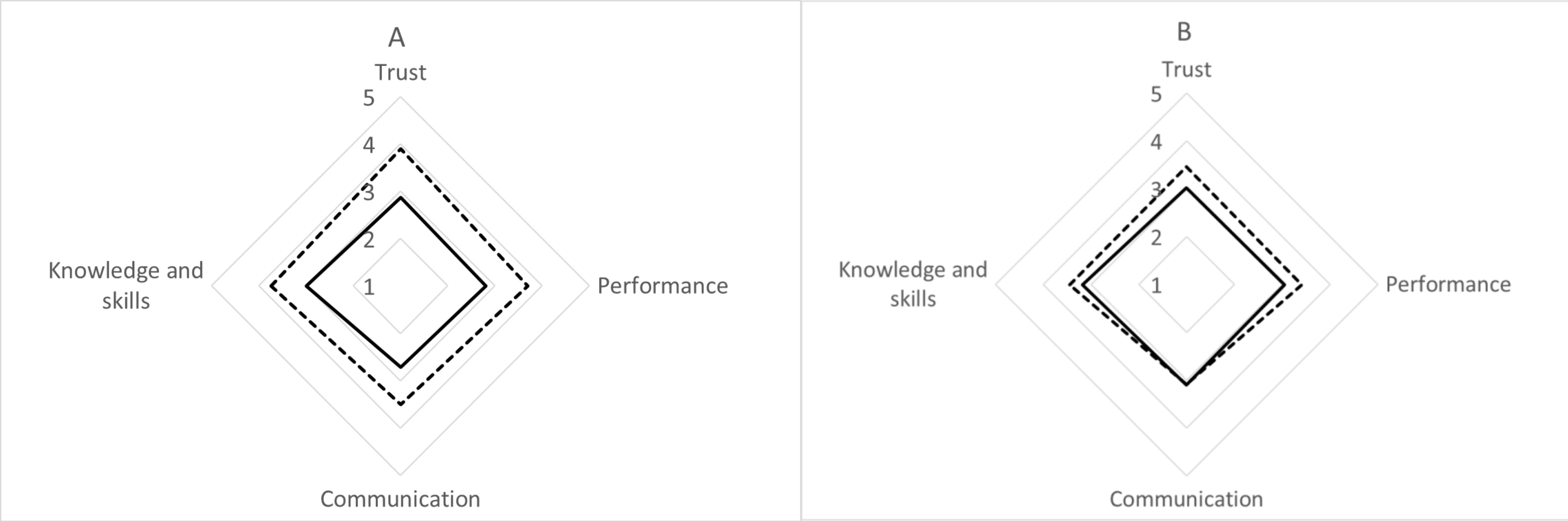

Figure 2.11: Farmer's (n = 113) opinions on trust, performance, communication and, knowledge and skills for support organizations for both A) LGD users and B) LGD non-users. Solid lines represent non-LGD (general support) organizations and dotted line represents LGD support organizations

2.9 List of tables

Table 2.1: General description of the variables from the Wildlife Tolerance Model and the hypotheses that were tested. See Appendix A for specific survey questions and Kansky et al., 2016 for more details of the WTM

	Description	Hypotheses
"Who are the farmers?"		
Years on farm	Number of years lived on the farm.	The number of years lived on a farm influences LGD use.
Age	Age categories being 20's & 30's, 40's & 50's and 60's & 70's.	Age influences LGD use with younger farmers more likely to use coexistence mitigation methods like LGDs.
Farm size	Farm size measured in hectares. The amount of livestock territory needed to protect from depredation, variety of predator species across varied farm types, the economic parameters related to farm type and the need for remote depredation mitigation methods all potentially contribute to farm size and its influence on the use of varied depredation mitigation methods.	Farm size influences LGD use.
Income from animal farming	Yearly income class from animal farming. The economic association relating to the husbandry and care costs associated with LGDs.	Income from animal farming influences LGD use.
Number of farming enterprise type (species) at the start of 2019.	Number of livestock species of varied farming enterprises being mutton sheep, wool sheep, cattle, goats, chickens, geese, and game. LGDs are more commonly associated with small stock protection.	Number of farming enterprise type (species) in relation to number of farming enterprise type (species) lost = tangible cost of depredation which influences LGD use (see tangible cost of predators).
Number of farming enterprises	Diversified farming enterprises being mutton sheep, wool sheep, cattle, goats, chickens, geese, and game.	The number of farming enterprises influences LGD use.

Number of non-lethal mitigation methods	Non-lethal mitigation methods being LGDs, human patrols, anti-fertility agents, aversive agents, wildlife proof mesh boundary fencing, electrified fencing, flashing cat's eyes, protective livestock collars, night pens / bomas, calling the local conservation authorities, synchronized breeding and radio collars.	The number of non-lethal mitigation methods influences LGD use.
Affordability, ease of use and effectiveness of non-lethal mitigation methods	The affordability, ease of use and effectiveness of non-lethal mitigation methods in reducing or preventing livestock depredation.	Individuals who believe non-lethal mitigation methods are affordable, easy to use and effective will more likely use LGDs.
"The farmer's environment"		
Number of predator types	Predator types being jackal, caracal, leopard, baboon, raptors, hyena, cheetah, and serval. LGDs have been used effectively with regards to mesopredators.	The number of predator types influences LGD use.
Extent of predator problem	The extent of the problem of a specific predator type (species being jackal, caracal, leopard, and baboon) or predators ranging from not a problem at all to a crisis.	The extent of problem of a specific predator type (species) influences LGD use.
Exposure to predator type *Adapted from WTM – outer model variables*	Exposure equates to the frequency a specific predator type (species being jackal, caracal, leopard, and baboon) and / or predators collectively are seen on the farm in both summer and winter, ranging from never to 5-7 days a week.	The extent of exposure to a specific predator type (species) influences LGD use.
Intangible costs of predators *Adapted from WTM – inner model variables*	Costs of living with predators on farm.	The higher the intangible cost of living with predators on farms the less likely the farmer will use a LGD and will prefer more lethal mitigation methods.

Tangible costs of predators *Adapted from WTM – inner model variables*	Number and ZAR value of livestock species (mutton sheep, wool sheep, cattle, and goats) lost to depredation in 2019.	The higher the tangible cost of living with predators on farms the less likely the farmer will use a LGD and will prefer more lethal mitigation methods.
"Social constructs"		
Intangible benefit of predators *Adapted from WTM – inner model variables*	Non-monetary benefit of living with predators being aesthetic value, appreciation value, existence value, cultural or symbolic value for farmers, their community, humankind, and nature.	Greater intangible benefit of living with predators positively influences LGD use.
Tangible benefit of predators *Adapted from WTM – inner model variables*	Perceived monetary and actual monetary benefit (ZAR) of living with predators for farmers, their community, humankind, and nature.	Greater tangible benefit of living with predators positively influences LGD use.
Like and / or dislike of predators	Extent of like or dislike for all predators from Dislike very much to like very much.	Greater like for predators positively influences LGD use. Greater dislike for predators negatively influences LGD use as farmers would prefer more lethal mitigation methods.
Number of positive experiences with predators *Adapted from WTM – outer model variables*	Number of positive meaningful experiences had with predators.	Farmers with more positive experiences with predators will more likely use a coexistence type mitigation method like LGDs over lethal mitigation methods.
Tolerance to predators *Adapted from WTM – outer model variables*	Tolerance to predators measured using 3 main parameters: 1) tolerance to killing a predator under different contexts, 2) population size of predators' farmer is willing to accept, 3) tolerance to spatial proximity to predators on both farm and in the area.	Farmers with a greater tolerance towards predators will more likely use a LGD as opposed to more lethal mitigation methods.

Tolerance to depredation *Adapted from WTM – outer model variables*	Tolerance to depredation measured using 2 main parameters: 1) number of specific livestock species farmer is willing to lose in a year, 2) ZAR value per livestock species farmer is willing to lose in one year.	Farmers with a greater degree of willingness to lose livestock will more likely use a LGD as opposed to more lethal mitigation methods.
WVO Utilitarian *Adapted from WTM – inner model variables*	Value priority in relation to wildlife for farmers who believe wildlife are primarily to be used or for the farmer's benefit.	Individuals prioritizing utilitarian WVOs will be less likely to use a LGD and more likely to use a more lethal mitigation method.
WVO Mutualism *Adapted from WTM – inner model variables*	Value priority in relation to wildlife for farmers who believe wildlife are deserving of rights.	Individuals prioritizing mutualistic WVOs will more likely use the perceived non-lethal LGD as a mitigation method.
Empathy to predators *Adapted from WTM – inner model variables*	An ability to feel compassion when imagining a predator species in distress or having problems.	Individuals with greater empathy towards predators will more likely use the perceived non-lethal LGD as a mitigation method over more lethal mitigation methods.
LGD support organizations	Awareness of LGD support organizations being COT and EWT.	Awareness of LGD support organizations influences LGD use.
Cheetah Outreach Trust (COT)	The extent of trust, degree of general performance, degree of communication and degree of knowledge and skills of Cheetah Outreach Trust (COT).	The greater the farmer's perceived extent of trust, degree of general performance, degree of communication and degree of knowledge & skills in COT, the more likely they will use an LGD.
Endangered Wildlife Trust (EWT)	The extent of trust, degree of general performance, degree of communication and degree of knowledge and skills of Endangered Wildlife Trust (EWT).	The greater the farmer's perceived extent of trust, degree of general performance, degree of communication and degree of knowledge & skills in EWT, the more likely they will use an LGD.

Table 2.2: Results summary, showing Mean and SD values for LGD non-users and LGD users. Also showing df, Fisher's exact test (fet), t-values, z score, *P*-values, and relative influence (ri) for "who are the farmers?", "farmer's environment" and "social constructs". Significant *P*-values indicated in **bold**. Fisher's exact test for counts below 5. DROP indicating variables dropped from Boosted Regression Tree (BRT) analysis. Combined BRT score for two variables being Cheetah Outreach Trust (COT) and number of farming enterprises at the start of 2019

	LGD non-users (n = 69)		LGD users (n = 44)							
Questionnaire Items	**Mean**	**SD**	**Mean**	**SD**	**df**	**fet**	**t**	**z**	**P**	**ri**
<u>Who are the farmers?</u>										
Sociodemographic variables										
Years lived on farm	26.28	18.88	19.93	16.60	111		1.826	1.717	0.085	2.61
Age group						0.261	expected count < 5		0.261	2.10
Proportion of income from farming						0.816	expected count < 5		0.816	0.03
Farm size (hectares)	2706.08	4162.55	2862.18	4711.20	111		-0.184	0.465	0.641	3.47
Yearly income class from animal farming						0.012	expected count < 5		**0.012**	7.32
Yearly income class total - both farming and additional						0.100	expected count < 5		0.100	2.50
Number of farming enterprises at the start of 2019	1.66	0.74	2.47	1.33		0.000	expected count < 5		**0.000**	21.92
Number of mutton sheep at the start of 2019	325.58	416.88	252.43	248.11	31		0.607	0.036	0.971	DROP
Number of wool sheep at the start of 2019	1431.10	839.67	1302.23	1871.75	30		0.265	1.671	0.094	DROP
Number of cattle at the start of 2019	1019.21	3673.84	189.82	175.70	68		1.212	0.776	0.438	1.85
Number of goats at the start of 2019	267.45	312.94	289.53	393.76	24		-0.153	0.078	0.937	DROP
Number of livestock species at the start of 2019	7212.10	42764.24	790.77	1285.95	111		0.994	0.792	0.428	2.27
Mitigation method (mm.) variables										
Sum of all mitigation methods used	3.98	2.23	4.91	3.26	83		-1.565	-1.035	0.300	1.02
Sum of lethal mitigation methods used	2.52	1.21	3.05	1.43	60		-1.490	-1.440	0.149	4.34
Sum of non-lethal mitigation methods used	2.13	1.20	3.29	1.85	75		-3.300	-3.078	**0.002**	21.15
Mean score of affordability for lethal mm.	3.82	0.84	3.60	0.79	33.49		0.965	1.371	0.170	5.80
Mean score of affordability for non-lethal mm.	3.25	0.92	3.54	0.79	75		-1.439	-1.359	0.174	4.17
Mean score of ease of use for lethal mm.	3.61	0.93	3.41	1.03	60		0.726	0.337	0.736	5.54
Mean score of ease of use for non-lethal mm.	3.61	1.02	3.66	0.83	75		-0.248	-0.041	0.967	4.36
Mean score of effectiveness for lethal mm.	3.69	0.79	3.50	0.93	60		0.812	0.651	0.515	2.78
Mean score of effectiveness for non-lethal mm.	3.66	0.88	3.89	0.86	75		-1.165	-1.160	0.246	6.68

Farmer's environment									
Predator variables									
Number of predator types (species) seen on farm	3.47	1.53	4.65	2.24	111	-3.329	-2.791	**0.005**	17.06
Extent of jackal problem	3.77	1.98	4.25	2.10	95	-1.126	-1.118	0.263	DROP
Extent of caracal problem	3.17	2.10	3.44	1.81	83	-0.598	-0.809	0.418	DROP
Extent of leopard problem	1.40	0.70	3.19	1.75	29	-3.097	-2.987	**0.002**	DROP
Extent of baboon problem	2.97	1.63	3.78	1.99	61	-1.766	-1.541	0.123	DROP
Extent of jackal, caracal, leopard, baboon problem	3.32	1.70	3.74	1.60	107	-1.277	-1.289	0.197	DROP
Extent of problem for all predators	2.92	1.54	3.23	1.30	111	-1.117	-1.333	0.182	20.06
Frequency of jackal seen	6.90	1.95	7.79	1.56	95	-2.334	-2.488	**0.012**	11.45
Frequency of caracal seen	4.27	2.29	4.81	2.12	83	-1.080	-1.146	0.252	DROP
Frequency of leopard seen	3.55	2.05	3.74	1.85	29	-0.256	-0.555	0.579	DROP
Frequency of baboon seen	5.47	2.70	6.56	2.53	61	-1.618	-1.494	0.135	DROP
Frequency of jackal, caracal, leopard, baboon seen	5.63	1.68	5.94	1.79	107	-0.907	-1.250	0.211	13.60
Frequency of all predators seen on farm in 2019	5.79	1.53	5.77	1.54	111	0.054	-0.406	0.684	DROP
Mean score of cost of living with predators	4.40	1.86	4.97	1.70	111	-1.650	-1.516	0.129	DROP
Number of mutton sheep lost from Jan 2019 - Dec 2019	2.98	10.41	7.50	19.01	111	-1.628	-1.655	0.095	DROP
% Mutton sheep lost from Jan 2019 – Dec 2019	0.01	0.03	0.02	0.06	111	-1.807	-1.497	0.134	DROP
Number of wool sheep lost from Jan 2019 - Dec 2019	16.76	44.30	20.34	60.25	111	-0.362	0.040	0.968	DROP
% Wool sheep lost from Jan 2019 – Dec 2019	0.01	0.05	0.03	0.09	111	-1.111	-0.144	0.885	DROP
Number of cattle lost from Jan 2019 - Dec 2019	1.94	6.33	3	6.66	111	-0.847	-1.565	0.117	DROP
% Cattle lost from Jan 2019 – Dec 2019	0.01	0.07	0.02	0.08	111	-0.744	-1.631	0.103	DROP
Number of goats lost from Jan 2019 - Dec 2019	1.17	4.78	7.56	23.39	111	-2.204	-2.209	**0.027**	DROP
% Goats lost from Jan 2019 – Dec 2019	0.00	0.03	0.03	0.07	111	-2.490	-2.237	**0.025**	DROP
ZAR value of all livestock species lost for the year	48851.23	81997.66	74001.13	106709.17	111	-1.411	-1.393	0.163	9.03
Organization awareness									
Awareness of general support organizations	2.98	1.39	2.13	1.48	111	3.069	2.973	**0.002**	18.81
Awareness of LGD support organizations	0.72	0.76	1.13	0.73	111	-2.833	-2.787	**0.005**	9.96

Social constructs										
Predator opinion variables										
Extent of like or dislike for all predators	2.76	1.26	2.90	1.09	111		-0.609	-0.634	0.525	4.65
Number of positive experiences with predators on farm						1.000	expected count < 5		0.517	0.07
Number of negative experiences with predators on farm						0.254	expected count < 5		0.165	0.34
Mean score of monetary benefit	2.50	1.41	2.62	1.08	111		-0.479	-1.085	0.278	4.42
Total monetary benefit of all items in ZAR	11927.53	43686.49	3636.36	14641.59	111		1.214	1.399	0.161	0.00
Mean score of non-monetary benefit	2.72	1.48	2.94	1.30	111		-0.792	-0.850	0.395	2.06
Mean score for utilitarian values	4.92	1.05	4.63	1.18	111		1.354	1.639	0.101	9.04
Mean score for mutualism values	5.03	0.97	5.12	1.30	111		-0.390	-0.737	0.461	1.63
Mean score for empathy to predators	3.80	1.68	4.05	1.51	111		-0.782	-1.084	0.278	5.65
Tolerance constructs										
Max. no. of mutton sheep willing to lose in 1 year	0.63	3.72	2.90	15.09	111		-1.196	-2.021	**0.043**	0.60
Max. ZAR value mutton sheep willing to lose in 1 year	1188.40	6568.69	750	2125.42	111		0.428	-0.815	0.415	0.00
Max. no. of wool sheep willing to lose in 1 year	2.52	8.81	5.38	15.28	111		-1.263	-1.015	0.310	0.00
Max. ZAR value wool sheep willing to lose in 1 year	2297.10	7554.85	5011.36	16827.61	111		-1.167	-0.355	0.722	0.00
Max. no. of cattle willing to lose in 1 year	0.36	1.01	0.63	2.08	111		-0.935	0.122	0.902	0.00
Max. ZAR value cattle willing to lose in 1 year	2384.20	8748.13	2602.27	9810.16	111		-0.123	0.260	0.794	0.00
Max. no. of goats willing to lose in 1 year	0.34	1.74	1.22	3.36	111		-1.823	-2.376	**0.017**	0.00
Max. ZAR value goats willing to lose in 1 year	1028.98	6287.17	2534.13	9657.13	111		-1.004	-2.353	**0.018**	0.00
Sum of ZAR value willing to lose for ALL species	10507.46	23228.34	13141	26253.41	111		-0.558	-0.641	0.521	1.69
Tolerance to predators visiting farm/land	134.24	159.63	117.61	145.09	111		0.559	0.299	0.765	1.16
Tolerance to predators visiting area/neighbourhood	141.94	161.58	120.25	147.67	111		0.719	0.484	0.628	4.11
Tolerance to killing a predator - 7 proximity scenarios	3.42	2.18	3.38	2.26	111		0.079	0.268	0.788	0.83
Tolerance to predator population for farm, district, Africa	2.56	1.15	2.60	1.18	111		-0.181	-0.180	0.856	1.89

Organization opinions										
Mean - all organizations trust	3.29	0.86	3.41	0.84	93.63		-0.701	-0.540	0.589	1.08
Mean - all organizations performance	3.31	0.72	3.30	0.79	110		0.119	-0.418	0.676	1.14
Mean - all organizations communication	3.26	0.89	3.22	0.85	110		0.271	0.282	0.778	0.94
Mean - all organizations knowledge & skills	3.44	0.76	3.44	0.65	110		-0.056	0.078	0.937	1.91
Mean - trust, perfor., comm., & skills for farmers assoc.	3.81	0.83	3.50	0.96	72		1.421	1.267	0.205	5.77
Mean - trust, perfor., comm., & skills for NWGA	3.99	0.69	3.45	0.95	50		2.297	1.958	**0.050**	2.51
Mean - trust, perfor., comm., & skills for Agri SA	3.66	0.80	3.46	0.85	48.67		1.011	1.112	0.266	3.61
Mean - trust, perfor., comm., & skills for municipality	1.63	0.94	1.90	1.00	46		-0.907	-0.890	0.373	0.37
Mean - trust, perfor., comm., & skills for DEADP	2.34	1.04	1.92	0.79	41		1.262	1.260	0.207	4.91
Mean - trust, perfor., comm., & skills for COT	3.38	0.95	3.80	0.87	33.32		-1.550	-1.701	0.088	39.44
Mean - trust, perfor., comm., & skills for EWT	3.33	0.94	3.62	1.02	49		-1.032	-0.989	0.322	0.05
Combined Boosted Regression Tree (BRT) score										
Mean score for trust, perfor., comm., & skills for COT	3.38	0.95	3.80	0.87	33.32		-1.550	-1.701	0.088	20.82
Number of farming enterprises at the start of 2019?	1.66	0.74	2.47	1.33		0.000	expected count < 5		**0.000**	13.32

2.10 List of appendices

Appendix A: Questionnaire for farmers with depredation events using LGDs (LGD users, n = 44) and farmers with depredation events not using LGDs (LGD non-users, n = 69)

Response variables	Questionnaire items	Response option / scale	collapsed criteria
Response variable	Do you own a livestock guardian dog (LGD) – yes or no?	Yes / No	
Sociodemographic variables for "Who are the farmers?" associated with LGD use (n = 113) Sociodemographic items			
	How many years have you lived on this farm?	Integer	
	What is your age group?	1 = 20's 2 = 30's 3 = 40's 4 = 50's 5 = 60's 6 = >70	1 = 20's + 30's 2 = 40's + 50's 3 = 60's + >70
	What proportion of your income is from farming?	1 = 0%-10% 2 = 10%-20% 3 = 20%-30% 4 = 30%-40% 5 = 40%-50% 6 = 50%-60% 7 = 60%-70% 8 = 70%-80% 9 = 80%-90% 10 = 90%-100% 11 = None	1 = 0%-30% 2 = 31%-70% 3 = 71%-100%

Size in hectares: Please indicate the size of your farm in hectares?	Integer	
What yearly income class is your household from your animal farming?	1 = Less than R5 000 per annum 2 = Between R5 000 – R25 000 per annum 3 = Between R25 000 – R100 000 per annum 4 = Between R100 000 – R250 000 per annum 5 = Between R250 000 – R365 000 per annum 6 = Between R365 000 – R500 000 per annum 7 = Between R500 000 – R750 000 per annum 8 = Between R750 000 - R1 000 000 per annum 9 = Greater than R1 000 000 per annum	1 = < R5000 - R100 000 2 = R100 001 - R500 000 3 = R500 001 - > R1 000 000
What yearly income class is your household in total? Include both farming and additional income for your household.	1 = Less than R5 000 per annum 2 = Between R5 000 – R25 000 per annum 3 = Between R25 000 – R100 000 per annum 4 = Between R100 000 – R250 000 per annum 5 = Between R250 000 – R365 000 per annum 6 = Between R365 000 – R500 000 per annum 7 = Between R500 000 – R750 000 per annum 8 = Between R750 000 - R1 000 000 per annum 9 = Greater than R1 000 000 per annum	1 = < R5000 - R100 000 2 = R100 001 - R500 000 3 = R500 001 - > R1 000 000
Total farming enterprises at the start of 2019?	Integer – sum of	
List the number of animals at the start of 2019?	Mutton sheep Wool sheep Cattle Goats	
Total number enterprise species at the start of 2019?	Integer – sum of	

Mitigation method variables for "Who are the farmers?" associated with LGD use (n = 113)

Mitigation method items		
	Total sum of all mitigation methods used.	Number of mitigation methods used both lethal and non-lethal
	Total sum of lethal mitigation methods used.	Number of mitigation methods used lethal
	Total sum of non-lethal mitigation methods used.	Number of mitigation methods used non-lethal
Mitigation measures affordability	Mean score of affordability for lethal mitigation methods.	5 = Very affordable 4 = Affordable 3 = Medium affordability 2 = Unaffordable 1 = Very unaffordable
	Mean score of affordability for non-lethal mitigation methods.	5 = Very affordable 4 = Affordable 3 = Medium affordability 2 = Unaffordable 1 = Very unaffordable
Mitigation measures ease of use	Mean score of ease of use for lethal mitigation methods.	5 = Very easy to use 4 = Easy to use 3 = Neither easy nor difficult to use 2 = Difficult to use 1 = Very difficult to use
	Mean score of ease of use for non-lethal mitigation methods.	5 = Very easy to use 4 = Easy to use 3 = Neither easy nor difficult to use 2 = Difficult to use 1 = Very difficult to use

Mitigation measures efficacy	Mean score of effectiveness for lethal mitigation methods.	5 = Very effective 4 = Effective 3 = Neither ineffective nor effective 2 = Ineffective 1 = Very ineffective
	Mean score of effectiveness for non-lethal mitigation methods.	5 = Very effective 4 = Effective 3 = Neither ineffective nor effective 2 = Ineffective 1 = Very ineffective

Predator variables for the "Farmer's environment" associated with LGD use (n = 113)

Predators		
	Which of these predators have you ever seen on your farm? If "other" types of predators have been seen on your farm, please indicate by filling in the "other", type of predator you have seen on your farm.	1 = Jackal 2 = Caracal 3 = Leopard 4 = Hyena 5 = Baboon 6 = Raptors (birds of prey) 7 = Cheetah 8 = Serval 9 = Other predator 1 10 = Other predator 2 11 = Other predator 3
	Total number of predator species seen on farm.	Integer - sum of predator species numbers

Predator problems		
Extent problem	Please indicate the extent of the problem predator/s are for your household based on, not a problem at all, to a crisis.	1 = Not a problem at all 2 = A slight problem 3 = A slight problem but manageable 4 = A medium problem that requires some intervention 5 = A problem that requires major intervention 6 = A problem that requires external assistance 7 = A crises
	Extent of problem: Jackal	Average score out of 7 per above
	Extent of problem: Caracal	Average score out of 7 per above
	Extent of problem: Leopard	Average score out of 7 per above
	Extent of problem: Baboon	Average score out of 7 per above
	TOTAL extent of predator problem from 1 - 7 for jackal, caracal, leopard, baboon.	A ratio score where 1 = Not a problem at all and 7 = A crises and this is calculated as an average extent of problem value, out of the number of 4 key predators per above
	TOTAL extent of predator problem from 1 - 7 for all predators being jackal, caracal, leopard, hyena, baboon, raptors, cheetah, and serval.	A ratio score where 1 = Not a problem at all and 7 = A crises and this is calculated as an average extent of problem value, out of the number of all predators selected

Predator exposure		
Exposure	Select the appropriate frequency: How often did you see these predators on your farm, or see or hear signs of these predators, in summer 2019? Select the appropriate frequency: How often did you see these predators on your farm, or see or hear signs of these predators, in winter 2019?	9 = 5-7 days a week 8 = 2-4 times a week 7 = 1 times a week-2 times a month 6 = 2 times a month-once a month 5 = once a month-once every 2 months 4 = once every 2 months-once every 3 months 3 = once every 3 months-once every 6 months 2 = once a year 1 = never
	Frequency summer and winter: Jackal	Average score out of 9 per above
	Frequency summer and winter: Caracal	Average score out of 9 per above
	Frequency summer and winter: Leopard	Average score out of 9 per above
	Frequency summer and winter: Baboon	Average score out of 9 per above
	Total exposure to predators in summer and winter from 1 - 9 for the 4 key predators.	A ratio score where 1 = never and 9 = 5-7 days a week and this is calculated as an average exposure to predators in summer value, out of the number of 4 key predators per above.
	Total exposure to predators in summer from 1 - 9 for all predators being jackal, caracal, leopard, hyena, baboon, raptors, cheetah, and serval.	A ratio score where 1 = never and 9 = 5-7 days a week and this is calculated as an average exposure to predators in summer value, out of the number of all predators selected.

Cost intangible	Living with predators on my farm is difficult because I need to be always vigilant. Living with predators on my farm is difficult because I worry about my safety and the safety of my family and animals. Living with predators on my farm is difficult because it takes up a lot of time to deal with them.	1 = Strongly disagree 2 = Moderately disagree 3 = Slightly disagree 4 = Neither 5 = Slightly agree 6 = Moderately agree 7 = Strongly agree
	Mean score of living with predators from 1 - 7.	Average for all 3 intangible costs where 1 = Strongly disagree and 7 = Strongly agree. The higher the number the higher the cost of living with predators
Cost tangible	Total number of mutton sheep lost from Jan 2019 - Dec 2019.	Integer sum of and ratio
	Percentage of total mutton sheep lost due to predation from Jan 2019 – Dec 2019.	Integer sum of and ratio
	Total number of wool sheep lost from Jan 2019 - Dec 2019.	Integer sum of and ratio
	Percentage of total wool sheep lost due to predation from Jan 2019 – Dec 2019.	Integer sum of and ratio
	Total number of cattle lost from Jan 2019 - Dec 2019.	Integer sum of and ratio
	Percentage of total cattle lost due to predation from Jan 2019 – Dec 2019.	Integer sum of and ratio
	Total number of goats lost from Jan 2019 - Dec 2019.	Integer sum of and ratio
	Percentage of total goats lost due to predation from Jan 2019 – Dec 2019.	Integer sum of and ratio
Cost tangible	Total value of all livestock species in ZAR lost from Jan 2019 - Dec 2019.	Integer sum of all

Organization variables for the "Farmer's environment" associated with LGD use (n = 113)			
Organization awareness			
organizations	Number of organizations.	Integer sum of	
	Awareness of general support organizations.	Integer sum of	
	Awareness of LGD support organizations.	Integer sum of	
Predator opinions for the "Social constructs" associated with LGD use (n = 113)			
Predator opinions			
Like/dislike	Total extent of like or dislike for all predators from 1 - 5.	1 = Dislike very much 2 = Dislike a little 3 = Neither dislike nor like 4 = Like 5 = Like very much	
Positive meaningful experiences	If yes, how many positive experiences have you had with predators on your farm?	Integer	0 = No positive experiences 1 = more than one positive experience
Negative meaningful experiences	If yes, how many negative, traumatic, or scary experiences have you had with predators on your farm?	Integer	0 = No negative experiences 1 = more than one negative experience
Benefit tangible (perception)	Mean score of monetary benefit for yourself, community, mankind, and nature.	Average score for yourself, community, mankind, and nature from 1 - 5. The higher the score the greater the monetary benefit	
Benefit tangible ZAR	Total monetary benefit of all 3 items in ZAR.	Integer – sum of ZAR benefit	

Benefit intangible	Mean score of non-monetary benefit for yourself, community, mankind, and nature.	Average score for yourself, community, mankind, and nature from 1 - 5. The higher the score the greater the non-monetary benefit
Wildlife Value Orientation: utilitarian	We should strive for a world where there is an abundance of wildlife for hunting and fishing. Hunting does not respect the lives of animals. Hunting is cruel and inhumane to the wild animals. People who want to hunt should be provided the opportunity to do so. Wildlife are valuable only if people get to use them in some way. The needs of humans should take priority over wildlife protection. Wildlife are on earth primarily for people to use. Humans should manage wildlife populations so that humans benefit.	1 = Strongly disagree 2 = Moderately disagree 3 = Slightly disagree 4 = Neither 5 = Slightly agree 6 = Moderately agree 7 = Strongly agree
	Mean score for utilitarian values from 1 – 7, where 1 is not very utilitarian and 7 is very utilitarian.	Per above (note reverse coding for "hunting does not respect the lives of animals" and "hunting is cruel and inhumane to wild animals")

Wildlife Value Orientation: mutualism	I feel a strong emotional bond with wild animals. I care about wildlife as much as I do other people. I value the sense of companionship I receive from wild animals. Wildlife are like my family and I want to protect them. Wildlife should have rights similar to the rights of humans. I view all living things as part of one big family. We should strive for a world where humans and wildlife can live side by side without fear.	Same as utilitarian scale per above
	Mean score for mutualism values from 1 – 7, where 1 is not very mutualistic and 7 is very mutualistic.	Per above

Empathy	Below are statements representing different ways that people might think about different wildlife types. We are interested in knowing your views about wildlife. Do you agree or disagree with these statements? When it comes to predators on my farm, I would describe myself as a soft-hearted person. Sometimes I don’t feel very sorry for predators on my farm when they are having problems. When I see predators on my farm being hurt or treated badly, I feel kind of protective towards them. When I am upset about something a predator on my farm has done, I usually try to “put myself in its shoes”. I sometimes try to understand predators on my farm better by imagining how things look from their perspective. When predators on my farm are being problematic, I often try to see things from their perspective as well.	1 = Strongly disagree 2 = Moderately disagree 3 = Slightly disagree 4 = Neutral 5 = Slightly agree 6 = Moderately agree 7 = Strongly agree
	Mean score for empathy from 1 – 7, where 1 is low empathy and 7 is high empathy.	Per above, (note reverse coding for "sometimes I don’t feel very sorry for predators on my farm when they are having problems")

Tolerance constructs for the "Social constructs" associated with LGD use (n = 113)

Tolerance constructs		
Tolerance - willing to lose per farming enterprise	What would be the maximum number of mutton sheep you would be willing to lose due to predators on your farm in one year?	Integer sum of
	What would be the maximum ZAR value of mutton sheep you would be willing to lose due to predators on your farm in one year?	Integer sum of
	What would be the maximum number of wool sheep you would be willing to lose due to predators on your farm in one year?	Integer sum of
	What would be the maximum ZAR value of wool sheep you would be willing to lose due to predators on your farm in one year?	Integer sum of
	What would be the maximum number of cattle you would be willing to lose due to predators on your farm in one year?	Integer sum of
	What would be the maximum ZAR value of cattle sheep you would be willing to lose due to predators on your farm in one year?	Integer sum of

	What would be the maximum number of goats you would be willing to lose due to predators on your farm in one year?	Integer sum of
	What would be the maximum ZAR value of goats you would be willing to lose due to predators on your farm in one year?	Integer sum of
Tolerance - willing to lose I ZAR	Summation of ZAR value willing to lose for all species.	Integer sum of
Tolerance predator exposure	What would be the total maximum number of days in the summer and winter season you would be able to tolerate or cope with predators visiting your farm / land?	Integer – sum of
	What would be the total maximum number of days in the summer and season you would be able to tolerate or cope with predators visiting your area / neighbourhood?	Integer – sum of
Tolerance to predator population	Would you like the population of predator types you get on your farm, to decrease, stay the same or increase on your far, district, Africa?	1 = Decrease a lot 2 = Decrease a little 3 = Stay the same 4 = Increase a little 5 = Increase a lot
	Total predator population size tolerance across farm, district, and Africa.	A ratio score where tolerance to predator populations is calculated as an average sum of tolerance of predator populations on farm, district, and Africa, where 1 = Decrease a lot and 5 = Increase a lot

Tolerance to kill	Many wild animals are known to cause damage to humans and their property. Some are herbivores capable of eating agricultural crops and gardens or raiding urban households. Others are carnivores capable of killing domestic livestock as well as scaring, injuring, or killing humans. Under what conditions do you think it would be justified to kill a wild animal? Please ignore for now if it is illegal or not, who would do the killing, how it would be killed or what would be done with its body.	0 = No 1 = Unsure 2 = Yes
	Questions **Do you think a predator should be killed if...**	
	...it is seen in the bush far away from any village or houses or livestock or agricultural crops.	Per above – index 1
	... it is seen in the vicinity of where livestock are grazing or on the urban fringe where they could enter people's houses.	Per above – index 2
	...it has injured or killed a domestic animal for the first time.	Per above – index 3
	... it causes repeated problems for you and your community but has never harmed a person.	Per above – index 4
	...it has threatened a child or adult human.	Per above – index 5
	...it has injured a child or adult human.	Per above – index 6
	...it has killed a child or adult human.	Per above – index 7

	Index for tolerance to kill - yes.	The first point where "yes" to killing a predator, from scenario 1 - 7 is selected to establish an index of tolerance towards killing a predator in certain scenarios. 8 means "unsure" was noted

Organization opinions for the "Social constructs" associated with LGD use (n = 113)

Organization opinions		
Organization's trust	Total mean score for all organizations trust.	1 = Very low trust 2 = Low trust 3 = Neither low nor high trust 4 = High trust 5 = Very high trust
Organization's performance	Total mean score for all organizations performance.	1 = Very poor performance 2 = Poor performance 3 = Neither poor nor good performance 4 = Good performance 5 = Very good performance
Organization's communication	Total mean score for all organizations communication.	1 = Very poor communication 2 = Poor communication 3 = Neither poor nor good communication 4 = Good communication 5 = Very good communication
Organization's knowledge and skills	Total mean score for all organizations knowledge and skills.	1 = Very poor knowledge & skills 2 = Poor knowledge & skills 3 = Neither poor nor good knowledge & skills 4 = Good knowledge & skills 5 = Very good knowledge & skills

Trust, performance, communication, knowledge, and skills for each organization	Total mean score for trust, performance, communication, knowledge, and skills for local farmers association.	Integer average
	Total mean score for trust, performance, communication, knowledge, and skills for National Wool Growers Association (NWGA).	Integer average
	Total mean score for trust, performance, communication, knowledge, and skills for Agri SA.	Integer average
	Total mean score for trust, performance, communication, knowledge, and skills for local municipality.	Integer average
	Total mean score for trust, performance, communication, knowledge and skills for Department of Environmental Affairs and Development Planning.	Integer average
	Total mean score for trust, performance, communication, knowledge, and skills for Cheetah Outreach Trust (COT).	Integer average
	Total mean score for trust, performance, communication, knowledge, and skills for Endangered Wildlife Trust (EWT).	Integer average

CHAPTER 3: APPLYING THE THEORY OF PLANNED BEHAVIOUR TO LIVESTOCK GUARDIAN DOG USE

Abstract

A variety of methods for reducing livestock depredation – ranging from lethal to non-lethal methods – is available to livestock farmers. With lethal predator control considered unacceptable in many places, livestock guardian dogs (LGDs) are becoming increasingly important as a potential tool. Understanding the intention of a farmer to use, or continue using, an LGD is a crucial step in enhancing LGD use. For this, human-wildlife conflict (HWC) research has mostly focused on attitudes as a key predictor in understanding the relationships between wildlife and humans. The Theory of Planned Behaviour (TPB) proposes that over and above attitude, human behaviour is also governed by social pressures and the perceived ease or difficulty in performing a behaviour. Using the TPB as a framework, I show – based on 113 questionnaires – that perceived behavioural control and subjective norms were more significant indicators of the intent to use, or continue using, an LGD than farmer's attitudes towards LGD use. My findings also show that the perceived extent of trust in an LGD support organization, performance of the LGD support organization, communication between the LGD support organizations and the farmer and degree of knowledge and skills of the LGD support organizations were strong predictors of the intent towards LGD use. I also show that farmer's considerations of the perceived affordability, ease of use and effectiveness of LGDs, were strong predictors of the intent towards LGD use. Mutualistic orientations were also shown to have a strong effect on farmers' attitudes towards LGD use. The TPB model with extra predictor variables that focus on LGD support organizations, farmer's perceptions of LGDs as a mitigation method, and identifying farmers with mutualistic orientations, can be used as a tool in guiding predictability of intent to use or continue using LGDs amongst livestock farming communities. My research shows that understanding farmer's perceptions of LGD use being within their own control with few barriers to action, as well as farmer's attitudes towards LGD use, are critical for LGD support organizations in building strategies towards improving LGD use. My research also shows that subjective norms are critical to understand LGD use and that positive engagement on LGD use with the broader farming community will enhance LGD use.

3.1 Introduction

Predators worldwide are under threat due to land use, habitat fragmentation, climate change and persecution by humans (Treves and Karanth, 2003; Brugière et al., 2015; Belbachir etal., 2015; Lindsey et al., 2018). The killing of predators is largely linked to the competition for resources (Graham et al., 2005; Thorn et al., 2011) and one such example is livestock, which has economic value for a farmer, but is easy prey to a predator (Graham et al., 2005). As the competition for resources intensifies – coupled with the recovery of predators in some areas – the incidents of livestock predator interactions have seen an increase (Inskip and Zimmerman, 2009; Khorozyan and Waltert, 2019). Furthermore, given the large home ranges of many predators, conflict over the predation of livestock inevitably arises (Treves and Karanth, 2003; Graham et al., 2005; Inskip and Zimmerman, 2009).

Where livestock land use is prevalent, enabling human-wildlife coexistence has significant conservation and socio-economic implications (Graham et al., 2005; Inskip and Zimmerman, 2009). One of the major challenges for predator conservation lies in the challenge of resolving lethal elimination of predators due to predator-livestock conflict (Treves and Karanth, 2003; Graham et al. 2005; Inskip and Zimmerman, 2009). A wide variety of strategies have been used to mitigate predation on livestock, ranging from fencing, poisoning, hunting and livestock guardian dogs (LGDs) (Green et al., 1984; Stahl et al., 2001, Ogada et al., 2003, Rigg et al., 2011). The complexity of human behaviour surrounding livestock depredation runs deeper than just the action towards the predator. This in turn can dictate the use of a specific method or mix of methods, from the plethora of mitigation methods available. One of these mitigation methods is the use of LGDs, which has already been established as an effective mitigation method to reduce depredation (Green and Woodruff, 1983; Coppinger et al., 1988; Landry, 1999; Hansen et al., 2002; Gehring et al., 2010; Leijenaar et al., 2015; Kinka and Young, 2018; Whitehouse-Tedd et al., 2019; Marker et al., 2020; Spencer et al., 2020). Although LGD use has seen a resurgence in certain areas (Landry, 1999; Rigg, 2001), it is still not a universally popular method of depredation mitigation and even in areas where LGDs are popular there are many farmers who do not use LGDs (Gehring et al., 2010). Therefore, understanding the behaviour and attitudes that drive LGD use, is a crucial first step in improving the use of LGDs as a coexistence mitigation method.

Many theoretical and social frameworks have been developed to predict human behaviours from attitudes (Fishbein and Ajzen, 1975; Ajzen 1985; Fazio 1986; Ajzen, 1991). However, the relationship between behaviour and attitude may not always be obvious, strong, or linear (Wicker, 1969; McCleery et al., 2006). Researchers attempting to use solely attitudinal models to predict behaviour might not be considering how the attitudes relate to behaviour (McCleery et al., 2006; McCleery, 2009). In this study I developed a framework based on the Theory of Planned Behaviour (TPB) (Ajzen 1985; Manfredo, 2008) to explore the relationships between farmers and their desire to use or continue using LGDs as a mitigation method to reduce livestock depredation. The model proposes that the key determinant of a person's behaviour is their intention to engage in that behaviour (Ajzen, 1991), however the gap between intent and the realised performance of behaviour is an ongoing debate (Hassan et al., 2016). The complexity in integrating social science and conservation requires a relatable model (Fox et al., 2006; Baruch-Mordo, 2009). The TPB model offers an approach that goes beyond the one-dimensional aspect of attitudes driving behaviour (Ajzen, 1991; Manfredo, 2008). The TPB model considers subjective norms and the perceived control over one's own behaviour, not only the consideration of attitudes in predicting behavioural intention (Fishbein and Ajzen, 1975). Attitude is reflected in a person's positive or negative evaluation of the behaviour, subjective norms are indicated by social pressure and the approval of a person's peers, family, or friends in carrying out the behaviour while perceived behavioural control (PBC) reflects the extent of difficulty a person perceives in carrying out the behaviour and whether the action is within their own volitional control (Fishbein and Ajzen, 1975; Ajzen and Madden, 1986; Hrubes et al., 2001). The model proposes that human behaviours are influenced not only by personal attitudes but also by social pressures placed upon the person as well as the perception that the resulting measures are within their own control and easy to implement (Ajzen, 1991). For this study, attitudes are defined as the farmer's attitude towards LGD use. Subjective norms reflect what is considered acceptable or the perceived opinion of LGD use, by the communities of farmers and their immediate family and friends. Perceived behavioural control reflects the extent to which farmer's believe using a LGD is within their own volitional control and whether it is easy or difficult to carry out the action.

The adaptability of this TPB model to incorporate a range of additional variables that go beyond the foundational variables of attitude, subjective norms, and perceived behavioural control, is also dependent on another factor, namely specificity. The model recognizes that attitudes might not necessarily predict behaviours unless measured with corresponding levels of specificity. Thus, attitudes about objects (LGDs) will not necessarily predict behaviours (using LGDs). For the attitudes to be an accurate predictor of the farmers' behaviour to use a LGD, the attitude and behaviour must correspond on four levels of specificity: action, target, context, and time. In this study, attitudes are related to the specific farmer's behaviour of using a specific mitigation measure, being an LGD, (action) on predators (target) on their farm (context) to prevent current livestock depredation for now and into the future (time). This adaptability makes it a useful model to study human-wildlife dimensions (Miller, 2017). The TPB model considers predominantly intentional behaviour, not necessarily unconscious behaviour that is actioned through routine, habit, or due to sociocultural norms (Sheeran et al., 2013). Criticism of the TPB model is predominantly related to the view that psychosocial behaviour is driven by unconscious action (Wegner and Wheatley, 1999). However, we need to consider the importance of consciousness as a causal agent in this study and therefore the use of the TPB model is justified.

I hypothesized that the intention to use LGDs is driven by more than only attitudes towards LGDs, by considering subjective norms and PBC, and that the TPB would improve the predictability of the intention to use LGDs as a mitigation method. With the flexibility of the TPB model, we can go beyond the scope of attitude, subjective norms and PBC by incorporating additional predictor variables (Ajzen, 1991). In this study, modified variables based on the Wildlife Tolerance Model (WTM) (Kansky et al., 2016) are hypothesized to improve the predictability of the TPB model. This framework will provide a more evidence-based approach for understanding the intent in LGD use and, in doing so, improve the successful adoption of LGD programs.

3.2 Methods

The most frequently used data collection method for TPB models is surveys (Zubair and Garforth 2006; Mastrangelo et al., 2014). Surveys are also one of the most widely used methods in social and conservation science that enable the quantification of human behaviour in relation to conservation (White et al., 2005; Newing 2010; Whitehouse-Tedd et al., 2021). Two stakeholder groups were compared in the survey sample, livestock farmers using LGDs, predominantly Anatolian Shepherd dogs (Fig. 3.1)., and those not using LGDs.

3.2.1 Study area

Please see chapter two (Fig. 2.1)

3.2.2 Participant selection and recruitment - see chapter two

Please see chapter two

3.2.3 Survey design and data collection - see chapter two

Please see chapter two. I structured a series of hypotheses based on these variables and constructs relating to LGD use (Table 3.1).

3.2.4 The Wildlife Tolerance Model

The Wildlife Tolerance Model (WTM) – a novel theoretical framework to identify key drivers of tolerance to living with damage-causing wildlife (Kansky et al., 2016) – was used as a framework for the survey design. I applied elements of inductive categorization (Mayring, 2000). The WTM proposes an outer model and an inner model. The outer model determines perceptions of costs relative to benefits of living with a species, based on the extent to which a person experiences a species. This then also determines tolerance. Further perceptions of costs and benefits are predicted by the inner model's eleven variables. I adapted the six outer model variables and 11 inner model variables to suit the parameters relating to human-wildlife coexistence in the context of LGD use and to then mobilize the TPB model (Appendix B).

3.2.5 The Theory of Planned Behaviour variables

The TPB components were measured according to Ajzen and Fishbein (1980) and Ajzen (1985). These psychological constructs made up the TPB framework regarding LGD use (Fig. 3.2)

Four attitudinal items relating to LGD use were used (Appendix B): using a LGD is/would be a good thing; using a LGD is/would be useless (negatively coded); using a LGD is/would be positive; using a LGD is/would be beneficial. Farmers attitudes towards using a LGD were assessed by asking the farmers to indicate the level of agreement to these items by using a five-point evaluative semantic differential scale. The coding for each item was from 1 (strongly disagree) to 5 (strongly agree). One question around LGD use was phrased negatively to balance any associated bias with regards to question direction.

Subjective norms comprised five items in the survey (Appendix B). These were always coded from 1 to 5 in order of increasing positivity towards LGD use. The five items were: most people important to me think using a LGD to prevent livestock predation by predators is admirable (1 = strongly disagree to 5 = strongly agree); among other farmers, how much agreement would there be that it is a good thing to use a LGD to prevent livestock predation by predators (1 = none to 5 = total); in your family, how much agreement would there be that it is a good thing to use a LGD to prevent livestock predation by predators (1 = none to 5 = total); how many of the farmers in your area do you think use a LGD to prevent livestock predation by predators (1 = none to 5 = all); think of the circle of friends you see frequently, what proportion of them use a LGD to prevent livestock predation by predators (1 = none to 5 = all).

Three statements were used to assess perceived behavioural control (PBC) in relation to LGD use and these were applied in a context relevant to both current LGD users and non-users (Appendix B). These three statements were: Using a LGD is/would be (options on a difficulty scale from 1 = very difficult to 5 = very easy); whether the farmer uses or continues to use a LGD is up to them (1 = completely false to 5 = completely true); the number of factors outside the farmers control which would prevent them from using a LGD to prevent livestock predation by predators are (options on a scale from 1 = very many to 5 = none).

One statement was used to assess behavioural intention to use or continue using a LGD as the response variable (Appendix B): I intend to get a LGD in the near future to prevent livestock predation by predators / I intend to continue to use a LGD to prevent livestock predation by predators in the next year. This was scored from 1 (very unlikely) to 5 (very likely).

The WTM variables were the number of positive experiences farmers have with predators, the intangible benefit of living with predators, the tolerance of predators, the tolerance to depredation, Wildlife Value Orientations (WVOs) (both utilitarian and mutualism orientations), empathy to predators and belief in animal mind (Appendix B). We also considered the trust, performance, communication, knowledge, and skills of LGD support organizations, Cheetah Outreach Trust (COT) and Endangered Wildlife Trust (EWT) as extra predictor variables as well as considering the perceived affordability, ease of use and effectiveness of LGDs as a mitigation method (Appendix B).

3.3 Analyses

To determine the relationship between model variables I used Partial Least Square Structural Equation Modelling (PLS-SEM). The PLS model is favoured here over the Covariance Structural Equation Model (CB-SEM) considering this is exploratory research where-as the CB is more popularly used to reject or confirm a hypothesis of an existing concept or theory. The PLS offered better statistical potential for what might be a smaller sample size of 113 stakeholders. Partial least squares SEM (PLS-SEM) is a powerful statistical technique to explore relationships among a set of model variables and identify the key pathways that exist among these variables (Hair et al., 2014). The PLS-SEM is defined by two models: the structural model and the measurement model. In this modelling the inner model is known as the structural model and the outer model the measurement model. The inner model defines the relationships between the independent and dependent latent variables. The outer model defines the relationships between the latent variables and their indicator items. These should not be confused with the inner and outer models of the WTM. To avoid any confusion between the TPB and the WTM I only used inner and outer models' terminology in relation to the WTM and used structural and measurement models terminology in reference to the PLS-SEM model.

The TPB model built upon the earlier model of Theory of Reasoned Action by adding the PBC construct to the model (Fishbein and Ajzen, 1975). Using the TPB framework in a PLS-SEM analyses I considered foundational TPB constructs (being subjective norms and PBC) that went beyond attitude alone and its association with LGD use. The flexibility of the TPB model meant further additional predictor variables could be incorporated (Ajzen, 1991). Modifying variables based on the WTM in the PLS-SEM analyses, means I could consider predictor variables outside of the foundational TPB constructs of attitude, subjective norms and PBC, and their related association on LGD use.

To examine the predictive power of the model, the coefficient of determination (R^2) was used (Hair et al., 2012; Wong, 2013; Hair et al., 2014). A higher R^2 value is indicative of well qualified latent variables that explain more variance via the structural path model relationships. Higher R^2 values also indicate that the values of the construct can be well predicted via the PLS path model. I used SmartPLS software (Ringle et al., 2014) to build the path models. I considered that the path coefficient should be larger than 0.20 as an indicator of its significance (Chin, 1998), but also noted that the significance did not always illustrate the operational performance fully and considered further significance testing using bootstrapping. The two types of measurement scales in SEM are formative and reflective scales. The indicators or items that form the latent variables in this case were highly correlated and interchangeable and were therefore reflective scales in this study. For this reason, I examined the reliability and validity of the scales. The outer loadings above 0.7 indicated the construct would explain close to or more than 50% of the indicator’s variance, thereby providing acceptable item reliability (Hair et al., 2019). Extremely low loadings, well below the 0.7 threshold were dropped from further analysis (Appendix C). Construct and variable reliability and validity was determined using Cronbach’s alpha reliability coefficients as well as composite reliability (Bagozzi and Yi, 1988). Indicator and internal consistency reliability were established when composite reliability was 0.7 or higher (Bagozzi and Yi, 1988; Hair et al., 2019) (Appendix C). I evaluated Average Variance Extracted (AVE) to check the convergent validity with a threshold of, or at least close to 0.5 (Hair et al., 2019) (Appendix C). Discriminant validity for latent variables was established using the heterotrait-monotrait ratio of correlations, where the “square root” of average variance extracted (AVE) of each latent variable should be greater than the correlations among the latent variables (Henseler et al., 2015). I also considered Fornell and Larcker’s (1981) criterion for establishing discriminant validity. This was established by comparing the “square root” of AVE of each latent variable which showed to be greater than the correlations among the latent variables tested.

I used Kendall's rank tests to examine the correlation between predictor variables. General linear models (GLM) were used to broadly examine differences between LGD users and LGD non-users. I grouped these variables as per chapter two into variables relating to farm and farmer characteristics, the farmer's environment (being predominantly predator variables) and finally all the social constructs and variables. To test the continuous variables between LGD users and LGD non-users a Mann-Whitney U Test was conducted. The structural model was assessed using a collinearity test (Hair et al., 2012; Wong, 2013; Hair et al., 2014). Kendall's rank, the GLM, Mann-Whitney U tests and collinearity tests were all conducted in SPSS (IBM SPSS Statistics version 27). Using bootstrap confidence intervals, the relative statistical importance of the path coefficients is reported (Hair et al., 2014). I used 500 complete bootstrapping samples to generate *T* statistics for both the structural and measurement model. With no missing values, there was no need for missing value replacement and therefore no risk of random data generation.

3.4 Results

In total, 273 farmers were surveyed of which 113 participants – 44 LGD users and 69 non-users – completed the entire survey (a 41% completion rate).

Model assessment - Partial Least Squares Structural Equation Model

Variables that failed the suggested threshold for construct reliability (CR) and AVE were dropped to improve the predictability of the model (Appendix C). I excluded belief in animal mind and tolerance to depredation from the final model due to the reliability criteria not being acceptable (Appendix C). Cronbach's alpha values showed good internal consistency reliability (Appendix C). Convergent validity was confirmed by the AVE value for each of the attitude, subjective norm and PBC constructs. To establish discriminant validity, I considered three tests. Heterotrait – Monotrait Ratio (HTMT) values were < 0.85, and I concluded that discriminant validity was established (Table 3.2). Using the Fornell and Larcker model, I noted that these values were larger than other correlation values among the latent variables indicating that discriminant validity was established (Table 3.3). The relative statistical importance of the path coefficients was reported (Table 3.4).

Variation in behavioural intent towards LGD use

Path model diagrams were used to visually display the relationships between the variables. The coefficient of determination, R^2, was almost forty nine percent for the endogenous latent variable of the behavioural intent to use or continue using an LGD (Fig. 3.3). The three latent variables of attitude towards LGD use, subjective norms relating to LGD use and perceived behavioural control (PBC) relating to LGD use explained 48.8% of the variance in behavioural intention to use or continue using an LGD (Fig. 3.3). The bootstrapping P values for the pathways of attitude – behavioural intent, subjective norms – behavioural intent, PBC – behavioural intent, Cheetah Outreach Trust (COT) – attitude, COT – PBC, COT – LGDs, LGD-MM – attitude and LGD-MM - PBC were all significant ($P < 0.05$; Table 3.5).

Importance of TPB constructs associated with LGD use

The structural model suggested that perceived behavioural control had the strongest associated effect on behavioural intent to use or continue using an LGD ($\beta = 0.362$; $P < 0.01$). That is the farmer's intention to use or continuing to use an LGD was most significantly influenced by their perceptions of using an LGD being within their own volitional control and that there are few barriers preventing farmers using LGD's (Fig. 3.3; Table 3.5). Subjective norms, being opinions on what is acceptable by the communities of farmers and their immediate family and friends, and their perceived opinion on the use of LGDs, accounted for the second highest associated effect on behavioural intent to use or continue using a LGD ($\beta = 0.275$; $P < 0.01$) (Fig. 3.3; Table 3.5). Of the three TPB constructs, attitude towards LGD use, although significant, had the lowest associated effect on behavioural intent to use or continue using an LGD ($\beta = 0.191$; $P = 0.04$) (Fig. 3.3; Table 3.5).

Importance of WTM on attitudes towards LGD use

In considering the WTM adapted constructs and variables for the outer model, 27% of variation in attitude was explained by the number of positive experiences farmers had with predators ($\beta = 0.054$; $P = 0.557$), the intangible benefit of predators ($\beta = 0.161$; $P = 0.132$), tolerance to predators ($\beta = 0.029$; $P = 0.823$), utilitarian WVOs ($\beta = 0.055$; $P = 0.619$), mutualistic WVOs ($\beta = 0.220$; $P = 0.06$) and empathy to predators ($\beta = 0.064$; $P = 0.630$) (Fig. 3.3; Table 3.5). Of all the WTM constructs and variables, the WVO of mutualism had the greatest associated effect on attitudes towards LGD use, although this was not statistically significant ($\beta = 0.220$; $P = 0.06$). Intangible benefits of predators, being the non-monetary benefit or predators in aesthetic value, appreciation value, existence value, cultural or symbolic value, had the second highest associated effect on attitudes towards LGD use, although this was not statistically significant ($\beta = 0.161$; $P = 0.132$).

Beyond WTM - extra predictors and their associated effects

The greatest variation in attitude towards LGD use was associated with farmer's perceptions of the trust, degree of general performance, degree of communication, and level of knowledge and skills in COT ($\beta = 0.239$; $P = 0.02$) (Fig. 3.3; Table 3.5). Farmers' perceptions of the affordability, ease of use and effectiveness of LGDs showed a significant effect on the variation in attitude towards LGD use (β = 0.216; $P < 0.01$) (Fig. 3.3; Table 3.5). The WVO of mutualism showed a strong effect on the variation in attitude towards LGD use (β = 0.220; $P = 0.06$) (Fig. 3.3; Table 3.5). The LGD support organization EWT showed a low effect on attitudes (β = -0.066; $P = 0.491$) (Fig. 3.3; Table 3.5).

Twenty two percent of variation in PBC was explained by perceptions of affordability, ease of use and effectiveness of LGDs, and perceptions of trust, degree of general performance, degree of communication and level of knowledge and skills in EWT and COT (Fig. 3.3). I noted that COT had the most significant effect on PBC (β = 0.368; $P < 0.01$), with affordability, ease of use and effectiveness of LGDs also showing a significant effect on PBC (β=0.175; P=0.04) (Fig. 3.3; Table 3.5).

Thirteen percent of variation in the affordability, ease of use and effectiveness of LGDs was explained by farmers' perceptions on the trust, degree of general performance, degree of communication, and level of knowledge and skills in LGD support organizations. The LGD support organization COT showed a significant effect on variation in the affordability, ease of use and effectiveness of LGDs (β = 0.344; $P < 0.01$) (Fig. 3.3; Table 3.5). The LGD support organization EWT had a lower effect on variation in the affordability, ease of use and effectiveness of LGDs (β = 0.057; $P = 0.571$) (Fig. 3.3; Table 3.5).

3.5 Discussion

Here I show that although attitude is an important determinant of the intent to use a LGD, subjective norms and perceived behavioural control are more important in the intent to use or continue using an LGD. The measurement of stakeholder's attitudes towards wildlife is considered an important factor in understanding the behavioural response to wildlife (Delibes-Mateos, 2014). The relationship between attitudes and behaviour is always interactive (Nilsson et al., 2020; Whitehouse-Tedd et al., 2021) and when studied alone might provide minimal insight into why stakeholders perform certain behaviours (Fishbein and Manfredo, 1992). I also show that to understand the drivers of behavioural intent better, it is important to not just include attitude but also how subjective norms and perceived behavioural control are associated with LGD use (McCleery et al., 2006; McCleery, 2009; Whitehouse-Tedd et al., 2021). I show that farmers who have positive attitudes towards using LGDs, think there is normative support for using LGDs and perceive LGD use to be easy, will have stronger intentions to use LGDs.

Conservation scientists and practitioners often pay insufficient attention to the complexities of human behaviour, and this might be a leading cause of conservation actions being less effective (Schultz, 2011; Selinske et al., 2018). Many social psychological models in other behavioural domains have been used to explain the variance in influencing conservation behaviour (St John et al., 2010). Here I have used the TPB as it offers a simple structure for understanding the complexity of human behaviour (Manfredo, 2008) and for this reason it is a useful model to understand farmer's intent to use LGD's. Previous literature, considering conservation challenges and utilizing the TPB model, focuses on the three cognitive structures of attitude, subjective norms and PBC (Hrubes et al., 2001; Daigle et al., 2002). My study showed that these three structures had a significant association on the behavioural intent to use or continue using an LGD, with PBC having the greatest associated effect on LGD use followed by subjective norms and attitude. The effect of these three cognitive structures on the behavioural intent varies among different behaviours and human populations (Brown et al., 2010). The WTM is an adaptable framework that can be universally applied, and this study highlighted the importance of using elements of the WTM within the TPB framework. My study showed that a series of WTM constructs influenced attitude towards LGD use, where the WVO of mutualism had a high effect on the attitude towards LGD use and the intangible benefit of predators had a medium effect, on attitude towards LGD use. The TPB model also showed that extra predictor variables like the perceived trust, degree of general performance, degree of communication and level of knowledge and skills of LGD support organizations as well as the perceived affordability, ease of use and effectiveness of LGDs, are valuable predictors of LGD use. Previous studies have shown that farmers' behaviour can be significantly affected by the influence of trusted advisors (Elliot et al., 2011; Bruijnis et al., 2013; Jones et al., 2015). Farmers' opinions on the extent of trust, degree of general performance, degree of communication and level of knowledge and skills of COT had the most significant association with perceived behavioural control but also a significant association with farmer's attitudes towards LGD use. The farmer's perceptions of affordability, effectiveness, and ease of use of LGDs was also significantly associated with the placement organization COT and was a strong predictor of the farmer's attitude towards LGD use. This is the first time that these variables are associated with LGD use. Consequently, this has important implications for the implementation of LGDs relating to human-wildlife coexistence.

Farmer's perceived behavioural control in relation to LGD use

The perceived level of autonomy in decision making and the perceived ease of implementation are well studied elements in farmer's decision-making processes. This pertains to many aspects of studies on farmer behaviour, from disease prevention to lamb mortality prevention and general decision making (Ellis-Iversen et al., 2010; Elliot et al., 2011; Singh et al., 2016). In this study, LGD support organizations (COT in this case) showed the most significant association with PBC and the LGD support organization variables of farmer's perceptions of trust in the organization, the general performance of the organization as well as degree of communication and perception of level of the organization's knowledge and skills. Farmers' perceptions of affordability, ease of use and effectiveness of LGDs had less associative effect on their belief that using a LGD was within their own volitional control than did COT, but it was still noted as a significant association on farmer's PBC. This not only highlights the importance of PBC in understanding farmer behaviour but also highlights the importance of LGD support organizations, like COT, in this method of conservation intervention and the significant influence they have in terms of affecting farmer's behavioural intent.

Research considering trust in terms of predator related interactions, has considered that higher trust may reduce perceptions of risk and increase tolerance for predators (Bruskotter and Wilson, 2013). We should consider the influence of trust in conservation management enterprises and that this might have an indirect effect on the tolerance for predators by improving stakeholder perceptions that carrying out the desired action will be within their own control, and easy enough to action. The use of LGDs is one such action, but consideration also needs to be given to the fact that in some cases the use of LGDs would be inappropriate and where LGD support organizations aim to promote the use of LGDs, the farmer's best interests need to be considered. The use of LGDs can negatively affect non-target wildlife (Urbigkit and Urbigkit 2010, Potgieter et al. 2016, Whitehouse-Tedd et al. 2020) and consideration needs to be given to the overall ecological impacts and both physiological and behavioural impacts of LGDs. Knowing how farmer's place trust in support organizations can help the LGD support organization gauge the degree of risk in considering their management strategies and what is in the best interest for the farmer (Slagle and Bruskotter, 2019).

If PBC, via the pathway of LGD support organizations, shows the greatest associated effect on LGD use, then this would be a valuable application for LGD support organizations to consider and the TPB is a useful pathway model to understand this. My research showed that I cannot generalize across all LGD support organizations and that COT's support strategies showed a greater degree of association with regards to influencing farmer's behaviour in relation to LGD use than did EWT. LGD support and placement organizations should consider promoting the fact that using a LGD is up to the farmers discretion and highlight the support the LGD organization offers farmers, thereby reducing the perception of barriers or difficulties in using an LGD and increasing positive perceptions relating to LGD use.

Subjective norms and their associated effect on LGD use

Various studies have found that the opinions of family, peers and friends are highly influential with regards to farmer decision-making behaviour (Martínez-García et al, 2013; Kauppinen et al., 2013; Mills et al., 2017). Subjective norms influence on the effectiveness of intervention programs is notable where human-wildlife coexistence is concerned (Sakurai et al., 2015). The consideration of this normative support for using LGDs had a significant association with the intent to use or continue using an LGD. One study found social pressure to be the most important determinant of behaviour, more so than attitude of the individual farmer (Bell et al., 2016). It has been previously proposed that understanding the effect a potential subjective norm has on attitudes, and possibly perceptions, could help predict effectiveness and reception of policy implementation (Ketting, 2020). Similarly, my study showed that after PBC, subjective norms showed the greatest associated effect on LGD use. Focusing on the behaviour of the target individual is crucial but the importance of considering the influence of family, friends, peers, and advisors is also critical to LGD adoption and intervention success. Conservation organizations looking to understand and promote LGD use should consider engagement that goes beyond the targeted farm and farmer owner or manager. Opportunities for the promotion of LGD programs should consider engaging with the greater farming community in each area as opposed to only the farmers. This broader engagement, that goes beyond the farmers and focuses on the value of LGD use, will likely improve community opinion on LGD use and will in turn improve overall intervention success.

Farmer's attitudes towards LGD use

The hypothesized relationship between attitude and the behavioural intent to use or continue using an LGD was not the only factor in considering LGD use and showed less significant association with LGD use than did either PBC or subjective norms. Although attitude was not the most important construct in understanding LGD use, understanding factors associated with attitude is nonetheless important in elucidating the psychology of LGD use. Attitude was most strongly associated with the constructs of belief in COT, mutualistic WVOs and perceptions of affordability, ease of use and effectiveness in LGDs. We can infer that the success in terms of adoption of LGD programs will be reliant on understanding the associations that influence farmer's attitudes towards LGD use. Farmer's perceptions of LGD support organizations, their mutualistic WVOs and farmer's perceptions of LGD affordability, ease of use and effectiveness were novel predictors influencing farmer's attitudes to LGD use and warrant further investigation.

Mutualistic individuals are characterized by a belief that humans and wildlife are meant to co-exist and / or live-in harmony (Teel and Manfredo, 2009; Teel et al., 2010). This study showed that one also needs to consider that farmers with strong mutualistic tendencies will have more positive attitudes towards LGDs and in turn their intent to use or continue using LGDs would be higher. This study also showed a moderately associative effect of the intangible benefits of predators on attitudes towards LGD use. Farmers who perceived greater intangible benefits of living with predators in terms of aesthetic value, appreciation value, existence value, cultural or symbolic value for themselves, their community, humankind, and nature, had more positive attitudes towards LGD use which is positively associated with the intent to use or continue using an LGD. The WTM has been a useful diagnostics tool used to inform conservation management (Kansky et al., 2016; Marino et al., 2020; Saif et al., 2020; Kansky et al., 2021) and my research shows that WTM determinants of attitude towards LGD use improved the predictability of the TPB model in terms of understanding farmer's intent in using or continuing to use LGDs. If mutualistic individuals are characterized by a believe that they should coexist with wildlife (Teel and Manfredo, 2009; Teel et al., 2010), then future research into LGD use should consider whether these mutualistic attributes were present prior to the farmer getting an LGD, or if these are transient attributes that could have arisen following receipt of an LGD. The identification of individuals within the community showing mutualistic orientations towards wildlife as well as greater degree of tolerance, empathy, and a higher number of positive experiences with predators would be a useful tool in positively influencing LGD use within a farming community.

Behaviour-science suggests that people may be influenced by the actions and perceived beliefs of others (Simpson and Willer, 2015) and that individuals show greater propensity to teamwork in the achievement of a common goal when social norms support a behaviour (Niemiec et al., 2016). The discussion of environmental issues can be encouraged via the pathway of affecting perceptions of others' beliefs (Geiger et al., 2017) and in a conservation context, interactions amongst peers can create social norms within a community around a conservation behaviour (McKiernan, 2017). The recruitment of conservation community role models is not new but considering the findings that subjective norms have a significant association with LGD use and that mutualism has a strong association with attitudes towards LGD use, means that the recruitment of mutualistic individuals within the broader farming community might well improve adoption of LGD programs from farmers less likely to show tolerant and empathetic tendencies towards predators.

We need to acknowledge, in the ongoing debate regarding the relationship between cognition and behaviour (Gold and Goodey, 1984), that in some cases the attitudes and determinants of behaviour do not always express the actual action of the behaviour. For example, some farmer's might express the desire to use less lethal mitigation methods of control in the interest of coexisting with predators, but their actions may not reflect this. Similarly, although the intent to use an LGD might be evident, the action of using one may not be realised. Over 50% of farmer's not using LGDs in this study were aware of the use of LGDs. Awareness leading to intent and action is not a simple process to understand and therefore future research should also focus on such stakeholders to better understand their intent regarding LGD use and why they are not using an LGD. I acknowledge that in some cases the use of an LGD is not necessarily the right course of action for a specific farmer to take, but the aim here is to better understand and address any challenges that are present and/or perceived.

3.6 Conclusion

The reintroduction of an ancient mitigation method of LGDs is seen as a valuable coexistence tool in the relationship between livestock farmers and predators (Rigg, 2001; Marker et al., 2020, Spencer et al., 2020) but little research has considered the factors influencing farmer's intent in using an LGD. The TPB model, utilizing elements of the WTM, has been a useful framework in understanding the behavioural intent influencing LGD use and thereby improving our understanding of how LGDs may be used as a coexistence tool. This psychosocial study focused on the individual farmers and their relationship with LGD use. Recognition of a multitude of external factors, economic and political, should be considered in future research (Argent and Walmsley, 2009). Critical examination of how economic and political factors influence LGD use will enable the building of a more holistic management strategy by LGD support organizations, that goes beyond the individual farmer.

Social norms can be difficult to diagnose, measure and change (Bicchieri, 2016). Consideration should be given to the marked differences between COT and EWT in terms of associative influence on LGD use, where farmer's partaking in the survey had received their support and LGD placement from COT, not EWT. This inadvertent bias raises an interesting opportunity for future research where the marked difference in associative effect between the two organizations indicates that LGD support organizations involvement with farmers will have a significant effect on the farmer's decision to use or not use an LGD. I recommend further research be considered as to the factors within COT that associate most strongly with farmer's intent to use an LGD. Such variables to consider could be time and type of engagement between the LGD support organization and the farmer, language, or cultural barriers between the LGD support organizations and the farmers, as well as financial support and husbandry care for the farmers with LGDs. Further research should also look to incorporate a more even spread of LGD placements from a larger sample size of support organizations and potentially throughout Southern Africa. By way of example, Cheetah Conservation Fund (CCF) in Namibia (Marker et al., 2020) and Cheetah Conservation Botswana (CCB) in Botswana (Horgan et al., 2021) are all involved in LGD support and placement. A review paper incorporating all these organizations, across multiple countries, would provide a useful sample for comparison to the current study and should consider behavioural modelling for farmers and LGD use.

I show that attitudes towards LGD use are not necessarily the only and most important construct to consider when determining intent in LGD use, but that PBC and subjective norms play even more crucial roles in influencing the intent to use or continue using an LGD. Using the WTM is a valuable tool for improving the predictability of the TPB model and that farmer's exhibiting mutualistic tendencies who recognize the intangible benefit of predators, are more likely candidates for LGD use. Extra predictor variables such as the belief in the LGD support organization COT and perceptions of LGDs affordability, ease of use and effectiveness were also crucial variables to consider in understanding farmer's intent to use or continue using an LGD. The pathways of behavioural intent that ultimately lead to decision making and action are important to understand to successfully manage intervention programs like LGDs, where human-wildlife coexistence is concerned. Using the TPB model and incorporating WTM into this framework can be applied on a global scale to LGD programs. Typically, attitudes are seen as a key determinant underpinning behavioural responses to wildlife in human-wildlife interactions (Delibes-Mateos, 2014). My research shows that consideration of social pressures in the form of subjective norms and PBC need to be considered when researching behavioural response. Behavioural modelling needs to consider a cross-disciplinary approach (Martin, 2020; Whitehouse-Tedd et al., 2021) and utilizing the flexibility of the TPB while incorporating elements of the WTM, will aid in building more flexible behavioural models that go beyond the consideration of attitudes in relation to behavioural intent. Using this framework will better enable conservation organizations to identify appropriate and early LGD adopters, build mechanisms to improve the broader farming community perceptions on LGD use and ultimately develop more robust management strategies for farmers facing livestock-predator challenges where the use of LGDs is an appropriate mitigation measure to use.

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3.8 List of figures

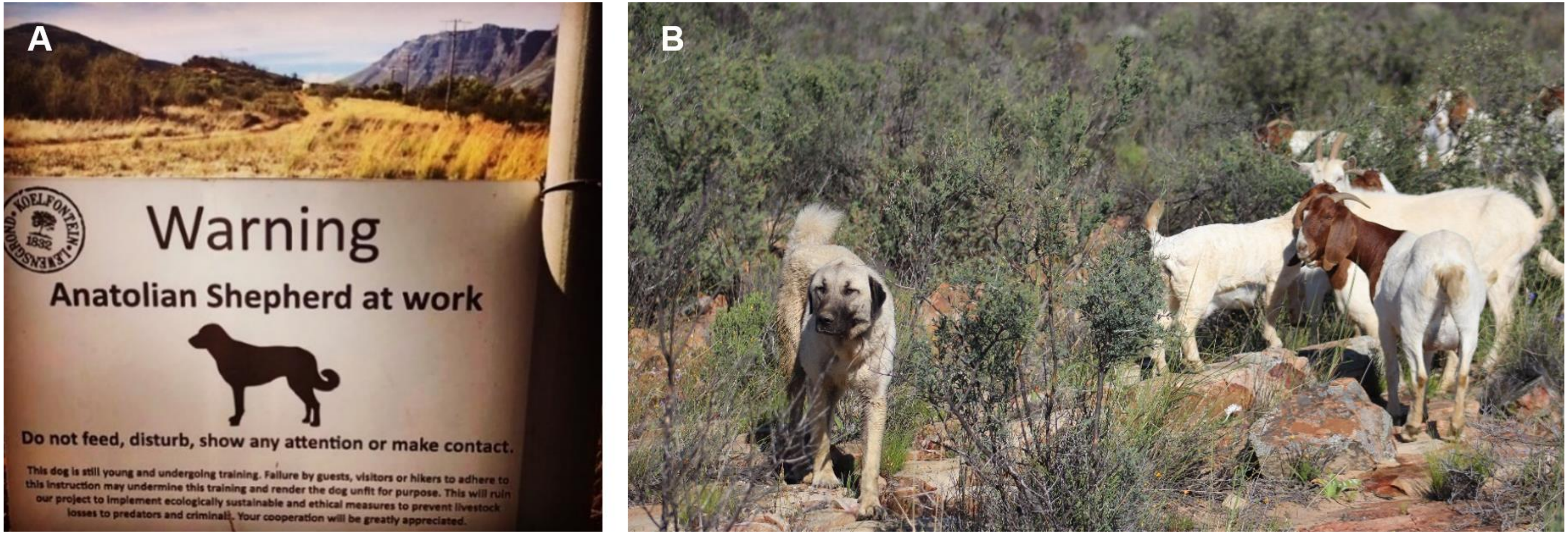

Figure 3.1: Anatolian Shepherd dogs at work, with A) a warning sign regarding a livestock guardian dog and B) a young male dog guarding his goat herd

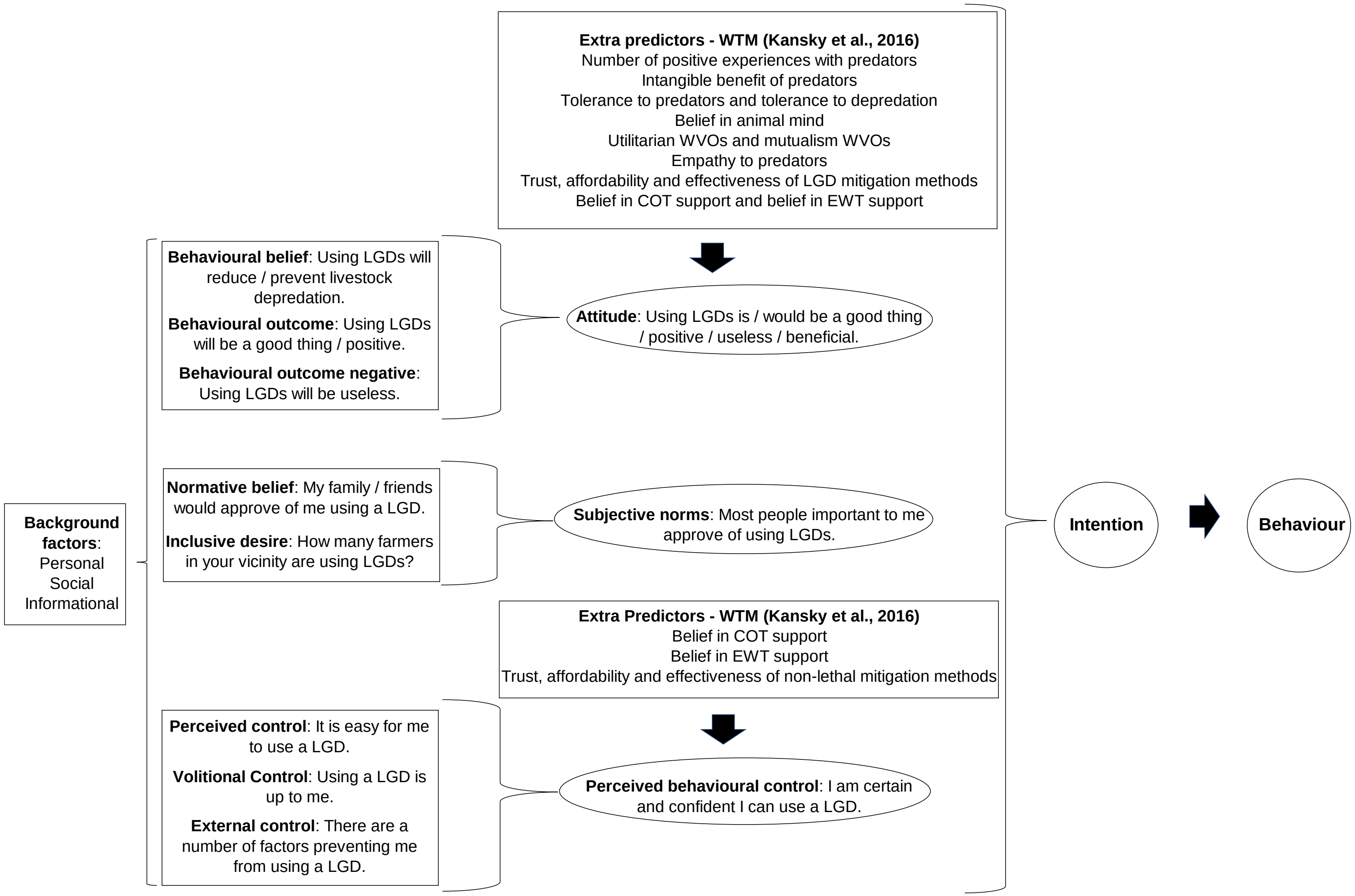

Figure 3.2: Conceptual framework for Theory of Planned Behaviour (TPB), depicting pathways to behavioural intent (adapted from Ajzen,1991). Abbreviations of Cheetah Outreach (COT, Endangered Wildlife Trust (EWT) and Livestock guardian dogs (LGDs)

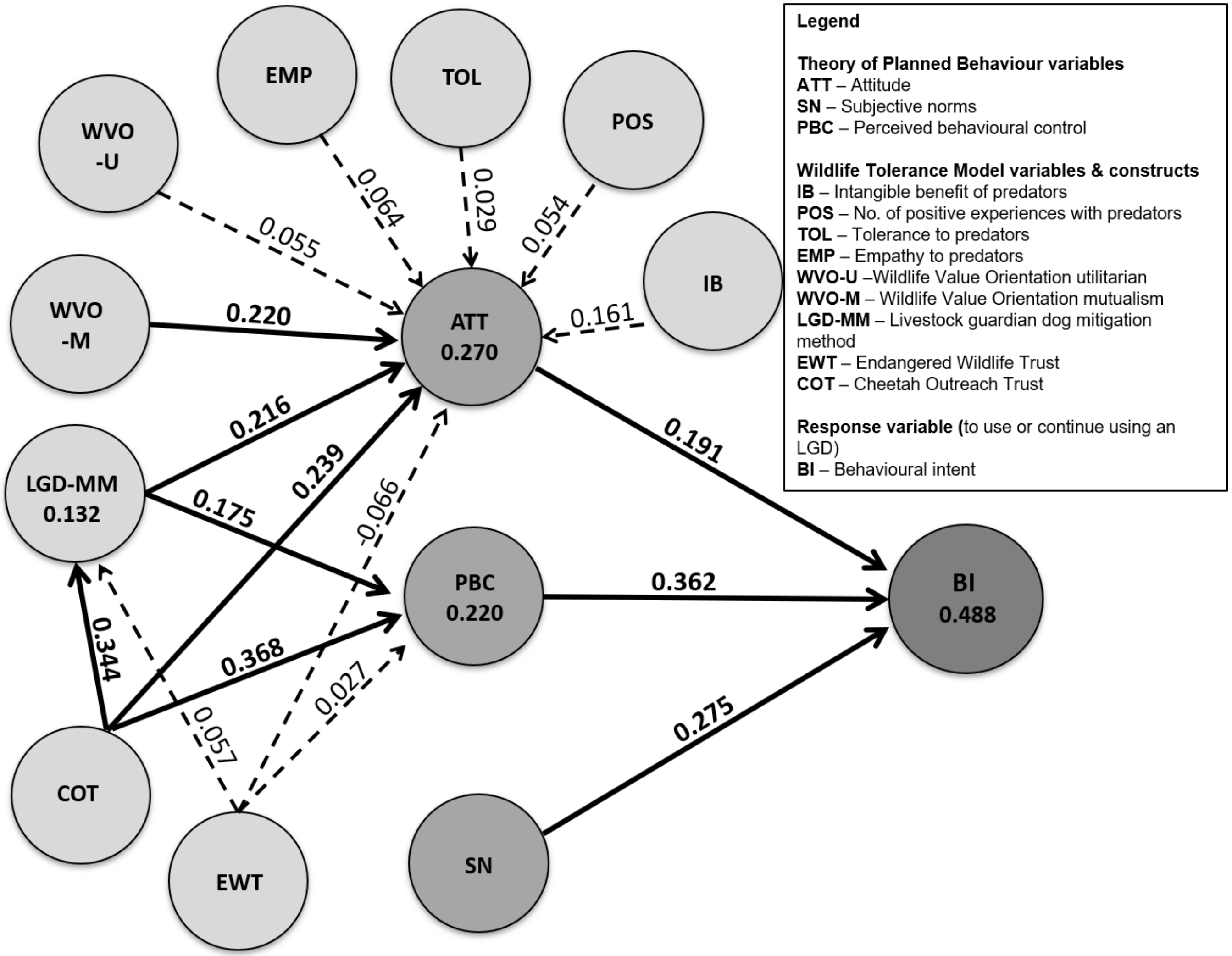

Figure 3.3: PLS-SEM path modelling where lines joining circles are the paths linking latent variables, and values adjacent to lines are path coefficients. Values within the circles are the adjusted coefficients of determination (R^2). Dotted lines are non-significant path coefficients while bold lines are significant path coefficients. Circle colour represents the response variable (BI, darkest shading), the TPB variables (ATT, SN, PBC, moderate shading) and the WTM adapted variables and constructs with extra predictor variables LGD-MM, COT and EWT (lightest shading)

3.9 List of tables

Table 3.1: **T**heory of Planned Behaviour constructs and variables from the Wildlife Tolerance Model. See Appendix B for specific survey questions and Kansky et al., 2016 for more details of the WTM

	Description	Hypotheses
Theory of Planned Behaviour constructs		
Behavioural intent	The intent to use or continue using an LGD.	**Response variable**
Attitude	Using LGDs is / would be a good thing / positive / useless / beneficial.	More positive attitudes towards LGDs positively affect the behavioural intent to use or continue using an LGD.
Subjective norms	Most people important to farmer, being friends, family and farming community approve of and/or use LGDs.	Normative support for LGD use positively effects the behavioural intent to use or continue using an LGD.
Perceived behavioural control	It is easy for farmer to use a LGD and using a LGD is up to the farmer. The factors preventing the farmer from using a LGD are…	The belief that using a LGD is easy and up to the farmer positively effects the behavioural intent to use or continue using an LGD.
Wildlife Tolerance Model variables/constructs impacting TPB constructs (Kansky et al., 2016)		
Intangible benefit of predators *Adapted from WTM – inner model variables*	Non-monetary benefit of living with predators being aesthetic value, appreciation value, existence value, cultural or symbolic value for farmers, their community, humankind, and nature.	Larger perceptions of intangible benefits of predators leads to more positive attitudes towards LGD use or continued use.

Number of positive experiences with predators *Adapted from WTM – outer model variables*	Number of positive meaningful experiences had with predators.	The higher the number of positive experiences with predators, the more positive the attitude towards predators.
Tolerance to predators *Adapted from WTM – outer model variables*	Tolerance to predators measured using 3 main parameters: 1) tolerance to killing a predator under different contexts, 2) population size of predators' farmer is willing to accept, 3) tolerance to spatial proximity to predators on both farm and in the area.	Greater degree of tolerance towards predators leads to more positive attitudes towards LGD use or continued use.
Tolerance to depredation *Adapted from WTM – outer model variables*	Tolerance to depredation measured using 2 main parameters: 1) number of specific livestock species farmer is willing to lose in a year, 2) ZAR value per livestock species farmer is willing to lose in one year.	Greater degree of willingness to lose livestock leads to more positive attitudes towards LGD use or continued use.
WVO Utilitarian *Adapted from WTM – inner model variables*	Value priority in relation to wildlife for farmers who believe wildlife are primarily to be used or for the farmer's benefit.	Individuals prioritizing utilitarian WVOs will have more negative attitudes towards LGD use or continued use.
WVO Mutualism *Adapted from WTM – inner model variables*	Value priority in relation to wildlife for farmers who believe wildlife are deserving of rights.	Individuals prioritizing mutualistic WVOs will have more positive attitudes towards LGD use or continued use.
Empathy to predators *Adapted from WTM – inner model variables*	An ability to feel compassion when imagining a predator species in distress or having problems.	Individuals with greater empathy towards predators will more likely use the perceived non-lethal LGD as a mitigation method over more lethal mitigation methods.

Belief in animal mind *Adapted from WTM – inner model variables*	Animals are aware, able to think for themselves and solve problems and have a range of feelings and emotions.	Individuals with greater belief in animal mind will have more positive attitudes towards LGD use or continued use.
Cheetah Outreach Trust (COT)	The extent of trust, degree of general performance, degree of communication and degree of knowledge & skills of Cheetah Outreach Trust (COT).	1. Individuals with higher scores for COT will have more positive attitudes towards LGD use. 2. Higher COT scores will drive perceived behavioural control of LGD use. 3. Support from COT will improve perception of LGDs as affordable, easy to use and effective.
Endangered Wildlife Trust (EWT)	The extent of trust, degree of general performance, degree of communication and degree of knowledge & skills of Endangered Wildlife Trust (EWT).	1. Individuals with higher scores for EWT will have more positive attitudes towards LGD use 2. Higher EWT scores will drive perceived behavioural control of LGD use. 3. Support from EWT will improve perception of LGDs as affordable, easy to use and effective.
LGD mitigation method (afford., use, effect.)	The affordability, ease of use and effectiveness of LGDs as a mitigation method in reducing or preventing livestock depredation.	1.Individuals who believe LGDs are affordable, easy to use and effective will have more positive attitudes towards LGD use 2. Higher perception scores of LGDs as affordable, easy to use and effective will drive perceived behavioural control.

Table 3.2: Discriminant validity tested using Heterotrait-Monotrait ratio, where values < 0.85, show that discriminant validity was established. All values are < 0.85. ATT is attitude, BI is behavioural intent, BIAM is belief in animal mind, COT is perceived trust, performance, communication and knowledge and skills in Cheetah Outreach Trust, EWT is perceived trust, performance, communication and knowledge and skills in Endangered Wildlife Trust, EMP is empathy to predators, IB is intangible benefit of predators, LGD-MM is perceived affordability, ease of use and effectiveness in livestock guardian dogs as a mitigation method, POS is number of positive experiences with predators, PBC is perceived behavioural control, SN is subjective norms, TOL-D is tolerance to depredation, TOL-P is tolerance to predators, WVO-M is Wildlife Value Orientation mutualism and WVO-U is Wildlife Value Orientation utilitarian

	AA	**BI**	**BIAM**	**COT**	**EWT**	**EMP**	**IB**	**LGD-MM**	**POS**	**PBC**	**SN**	**TOL-D**	**TOL-P**	**WVO-M**	**WVO-U**
ATT															
BI	0.580														
BIAM	0.497	0.109													
COT	0.330	0.389	0.145												
EWT	0.151	0.087	0.145	0.269											
EMP	0.323	0.153	0.450	0.111	0.386										
IB	0.324	0.114	0.366	0.071	0.338	0.666									
LGD-MM	0.349	0.593	0.121	0.363	0.150	0.112	0.138								
POS	0.100	0.119	0.192	0.266	0.234	0.244	0.476	0.016							
PBC	0.797	0.722	0.337	0.517	0.306	0.463	0.411	0.387	0.150						
SN	0.751	0.651	0.345	0.405	0.133	0.281	0.231	0.339	0.092	0.780					
TOL-D	0.264	0.281	0.363	0.167	0.226	0.322	0.308	0.196	0.271	0.396	0.270				
TOL-P	0.264	0.096	0.309	0.077	0.431	0.814	0.805	0.060	0.430	0.618	0.215	0.332			
WVO-M	0.310	0.173	0.689	0.113	0.134	0.514	0.246	0.165	0.197	0.386	0.243	0.247	0.252		
WVO-U	0.124	0.064	0.514	0.106	0.149	0.348	0.319	0.103	0.233	0.295	0.245	0.289	0.321	0.402	

Table 3.3: Discriminant validity tested using Fornell-Larcker criterion, where values larger than other correlation values indicate discriminant validity. All correlated values indicated discriminant validity was established. ATT is attitude, BI is behavioural intent, BIAM is belief in animal mind, COT is perceived trust, performance, communication and knowledge and skills in Cheetah Outreach Trust, EWT is perceived trust, performance, communication and knowledge and skills in Endangered Wildlife Trust, EMP is empathy to predators, IB is intangible benefit of predators, LGD-MM is perceived affordability, ease of use and effectiveness in livestock guardian dogs as a mitigation method, POS is number of positive experiences with predators, PBC is perceived behavioural control, SN is subjective norms, TOL-D is tolerance to depredation, TOL-P is tolerance to predators, WVO-M is Wildlife Value Orientation mutualism and WVO-U is Wildlife Value Orientation utilitarian

	AA	**BI**	**BIAM**	**COT**	**EWT**	**EMP**	**IB**	**LGD-MM**	**POS**	**PBC**	**SN**	**TOL-D**	**TOL-P**	**WVO-M**	**WVO-U**
ATT	0.859														
BI	0.548	1.000													
BIAM	0.420	0.083	0.605												
COT	0.308	0.388	0.078	0.989											
EWT	0.142	0.089	0.005	0.267	0.985										
EMP	0.293	0.149	0.254	0.109	0.364	0.795									
IB	0.298	0.111	0.262	0.068	0.328	0.597	0.922								
LGD-MM	0.326	0.588	0.042	0.360	0.149	0.092	0.135	0.983							
POS	0.096	-0.119	-0.029	-0.265	0.233	0.234	0.463	-0.016	1.000						
PBC	0.493	0.602	0.124	0.434	0.163	0.326	0.280	0.313	-0.032	0.695					
SN	0.662	0.597	0.201	0.365	0.065	0.247	0.207	0.306	0.016	0.543	0.743				
TOL-D	-0.216	-0.211	-0.050	-0.060	-0.172	-0.233	-0.257	0.013	-0.225	-0.232	-0.125	0.479			
TOL-P	0.236	0.096	0.179	0.052	0.396	0.707	0.732	0.057	0.397	0.379	0.197	-0.246	0.843		
WVO-M	0.287	0.126	0.446	0.030	0.083	0.420	0.221	0.044	0.109	0.253	0.173	-0.109	0.194	0.666	
WVO-U	-0.155	-0.049	-0.203	-0.052	-0.141	-0.337	-0.297	-0.099	-0.013	-0.165	-0.163	0.038	-0.281	-0.315	0.520

Table 3.4: Path Coefficients with relative statistical importance, where values close to or above 0.2 are considered significant (Hair et al, 2019). COT is perceived trust, performance, communication and knowledge and skills in Cheetah Outreach Trust, EWT is perceived trust, performance, communication and knowledge and skills in Endangered Wildlife Trust, LGD-MM is perceived affordability, ease of use and effectiveness in livestock guardian dogs as a mitigation method and WVO is Wildlife Value Orientations

Path coefficient variables	Attitude	Behavioural intent	LGDs	No. of positive experiences with predators	Perceived behavioural control	Subjective norms
Attitude		0.191				
Behavioural intent						
COT	0.239		0.344		0.368	
EWT	-0.066		0.057		0.027	
Empathy to predators	0.064					
Intangible benefit of predators	0.161					
LGD-MM	0.216				0.175	
No. of positive experiences with predators	0.054					
Perceived behavioural control		0.362				
Subjective norms		0.275				
Tolerance to predators	0.029					
WVO Mutualism	0.220					
WVO Utilitarian	0.055					

Table 3.5: Bootstrapping: Original sample, sample mean, standard deviation, T-values, and P-values for pathway modelling. **Bold** values indicate significant pathways $P < 0.05$. COT is perceived trust, performance, communication and knowledge and skills in Cheetah Outreach Trust, EWT is perceived trust, performance, communication and knowledge and skills in Endangered Wildlife Trust, LGD-MM is perceived affordability, ease of use and effectiveness in livestock guardian dogs as a mitigation method and WVO is Wildlife Value Orientations

	Original sample	Sample mean	Standard deviation	T values	P values
Attitude -> Behavioural intent	0.191	0.190	0.093	2.054	**0.041**
COT -> Attitude	0.239	0.237	0.103	2.323	**0.021**
COT -> LGDs-MM	0.344	0.341	0.091	3.772	**0.000**
COT -> Perceived behavioural control	0.368	0.372	0.094	3.917	**0.000**
EWT -> Attitude	-0.066	-0.068	0.096	0.690	0.491
EWT -> LGD-MM	0.057	0.053	0.100	0.566	0.571
EWT -> Perceived behavioural control	0.027	0.029	0.093	0.292	0.770
Empathy to predators -> Attitude	0.064	0.056	0.132	0.482	0.630
Intangible benefit of predators -> Attitude	0.161	0.117	0.107	1.508	0.132
LGD-MM -> Attitude	0.216	0.220	0.072	3.015	**0.003**
LGD-MM -> Perceived behavioural control	0.175	0.171	0.087	2.005	**0.046**
No. of positive experiences with predators -> Attitude	0.054	0.053	0.092	0.587	0.557
Perceived behavioural control -> Behavioural intent	0.362	0.351	0.086	4.236	**0.000**
Subjective norms -> Behavioural intent	0.275	0.293	0.094	2.946	**0.003**
Tolerance to predators -> Attitude	0.029	0.060	0.128	0.224	0.823
WVO Mutualism -> Attitude	0.220	0.235	0.118	1.867	0.063
WVO Utilitarian -> Attitude	0.055	0.005	0.111	0.498	0.619

3.10 List of appendices

Appendix B: Model constructs for Theory of Planned Behaviour with questionnaire for farmers with depredation events using LGDs (LGD users, n = 44) and farmers with depredation events not using LGDs (LGD non-users, n = 69)

Response variables	Questionnaire items	Response option / scale
Model constructs for Theory of Planned Behaviour		
Behavioural intent - response variable	I intend to use / continue to use a LGD to prevent livestock predation by predators.	1 = Very unlikely 2 = Unlikely 3 = Maybe 4 = Likely 5 = Very likely
Attitude		
item 1	In your opinion, using livestock guardian dogs (LGDs) to prevent livestock predation by predators is / would be a good thing.	1 = Strongly disagree 2 = Disagree 3 = Neither agree nor disagree 4 = Agree 5 = Strongly agree
item 2	In your opinion, using livestock guardian dogs (LGDs) to prevent livestock predation by predators is / would be useless (note: reverse coded).	5 = Strongly disagree 4 = Disagree 3 = Neither agree nor disagree 2 = Agree 1 = Strongly agree
item 3	In your opinion, using livestock guardian dogs (LGDs) to prevent livestock predation by predators is / would be positive.	1 = Strongly disagree 2 = Disagree 3 = Neither agree nor disagree 4 = Agree 5 = Strongly agree

item 4	In your opinion, using livestock guardian dogs (LGDs) to prevent livestock predation by predators is / would be beneficial.	1 = Strongly disagree 2 = Disagree 3 = Neither agree nor disagree 4 = Agree 5 = Strongly agree
Subjective norms item 1	Most people important to me think using a LGD to prevent livestock predation by predators is admirable.	1 = Strongly disagree 2 = Disagree 3 = Neither agree nor disagree 4 = Agree 5 = Strongly agree
item 2	Among other farmers, how much agreement would there be that it is a good thing to use a LGD to prevent livestock predation by predators?	1 = None 2 = Little 3 = Medium 4 = Much 5 = Total
item 3	In your family, how much agreement would there be that it is a good thing to use a LGD to prevent livestock predation by predators?	1 = None 2 = Little 3 = Medium 4 = Much 5 = Total
item 4	How many of the farmers in your area do you think use a LGD to prevent livestock predation by predators?	1 = None 2 = Few 3 = About half 4 = Many 5 = All

item 5	Think of the circle of friends you see frequently, what proportion of them use a LGD to prevent livestock predation by predators?	1 = None 2 = Less than half 3 = About half 4 = More than half 5 = All
Perceived behavioural control		
item 1	For me, using a LGD to prevent livestock predation by predators is / would be…	1 = Very difficult 2 = Difficult 3 = Neither easy nor difficult 4 = Easy 5 = Very easy
item 2	Whether I use / continue to use a LGD to prevent livestock predation by predators is up to me.	1 = Completely false 2 = False 3 = Neither true nor false 4 = Mostly true 5 = Completely true
item 3	The number of factors outside my control which would prevent me from using / continuing to use a LGD to prevent livestock predation by predators are… (note reverse coded)	5 = None 4 = Few 3 = Medium 2 = Many 1 = Very many
Model constructs adapted from Wildlife Tolerance Model (Kansky et al., 2016)		
Benefit constructs		
Positive meaningful experiences	If yes, how many positive experiences have you had with predators on your farm?	integer
Benefit intangible	Mean score of non-monetary benefit for yourself, community, mankind, and nature.	Average score for yourself, community, mankind, and nature from 1 - 5. The higher the score the greater the non-monetary benefit

Tolerance constructs		
Tolerance - willing to lose per farming enterprise	What would be the maximum number of mutton sheep you would be willing to lose due to predators on your farm in one year?	integer sum of
	What would be the maximum ZAR value of mutton sheep you would be willing to lose due to predators on your farm in one year?	integer sum of
	What would be the maximum number of wool sheep you would be willing to lose due to predators on your farm in one year?	integer sum of
	What would be the maximum ZAR value of wool sheep you would be willing to lose due to predators on your farm in one year?	integer sum of
	What would be the maximum number of cattle you would be willing to lose due to predators on your farm in one year?	integer sum of
	What would be the maximum ZAR value of cattle sheep you would be willing to lose due to predators on your farm in one year?	integer sum of
	What would be the maximum number of goats you would be willing to lose due to predators on your farm in one year?	integer sum of

	What would be the maximum ZAR value of goats you would be willing to lose due to predators on your farm in one year?	integer sum of
Tolerance to kill	Many wild animals are known to cause damage to humans and their property. Some are herbivores capable of eating agricultural crops and gardens or raiding urban households. Others are carnivores capable of killing domestic livestock as well as scaring, injuring, or killing humans. Under what conditions do you think it would be justified to kill a wild animal? Please ignore for now if it is illegal or not, who would do the killing, how it would be killed or what would be done with its body.	0 = No 1 = Unsure 2 = Yes
	Questions **Do you think a predator should be killed if...** ...it is seen in the bush far away from any village or houses or livestock or agricultural crops.	Per above – index 1
	... it is seen in the vicinity of where livestock are grazing or on the urban fringe where they could enter people's houses.	Per above – index 2
	...it has injured or killed a domestic animal for the first time.	Per above – index 3
	... it causes repeated problems for you and your community but has never harmed a person.	Per above – index 4
	...it has threatened a child or adult human.	Per above – index 5
	...it has injured a child or adult human.	Per above – index 6
	...it has killed a child or adult human.	Per above – index 7

	Index for tolerance to kill - yes	The first point where "yes" to killing a predator, from scenario 1 - 7 is selected to establish an index of tolerance towards killing a predator in certain scenarios. 8 means "unsure".
Tolerance to predator population	Would you like the population of predator types you get on your farm, to decrease, stay the same or increase on your farm, district, Africa?	1 = Decrease a lot 2 = Decrease a little 3 = Stay the same 4 = Increase a little 5 = Increase a lot
Tolerance predator exposure	What would be the Total maximum number of days in the summer and winter season you would be able to tolerate or cope with predators visiting your farm / land?	Integer – sum of
	What would be the total maximum number of days in the summer and winter season you would be able to tolerate or cope with predators visiting your area / neighbourhood?	Integer – sum of

Wildlife Value Orientation constructs		
Wildlife Value Orientation: utilitarian	We should strive for a world where there is an abundance of wildlife for hunting and fishing. Hunting does not respect the lives of animals (note: reverse coded). Hunting is cruel and inhumane to the wild animals (note: reverse coded). People who want to hunt should be provided the opportunity to do so. Wildlife are valuable only if people get to use them in some way. The needs of humans should take priority over wildlife protection. Wildlife are on earth primarily for people to use. Humans should manage wildlife populations so that humans benefit.	1 = Strongly disagree 2 = Moderately disagree 3 = Slightly disagree 4 = Neither 5 = Slightly agree 6 = Moderately agree 7 = Strongly agree

Wildlife Value Orientation: mutualism	I feel a strong emotional bond with wild animals. I care about wildlife as much as I do other people. I value the sense of companionship I receive from wild animals. Wildlife are like my family and I want to protect them. Wildlife should have rights similar to the rights of humans. I view all living things as part of one big family. We should strive for a world where humans and wildlife can live side by side without fear.	1 = Strongly disagree 2 = Moderately disagree 3 = Slightly disagree 4 = Neither 5 = Slightly agree 6 = Moderately agree 7 = Strongly agree
Belief in animal mind	Most animals are unaware of what is happening to them (note: reverse coded). Most animals can experience a range of feelings and emotions (e.g., pain, fear, contentment, maternal affection). Most animals can think to some extent to solve problems and make decisions about what to do. Most animals are more like computer programs, i.e., mechanically responding to instinctive urges without awareness of what they are doing (note: reverse coded).	1 = Strongly disagree 2 = Moderately disagree 3 = Slightly disagree 4 = Neither 5 = Slightly agree 6 = Moderately agree 7 = Strongly agree

Empathy and belief in animal mind constructs		
Empathy	Below are statements representing different ways that people might think about different wildlife types. We are interested in knowing your views about wildlife. Do you agree or disagree with these statements? When it comes to predators on my farm, I would describe myself as a soft-hearted person. Sometimes I don't feel very sorry for predators on my farm when they are having problems (note: reverse coded) When I see predators on my farm being hurt or treated badly, I feel kind of protective towards them. When I am upset about something a predator on my farm has done, I usually try to "put myself in its shoes". I sometimes try to understand predators on my farm better by imagining how things look from their perspective. When predators on my farm are being problematic, I often try to see things from their perspective as well.	1 = Strongly disagree 2 = Moderately disagree 3 = Slightly disagree 4 = Neutral 5 = Slightly agree 6 = Moderately agree 7 = Strongly agree

LGD support organizations opinions		
Cheetah Outreach Trust (COT) - trust	Total mean score for all organizations trust.	1 = Very low trust 2 = Low trust 3 = Neither low nor high trust 4 = High trust 5 = Very high trust
Cheetah Outreach Trust (COT) - performance	Total mean score for all organizations performance.	1 = Very poor performance 2 = Poor performance 3 = Neither poor nor good performance 4 = Good performance 5 = Very good performance
Cheetah Outreach Trust (COT) - communication	Total mean score for all organizations communication.	1 = Very poor communication 2 = Poor communication 3 = Neither poor nor good communication 4 = Good communication 5 = Very good communication
Cheetah Outreach Trust (COT) - knowledge and skills	Total mean score for all organizations knowledge and skills	1 = Very poor knowledge & skills 2 = Poor knowledge & skills 3 = Neither poor nor good knowledge & skills 4 = Good knowledge & skills 5 = Very good knowledge & skills
Endangered Wildlife Trust (EWT) - organizations trust	Total mean score for all organizations trust.	1 = Very low trust 2 = Low trust 3 = Neither low nor high trust 4 = High trust 5 = Very high trust

Endangered Wildlife Trust (EWT) - performance	Total mean score for all organizations performance.	1 = Very poor performance 2 = Poor performance 3 = Neither poor nor good performance 4 = Good performance 5 = Very good performance
Endangered Wildlife Trust (EWT) - communication	Total mean score for all organizations communication.	1 = Very poor communication 2 = Poor communication 3 = Neither poor nor good communication 4 = Good communication 5 = Very good communication
Endangered Wildlife Trust (EWT) - knowledge and skills	Total mean score for all organizations knowledge and skills.	1 = Very poor knowledge & skills 2 = Poor knowledge & skills 3 = Neither poor nor good knowledge & skills 4 = Good knowledge & skills 5 = Very good knowledge & skills
Non-lethal mitigation method		
LGDs mitigation measures affordability	Mean score of affordability LGD mitigation method.	5 = Very affordable 4 = Affordable 3 = Medium affordability 2 = Unaffordable 1 = Very unaffordable
LGDs mitigation measures ease of use	Mean score of ease of use for LGD mitigation method.	5 = Very easy to use 4 = Easy to use 3 = Neither easy nor difficult to use 2 = Difficult to use 1 = Very difficult to use
LGDs mitigation measures effectiveness	Mean score of effectiveness for LGD mitigation method.	5 = Very effective 4 = Effective 3 = Neither ineffective nor effective 2 = Ineffective 1 = Very ineffective

Appendix C: Results summary for reflective measurement model. The adequate threshold for outer loadings should be 0.70 or higher (Hair et al., 2014; Hair et al., 2019). Minimum acceptable level for individual indicator reliability values is 0.4 but closer or above 0.7 is preferred (Hair et al., 2014; Hair et al., 2019). Indicator reliability values that are negative outer loadings and fail (FAIL) the threshold are not indicated. Variables and whole constructs that failed the suggested threshold for outer loadings, indicator reliability, composite reliability (CR) and average variance extracted (AVE) were dropped (see DROP) to improve the predictability of the model and the Cronbach's alpha values, CR and AVE for internal consistency reliability. COT is perceived trust, performance, communication and knowledge and skills in Cheetah Outreach Trust, EWT is perceived trust, performance, communication and knowledge and skills in Endangered Wildlife Trust, LGD-MM is perceived affordability, ease of use and effectiveness in livestock guardian dogs as a mitigation method WVO is Wildlife Value Orientations

Latent variable	**Item indicators for coding analysis**	**Outer Loadings**	**Indicator reliability (i.e., "loadings")**	**Cronbach's alpha**	**Composite reliability (CR)**	**AVE**
Attitude	att_beneficial	0.900	0.948	0.882	0.918	0.738
	att_good thing	0.828	0.910			
	att_positive	0.853	0.924			
	att_useless	0.854	0.924			
Belief in animal mind *DROP construct	bam_1	0.260	0.510	0.496	0.672	0.366
	bam_2	0.765	0.875			
	bam_3	0.524	0.724			
	bam_4	0.732	0.855			
Behavioural intent	bi_intent	1.000	1.000	1.000	1.000	1.000
COT	org_trust_CO	0.987	0.993	0.992	0.994	0.977
	org_perform_CO	0.993	0.997			
	org_comms_CO	0.984	0.992			
	org_skills_CO	0.991	0.995			
EWT	org_trust_EWT	0.987	0.994	0.990	0.992	0.970
	org_perform_EWT	0.993	0.997			
	org_comms_EWT	0.980	0.990			
	org_skills_EWT	0.981	0.990			

Empathy to predators	emp_E1	0.813	0.901	0.871 * improved score to 0.913	0.908 * improved score to 0.935	0.633 * improved score to 0.741
	emp_E2 * DROP	0.394	0.627			
	emp_E3	0.836	0.915			
	emp_P1	0.861	0.928			
	emp_P2	0.854	0.924			
	emp_P3	0.900	0.949			
Intangible benefit of predators	ben_nonmon_community	0.903	0.950	0.941	0.958	0.850
	ben_nonmon_mankind	0.942	0.971			
	ben_nonmon_nature	0.890	0.943			
	ben_nonmon_yourself	0.952	0.976			
No. of positive experiences with predators	no_pos_exp	1.000	1.000	1.000	1.000	1.000
LGD-MM	mm_LGDs_afford	0.980	0.990	0.982	0.988	0.966
	mm_LGDs_effi	0.990	0.995			
	mm_LGDs_use	0.979	0.989			
Perceived behavioural control	pbc_factors_control	0.746	0.864	0.456 * improved score to 0.632	0.685 * improved score to 0.833	0.483 * improved score to 0.715
	pbc_uptome * DROP	0.156	0.395			
	pbc_use	0.932	0.966			
Subjective norms	sn_admirable	0.730	0.855	0.796	0.859	0.552
	sn_family_goodthing	0.833	0.913			
	sn_farmers_goodthing	0.806	0.898			
	sn_no_farmers_use	0.681	0.825			
	sn_no_friends_use	0.648	0.805			
Tolerance to predators	tol_no_days_TOTAL_farm	0.887	0.942	0.863	0.907	0.710
	tol_no_days_TOTAL_area	0.880	0.938			
	tol_kill_index1	0.732	0.855			
	pred_pop_TOTAL	0.862	0.928			

WVO Mutualism	wvo_care1	0.562	0.750			
	wvo_care2	0.646	0.804			
	wvo_care3	0.815	0.903			
	wvo_care4	0.872	0.934	0.786	0.842	0.444
	wvo_socaff1	0.473	0.688			
	wvo_socaff2	0.707	0.841			
	wvo_socaff3	0.477	0.690			
WVO Utilitarian	wvo_hunt1 * DROP	0.233	0.483			
	wvo_hunt2	0.666	0.816			
	wvo_hunt3	0.682	0.826	0.730	0.707	0.270
	wvo_hunt4	0.652	0.807	* improved	* improved	* improved
	wvo_use1 * DROP	0.131	0.362	score to	score to	score to
	wvo_use2	0.640	0.800	0.778	0.806	0.455
	wvo_use3	0.551	0.742			
	wvo_use4 * DROP	0.198	0.445			
Tolerance to depredation	TOTAL_ZAR_willing_lose_cattle	-0.543	FAIL			
*DROP construct	TOTAL_ZAR_willing_lose_goats	-0.006	FAIL			
	TOTAL_ZAR_willing_lose_msheep	0.390	0.625			
	TOTAL_ZAR_willing_lose_wsheep	0.694	0.833	0.567	0.126	0.229
	TOTAL_no_willing_lose_cattle	-0.598	FAIL			
	TOTAL_no_willing_lose_goats	0.066	0.256			
	TOTAL_no_willing_lose_msheep	0.242	0.492			
	TOTAL_no_willing_lose_wsheep	0.697	0.835			

CHAPTER 4: GENERAL CONCLUSION AND RECOMMENDATIONS

In a global agricultural context, the relationship between predators and farmers is frequently termed as Human-Wildlife Conflict, or preferably Human-Wildlife Coexistence (HWC), and is often considered a relationship that involves the persecution of predators by livestock managers as prevention or retaliation against livestock depredation (Torres et al., 2018). In a South African context, from the mid 1990's, complaints from farmers rose steadily as what many farmers saw was a dramatic increase in the number of depredation events on their farms (Nattrass and Conradie, 2015). In recent times with the growth in ecological understanding, animal welfare and the recognition of the place we share with animals on this earth, a new thinking is developing around coexistence strategies as opposed to lethally eliminating the predatory threat to livestock farming (Bergman, 2013). Once such perceived non-lethal method is the use of livestock guardian dogs (LGDs), which are considered a coexistence tool in the relationship between livestock farmers and predators (Rigg, 2001; Marker et al., 2020; Spencer et al., 2020).

The use of LGDs is important to understand, since enabling human-wildlife coexistence (HWC) is considered to have significant conservation and socio-economic implications (Graham et al., 2005; Inskip and Zimmerman, 2009). Added to this, the effectiveness of LGD use is now recognised (Rust et al., 2013; Kinka and Young, 2018; Spencer et al., 2020; Whitehouse-Tedd et al., 2020). Previous literature has not only considered the measurement of LGD effectiveness but also the implications of how LGDs might negatively affect non-target wildlife (Urbigkit and Urbigkit 2010, Potgieter et al. 2016, Whitehouse-Tedd et al. 2020), the physiological and behavioural impacts that LGDs have on their immediate environment and co-occurring species (Smith et al., 2020), as well as behavioural problems such as integration of LGDs into the flock, LGDs potentially killing livestock and wildlife, excessive playfulness, lack of attentiveness to the herd and roaming away from the herd (Green and Woodruff, 1990; Marker et al., 2005; Whitehouse-Tedd et al., 2019; Smith et al., 2020). As much of this research has focused on LGDs specifically, little research has considered the human dimension in this relationship and the factors that influence the use of LGDs. Understanding these factors and how they influence LGD use is a glaring gap in current LGD research. Thus, the objectives of this study were to firstly provide a comprehensive view of LGDs and previous research on this subject (chapter one) to characterize farmer and farm related factors associated with LGD use (chapter two) and finally, using the Theory of Planned Behaviour (TPB) and Wildlife Tolerance Model (WTM), build a predictive framework for understanding the behavioural intent behind LGD use (chapter three).

In a quantitative survey study amongst 113 livestock farmers this study showed that LGD use can be attributed to a series of associations relating to the farmer's demographics, farm environment, predators, psychosocial constructs and the LGD support organizations. I showed that sociodemographic factors of age, the duration of time spent living on the farm and the size of the farm itself were unrelated to LGD use, but that farmers using LGDs were more likely to use a greater number of non-lethal mitigation methods compared with LGD non-users, have a reduced proportion of their total income derived from animals, and have a higher diversity of livestock species. In terms of LGD use related to other methods of non-lethal mitigation control, this study indicated that the three most frequently used non-lethal mitigation methods for both LGD users and LGD non-users, were all related to fencing type methods being night pens/bomas, wildlife proof mesh boundary fencing and electrified fencing. Amongst non-lethal mitigation methods, only aversive agents were considered more effective, affordable, and easier to use than LGDs. Although LGDs were considered less affordable and harder to use than poison, LGDs were considered a more effective mitigation method and notably poison was considered the most effective, affordable, and easy to use mitigation method of all lethal mitigation methods. It should be noted that the use of LGDs might not always be the best nor appropriate mitigation measure to use.

The lower levels of income derived from animal farming and the higher diversity of livestock species, both associated with LGD use, might well relate to farming type. It has been noted in previous literature that reduction in livestock losses after LGD placement was similar for different farm types but that further research will be of interest to identify novel farm type factors influencing LGD performance (Marker et al., 2020). I propose that future research into farm type should not only consider its influence on LGD performance, but that farm type might well influence LGD use. I also considered the associations between the farmer's environment in terms of predators. Unsurprisingly the number of predator types (species) and the extent of the predator problem across all predators seen on the farm was significantly associated with LGD use. The extent of leopard problem was most significantly associated with LGD use, when compared to the extent of problem of other predator species. However, in the Western Cape where several farmers were surveyed, the perception that leopards are a major predator of livestock (Martins, 2011; Conradie, 2012) might have contributed to leopards showing the most significant association with LGD use when considering the extent of depredation problems across multiple predator types. In contrast to the extent of predator problem, when we considered the frequency of predator species seen, that is exposure to predators, black-backed jackal were the most significant predator species associated with LGD use in terms of exposure to predators. It is known that black-backed jackal account for over 65% of depredation related livestock losses in South

Africa (van Niekerk, 2010), and have a wide habitat tolerance (Nattrass and Conradie, 2015; Minnie et al., 2016). The exposure to black-backed jackals and its significant association with regards to LGD use highlights the importance of considering what type of predator problem is being experienced when implementing interventions.

Most notably my research showed that LGD use was not related to value and ideological opinions on wildlife. The WTM (Kansky et al., 2016) psychosocial variables relating to wildlife value orientations, empathy towards predators, tangible and intangible costs of predators, tangible, and intangible benefits of predators, like or dislike of predators and number of positive experiences with predators did not show any significant association with LGD use. Tolerance to depredation in terms of number and monetary value of livestock lost as well as tolerance towards killing a predator, population size of predators and tolerance to spatial proximity of predators on the farm and in the area, did not significantly associate with LGD use either.

This study shows that understanding the implications relating to predator type, number of farming enterprises, mitigation methods, and the exposure and extent of specific predator problems are potentially more useful characteristics to consider than farmer's psychosocial constructs when considering LGD use. The use of Boosted Regression Trees (BRTs) provided a useful analysis tool, where with this type of machine learning model I was able to fit complex nonlinear relationships and consider relative influence on LGD use. The BRT analysis showed that the LGD support organization Cheetah Outreach Trust (COT) had the greatest relative influence out of the plethora of variables tested in relation to LGD use. Farmers' perceptions on trust in COT, general performance of COT, degree of communication by COT and level of knowledge and skills of COT were significantly associated with LGD use. Notably the relative influence of COT on LGD use was greater than Endangered Wildlife Trust (EWT). We infer that there are important factors within LGD support organizations that influence LGD use and note that the majority of LGD users surveyed had their LGDs placed by COT not EWT and might show inadvertent bias towards COT vs EWT. Much consideration, that goes beyond the scope of this study, needs to be given to this finding and the factors within LGD support organizations that might influence LGD use. These being the cost and sustainability of the LGD support programs, the way LGD support organizations engage with farmers, whether LGDs are the most appropriate mitigation method to use and if or how LGD support organizations can put the best interests of the farmer ahead of their desire to see improved adoption of LGD programs. The characterizations of farmers and their farm environments in relation to LGD use will aid LGD support organizations in designing robust intervention models when considering LGD placement, adoption, and program sustainability. For LGD support organizations, understanding the characteristics of farms and farmers is an integral pathway to LGD program success but understanding the farmer's decision-making process in terms of LGD use is another key component to consider.

Leading on from chapter two, the adaptability of the TPB model (Ajzen, 1991; Manfredo, 2008) allowed me to incorporate a range of additional variables that were associated with LGD use. The three constructs of attitude, subjective norms, and perceived behavioural control (PBC) explained 48.8% of the variance in behavioural intent to use or continue using an LGD. Although attitudes are considered an important factor in understanding the behavioural response to wildlife (Delibes-Mateos, 2014), a significant finding in this chapter was that farmer's PBC had the most significant association on LGD use, with subjective norms showing the second greatest association and attitudes the lowest association on LGD use. In using the WTM variables, my research also showed that the Wildlife Value Orientation (WVO) of mutualism had a marked association on attitudes towards LGD use. The TPB model also indicated that extra predictor variables like the perceived affordability, ease of use and effectiveness of LGDs, are valuable predictors on both attitude and PBC in determining the intent to use or continue using an LGD. The TPB model also indicated that the perceived trust, degree of general performance, degree of communication and level of knowledge and skills of LGD support organization COT, was the most significant predictor on attitude and PBC in terms of intent to use or to continue using an LGD. I showed that COT had a much greater association with the intent to use or continue using a LGD then did EWT, however I noted inadvertent bias relating to COT as farmer's partaking in the survey had received their support and LGD placement from COT, not EWT. This finding emphasises the importance of the LGD support organization being known to the farmers and actively involved in the LGD placement. In conclusion for chapter three I consider that PBC is the most important construct to consider with regards to LGD use, with subjective norms and attitudes towards LGD use also critical in their association with the intent to use or to continue using an LGD. I also consider the critical role that belief in a LGD support organization (COT in this case), and farmer's perceptions on affordability, ease of use and effectiveness of LGDs play in terms of their association with LGD use. I note that mutualism has a marked association with attitudes towards LGD use. Considering these associative influences on LGD use I can conclude that LGD support organizations and particularly in this case COT, should ensure farmers understand LGD use is within their own volitional control and aim to reduce any barriers to using LGDs, where affordability, ease of use and perceived effectiveness of LGDs are key in this consideration. I also propose that farmers with mutualistic orientations towards wildlife would be early adopters of LGDs, but that LGD support organizations need to consider the significance of subjective norms as a pathway to understanding LGD use, and this means engagement needs to go beyond the target individuals (farmers) and must include the influence of family, friends, peers, and advisors.

Beyond the characterization of farmers using LGDs, the factors influencing LGD use and a framework for understanding factors associated with LGD use, this study highlighted several areas that require further research with regards to LGDs. In considering farms and farmer characteristics, the interactive effects between various lethal and non-lethal mitigation methods might well have notable findings for organizations promoting the use of less lethal to non-lethal methods in reducing livestock depredation. Exploring these interactive effects between mitigation methods will also aid in designing the most appropriate mitigation methods for a mosaic of farm types with different environmental factors all affecting depredation mitigation success. Using LGDs is but one effective method to reduce livestock depredation and considering LGD use in conjunction with other mitigation methods might lead to greater intervention success in reducing livestock depredation. The findings that LGD users derived lower income from animal farming and that the number of farming enterprises was significantly associated with LGD use, where anecdotally LGDs were more frequently used with goats on a farm with diversified farming enterprises, indicates that farm type might also be a factor associated with LGD use. Future research should consider including broader variations in terms of farm type with the aim of identifying the most appropriate farm types for LGD use. Previous literature has also considered farm type relevant in terms of LGD performance (Marker et al., 2020) as well as the economic implications of farm type and LGD use (Horgan et al., 2021). This study also indicates that in terms of predatory exposure, black-backed jackals are the most significant predator associated with LGD use and further research is necessary regarding the responses of black-backed jackals to LGDs and even other lethal and non-lethal mitigation methods. With LGD support organization, COT showing the greatest relative influence on LGD use as well as significant associations with farmer’s PBC and attitudes towards LGD use, further research needs to be considered with regards to other LGD support organizations and their associative effect on LGD use. Cheetah Conservation Fund (CCF) in Namibia (Marker et al., 2020) and Cheetah Conservation Botswana (CCB) in Botswana (Horgan et al., 2021) are all involved in LGD support and placement. A study incorporating all these organizations, across multiple countries, would provide a useful sample for a comparative study and which specific factors within LGD support organizations influence LGD use positively or negatively. With our findings showing that over 50% of farmer’s not using LGDs in this study were aware of the use of LGDs, consideration needs to be given to why these farmers are not using an LGD. In some cases, LGDs are not always the most appropriate form of mitigation control and LGD support organizations consideration for the farmer's best interests over and above their conservation objectives is another field of study that would prove invaluable in improving the sustainability of these LGD programs. As this study showed, the significance of subjective norms on the intent to use or continue using a LGD means that future research needs to go beyond the behaviour of the target individual, and to incorporate the influence of family, friends, peers, and advisors when considering LGD use.

In closing, LGDs are increasingly being considered as a potential tool for coexistence in agricultural landscapes where farmer and predator conflict persists. Understanding the implications relating to predator type, number of farming enterprises, mitigation methods, and the exposure and extent of specific predator problems are useful characteristics for LGD support organizations to consider over and above farmer's psychosocial constructs. The TPB model, utilizing elements of the WTM, provides a framework for understanding the factors influencing behavioural intent to use LGDs. With LGD support organizations being critical as a pathway associated with LGD use, this research provides valuable insight to support the realization of more sustainable strategies regarding LGD use.

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